ENTERPRISE IN ORBIT: THE SUPPLY AND DEMAND FOR COMMUNICATION SATELLITES, 1964-92

THESIS SUBMITTED FOR THE DEGREE OF DOCTOR OF PHILOSOPHY AT THE UNIVERSITY OF OXFORD

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Abstract

The objective of this study is to develop a general understanding of the evolution of the commercial communication satellite industry. Initial information classifies the industry as an oligopoly with the vendors as price setters. The approach to this thesis is to examine the supply and demand of satellites as a capital good.

Assuming the demand curve slopes downwards, the study examines the change in the price of a standard unit satellite. The underlying motivation is the conventional identification problem. Over three generations, the technical attributes of communication satellites are advancing. Taking the hedonic regression approach, the price of satellites is shown to decrease over time. Exploring the relationship between price and complexity, it is demonstrated that in the short-run the oligopoly structure of this industry is accompanied by a simple form of cost-plus price-setting. This finding solves the identification problem, so that simultaneous equation methods are not required. Assuming a constant degree of monopoly power in the industry, changes in multi-factor productivity are estimated. Productivity growth increases until 1980, but decreases slightly afterwards. The learning coefficients estimated for this industry are smaller than those found for the airframe industry.

The fall in quality-corrected prices, however, is not big enough to support the interpretation that the expansion of satellite capacity was due to supply shifts along a stationary market demand schedule. Factors driving demand lead to a faster rate of expansion outside the original western world, but in the second half of the period, the ability to use software data compression moderated the rate of growth of demand for new satellites. The study explains the adjustment of the stock of satellite capacity in response to the desired stock: the speed at which countries adjust their stock depends on their characteristics and regional profile.

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Table of contents

TABLE OF FIGURES iv
TABLE OF TABLES viii
ACRONYMS xii
GLOSSARY xiv
LIST OF VARIABLES xvii
I. INTRODUCTION 1
1. EVOLUTION OF THE COMMUNICATION SATELLITE INDUSTRY 9
1.1 Structure of the communication satellite industry 12
1.1.1 Three types of players 12
1.1.2 Integration in the space industry 16
1.1.3 Other aspects 21
1.2 Communication growth 26
1.2.1 Telecommunication infrastructure growth 27
1.2.2 Telecommunication traffic growth 29
1.2.3 Broadcasting growth 30
1.2.4 Communication satellite growth 33
1.3 History of satellite communications 35
1.3.1 General history of the satellite communications 36
1.3.2 Disaggregation by manufacturing 39
1.3.3 Disaggregation by ownership 47
1.3.4 Other measures of the evolution of supply of satellites 54
1.4 Conclusion 56
Annex 1.1 58
2. NATURE OF THE COMMUNICATION SATELLITE TECHNOLOGY 60
2.1 Architecture of a communication satellite system 62
2.1.1 Components of satellites 63
2.1.2 An elementary course in satellite design for economists 67
2.2 Evolution of telecommunication satellites 70
2.2.1 The data 70
2.2.2 From characteristics to variables 71
2.2.3 Descriptive statistics 74
2.2.4 Evolution of satellite characteristics 81
2.3 Three generations of commercial communication satellites 89
2.4 Conjecture on the economic significance of the variables 91
2.5 Conclusion 92
3. HEDONIC PRICE REGRESSIONS 94
3.1 Evolution of communication satellite prices 95
3.2 Theory and data 98
3.2.1 Literature review 99
3.2.2 Model 102
3.2.3 Data 106
3.3 Hedonic regression results 105
3.3.1 Pooled regressions 107

3.3.2 Different manufacturers 118
3.3.3 Different customers 124
3.4 Price indices 131
3.4.1 General price indices 132
3.4.2 Different manufacturers 136
3.4.3 Different customers 137
3.5 Conclusion 139
4. SUPPLY CONDITIONS AND TECHNOLOGY CHANGE 142
4.1 Complexity measures 144
4.1.1 Pooled sample 146
4.1.2 Split sample 153
4.2 Price indices 155
4.2.1 General price indices 155
4.2.2 Different manufacturers 158
4.2.3 Different customers 159
4.3 Buyer/seller price comparison between US and Europe 160
4.4 Productivity 163
4.4.1 Model and data 163
4.4.2 Partial factor productivity 166
4.4.3 Total factor productivity 167
4.5 Learning 170
4.5.1 Model 170
4.5.2 Results 172
4.6 Conclusion 173
Annex 4.1 176
Annex 4.2 179
5. DEMAND FOR COMMUNICATION SATELLITES 182
5.1 Model of demand for communication satellite capacity 184
5.1.1 Desired capital stock 186
5.1.2 Stock adjustment model 189
5.2 Data 191
5.2.1 Variables 192
5.2.2 Evolution of stock and orders 196
5.3 Instruments for demand shifters 202
5.3.1 Principal component analysis 202
5.3.2 Traffic demand regression 213
5.3.3 Desired satellites stock 216
5.4 Stock adjustment model 220
5.4.1 Fixed stock adjustment 220
5.4.2 Time varying stock adjustment 227
5.4.3 Comments on the results 235
5.5 Conclusions 236
Annex 5.1 239
6. CONCLUSION 240
BIBLIOGRAPHY 245
APPENDICES 250
APPENDIX A : LIST OF SATELLITES 251

APPENDIX B : LIST OF THE MANUFACTURERS, CUSTOMERS AND OPERATORS OF COMMUNICATION SATELLITES 260
APPENDIX C : DEMAND-SIDE COUNTRIES 263
APPENDIX D : GROWTH OF DEMAND VARIABLES 266
APPENDIX E : ORBIT DESCRIPTION 276
APPENDIX F : CHARACTERISTICS OF COMMERCIAL COMMUNICATION SATELLITES 278
APPENDIX G : NUMBER OF EQUIVALENT VOICE CHANNELS 283
APPENDIX H : HEDONIC REGRESSION MODELS 284
APPENDIX I : CHOW TESTS FOR STRUCTURAL CHANGE 285
Appendix I.1: Differences in time scale 286
Appendix I.2: Differences in manufacturing region 292
Appendix I.3: Differences in purchasing region 296
APPENDIX J : LEARNING COEFFICIENTS 303
APPENDIX K : DEMAND SHIFT RESULTS 305
APPENDIX L : STOCK DEMAND CALCULATIONS 314
APPENDIX M : STOCK ADJUSTMENT ANALYSIS 327

Table of Figures

Figure I.1: Identification problem..... 5
Figure 1.1: Stock (solid line) and cumulative number of awarded (dotted line) and launched (dashed line) commercial communication satellites; yearly..... 36
Figure 1.2: Cumulative number of awarded satellites produced in the different regions of the world, with a breakdown of US manufacturers. 40
Figure 1.3: Cumulative number of launched satellites produced in the different regions of the world, with a breakdown of US manufacturers. 41
Figure 1.4: Lorenz curve, manufacturers; number of awarded satellites. 44
Figure 1.5: Lorenz curve, manufacturers; value of awarded satellites..... 44
Figure 1.6: Lorenz curve, manufacturers; number of launched satellites. 45
Figure 1.7: Lorenz curve, manufacturers; value of launched satellites..... 45
Figure 1.8: Evolution of the Herfindahl index, manufacturers; number of awarded satellites. 46
Figure 1.9: Evolution of the Herfindahl index, manufacturers; value of awarded satellites. 47
Figure 1.10: Cumulative number of awarded satellites per region of ownership. 48
Figure 1.11: Cumulative number of launched satellites per region of ownership. 48
Figure 1.12: Stock of in-orbit satellites by region of ownership; numbers..... 49
Figure 1.13: Stock of in-orbit commercial communication satellites; value. 50
Figure 1.14: Lorenz curve, customers; number of awarded satellites..... 51
Figure 1.15: Lorenz curve, customers; value of awarded satellites. 51
Figure 1.16: Lorenz curve, customers; number of launched satellites..... 52
Figure 1.17: Lorenz curve, customers; value of launched satellites. 52
Figure 1.18: Evolution of the Herfindahl index, customers; number of awarded satellites. 53
Figure 1.19: Evolution of the Herfindahl index, customers; value of awarded satellites. 54
Figure 1.20: Stock of capacity (solid line) and cumulative quantity of ordered (dotted line) of launched (dashed line) capacity; number of transponders. 55
Figure 1.21: Stock of capacity (solid line) and cumulative quantity of ordered (dotted line) and of launched (dashed line) capacity; total bandwidth. 55
Figure 1.i: Evolution of the Herfindahl index, manufacturers; number of launched satellites. 58
Figure 1.ii: Evolution of the Herfindahl index, manufacturers; value of launched satellites. 58
Figure 1.iii: Evolution of the Herfindahl index, customers; number of launched satellites. 59
Figure 1.iv: Evolution of the Herfindahl index, customers; value of launched satellites. 59
Figure 2.1: The elements of a satellite communication system. 62
Figure 2.2: Components of the payload. 64
Figure 2.3: Example of satellite footprint. 65
Figure 2.4: Types of antenna beams. 67

Figure 2.5: Lifetime of a battery (in number of cycles) in function the depth of discharge. 69
Figure 2.6: Evolution of the indexed weighted mean of each characteristic over the time periods chosen. 74
Figure 2.7: Evolution of the indexed weighted mean of each characteristic over the time periods chosen, with the exception of the variables *eqvvoice* and *eolpower*..... 75
Figure 2.8: Evolution of the indexed weighted mean of the transponder frequency band proportion over the time periods chosen. 76
Figure 2.9: Comparative evolution of the characteristics of communication satellites by region of manufacturer; natural logarithm of the normalised indicated variable relative to the mean value of the satellites contracted to Hughes Aircraft during the period 1964-71 77
Figure 2.10: Evolution of the proportion of transponders of each frequency band by region of manufacturer. 78
Figure 2.11: Comparative evolution of the characteristics of communication satellites by region of customer/operator; natural logarithm of the normalised indicated variable relative to the mean value of the satellites contracted by international satellites during the period 1964-71. 80
Figure 2.12: Evolution of the proportion of transponders of each frequency band by region of customer/operator. 81
Figure 2.13: Number of launched transponders per unit of mass for the sample period (1965-96). 83
Figure 2.14: Number of launched transponders per unit of total power for the sample period (1965-96). 84
Figure 2.15: Total end-of-life power per unit of mass at launch for the sample period (1965-96). 85
Figure 2.16: Transponder power as a proportion of end-of-life total power at launch for the sample period (1965-96) 85
Figure 2.17: Transponder power per unit of bandwidth at launch for the sample period (1965-96). 86
Figure 2.18: Lifetime per unit of total power at launch for the sample period (1965-96). 87
Figure 2.19: Effective Isotropic Radiated Power (EIRP) per unit of bandwidth at launch for the sample period (1965-96) 88
Figure 2.20: Number of transponders per unit of bandwidth excluding the mobile communication satellites at launch for the sample period (1965-96). 89
Figure 3.1: Evolution of average price 96
Figure 3.2: Evolution of average price with respect to launch mass. 96
Figure 3.3: Evolution of average price per signal capacity. 97
Figure 3.4: Evolution of average price per average EIRP 97
Figure 3.5: Evolution of the antenna gain. 115
Figure 3.6: Hedonic price indices; all models; pooled results. 132
Figure 3.7: Hedonic price indices; all models; split low results. 133
Figure 3.8: Hedonic price indices; all models; split high results. 133
Figure 3.9: Hedonic price indices; model 3. 134
Figure 3.10: Hedonic price indices; model 4. 134
Figure 3.11: Hedonic price indices; model 3 (DL36479, DL38293), compared with an index of price to mass ratio (ecpi80/gtomass). 135

Figure 3.12: Hedonic price index; model 3 (DL36479, DL38293), compared with the non-quality adjusted price index (ecpi80)..... 136
Figure 3.13: Hedonic price indices, North American manufacturers; model 4..... 137
Figure 3.14: Hedonic price indices, model 4, US, international (I) and other customers (O), pooled results..... 139
Figure 4.1: Calculated complexity at launch for the sample period 1965-96; pooled results, model 3..... 147
Figure 4.2: Calculated complexity at launch for the sample period 1965-96; split results, model 3..... 147
Figure 4.3: Calculated complexity at launch for the sample period 1965-96; pooled results, model 4..... 148
Figure 4.4: Calculated complexity at launch for the sample period 1965-96; split results, model 4..... 148
Figure 4.5: Awarded price of each satellite with respect to the calculated complexity measure, in logarithm; pooled results, model 3..... 150
Figure 4.6: Awarded price of each satellite with respect to the calculated complexity measure, in logarithm; split results, model 3..... 150
Figure 4.7: Awarded price of each satellite with respect to the calculated complexity measure, in logs; non-chained split results, model 3..... 151
Figure 4.8: Awarded price of each satellite with respect to the calculated complexity measure, in logs; pooled results, model 4..... 152
Figure 4.9: Awarded price of each satellite with respect to the calculated complexity measure, in logarithm; split results, model 4..... 152
Figure 4.10: Relative (1980 = 1) yearly average of the mass and complexity (model 3, split results) versus the price (in logs)..... 153
Figure 4.11: Temporal evolution of complexity (in logs); North American manufacturers; 1964-93; split sample, model 3..... 154
Figure 4.12: Price versus normalised complexity (1980 = 1); North American manufacturers; 1964-93; pooled sample, model 3..... 154
Figure 4.13: Price versus normalised complexity (1980 = 1); North American manufacturers; 1964-93; split sample, model 3..... 155
Figure 4.14: Hedonic price indices; model 3; split results; compared with various price indices..... 156
Figure 4.15: Hedonic price indices, model 3, split results; compared with deflated price indices of electronic components..... 156
Figure 4.16: Hedonic price indices, model 4, North American manufacturers, split results; compared with deflated price indices of electronic components..... 158
Figure 4.17: Hedonic price indices, model 4, US, international and other customers, pooled results; compared with deflated price indices of electronic components..... 159
Figure 4.18: Composite index of partial factor productivity for capital, labour and material; all input indices are deflated by the CPI..... 167
Figure 4.19: Total factor productivity index; models 3 and 4; US manufacturers; split regressions..... 168
Figure 4.20: Composite total factor productivity growth with varying elasticity of output with respect to capital..... 169
Figure 4.21: Gross composite total factor productivity growth (TFPG) and net output composite productivity growth (NOPG)..... 170

Figure 4.22: Cumulative complexity growth; models 3 and 4..... 171
Figure 4.i: Temporal evolution of complexity; North American manufacturers; 1964-93; logs, pooled sample, model 3. 176
Figure 4.ii: Temporal evolution of complexity; North American manufacturers; 1964-93; logs, pooled sample, model 4. 176
Figure 4.iii: Price versus normalised complexity (1980 = 0 for complexity); North American manufacturers; 1964-93; logs, pooled sample, model 3. 177
Figure 4.iv: Price versus normalised complexity (1980 = 0 for complexity); North American manufacturers; 1964-93; logs, pooled sample, model 4. 177
Figure 4.v: Temporal evolution of complexity; North American manufacturers; 1964-93; logs, split sample, model 4. 178
Figure 4.vi: Price versus normalised complexity (1980 = 0 for complexity); North American manufacturers; 1964-93; logs, split sample, model 4. 178
Figure 5.1: Path of a telecommunication signal from one country to the global region covered by the satellite; own country *i*, all countries *j*. 184
Figure 5.2: Own country stock; 1980..... 197
Figure 5.3: Own country stock; 1990..... 197
Figure 5.4: Own country stock (bandwidth in MHz); 1980..... 198
Figure 5.5: Own country stock (bandwidth in MHz); 1993..... 199
Figure 5.6: Evolution of the bandwidth capacity stock (in logs); Western World domestic satellite owners (Group 1). 200
Figure 5.7: Evolution of the change in bandwidth capacity stock (in logs); Western world domestic satellite owners (Group 1)..... 201
Figure 5.8: Evolution of the bandwidth capacity orders (in logs); Western World domestic satellite owners (Group 1). 201
Figure 5.9: Evolution of the change in bandwidth capacity orders of other countries; Western World domestic satellite owners (Group 1)..... 202
Figure 5.10: First principal component; Group 1. 205
Figure 5.11: Second principal component; Group 1..... 205
Figure 5.12: First principal component; Group 2. 206
Figure 5.13: Second principal component; Group 2..... 206
Figure 5.14: First principal component; 'old' technology; Group 1..... 212
Figure 5.15: First principal component; recent technology; Group 1..... 212
Figure 5.16: First predicted traffic demand results (in logs - 6); equation (5.6); Western World domestic satellite owners (Group 1)..... 216
Figure 5.17: Second predicted traffic demand results (in logs - 6); equation (5.7); Western World domestic satellite owners (Group 1)..... 216
Figure 5.18: Fixed effects results, fixed λ (equation 5.14); second traffic demand predicted results (equation 5.7); North American manufacturers price index, model 3 (table 3.12). 223
Figure 5.19: Adjustment coefficient, fixed (equation 5.14); second traffic demand predicted results (equation 5.7); North American manufacturers price index (table 3.12). 226
Figure 5.20: Fixed effects results, variable λ (equation 5.17); second traffic demand predicted results (equation 5.7); North American manufacturers price index, model 3 (table 3.12). 233

Table of Tables

Table 1.1: Average price of commercial launch services according to the mass of geostationary satellites. 15
Table 1.2: Country groups..... 26
Table 1.3: Growth of main telephone lines in operation..... 27
Table 1.4: Growth of telecommunication investment..... 28
Table 1.5: Growth of international outgoing telephone traffic. 30
Table 1.6: Number of cable television subscribers as a percentage of households in 1993. 31
Table 1.7: Estimated number of DTH satellite receivers as a percentage of households. 31
Table 1.8: Order of adoption of domestic satellite technology. 33
Table 1.9: Growth of the owner net stock of satellites; 1975-85. 34
Table 1.10: Growth of the owner net stock of satellites; 1985-95. 35
Table 3.1: Evolution of the average number of satellites ordered per contract..... 106
Table 3.2: Regression results, model 1, equations (3.3) and (3.4); dependent variable: ln(*ecpi80*). 108
Table 3.3: Regression results, model 2, equations (3.5) and (3.6); dependent variable: ln(*ecpi80*). 109
Table 3.4: Regression results, model 3, equations (3.7) and (3.8); dependent variable: ln(*ecpi80*). 110
Table 3.5: Regression results, model 4, equations (3.9) and (3.10); dependent variable: ln(*ecpi80*). 111
Table 3.6: Sign variation of estimates of the characteristic variables and dummy variables across years and models. 112
Table 3.7: Classification of the four models according to adjusted R^2 and F-statistics. 116
Table 3.8: Summary of tests for structural change across ownership regions. 117
Table 3.9: Number of observations of each category, sub-periods versus manufacturers..... 119
Table 3.10: Regression results for different regions of manufacturing, model 1, equations (3.3) and (3.4); dependent variable: ln(*ecpi80*). 119
Table 3.11: Regression results for different regions of manufacturing, model 2, equations (3.5) and (3.6); dependent variable: ln(*ecpi80*). 120
Table 3.12: Regression results for different regions of manufacturing, model 3, equations (3.7) and (3.8); dependent variable: ln(*ecpi80*). 121
Table 3.13: Regression results for different regions of manufacturing, model 4, equations (3.9) and (3.10); dependent variable: ln(*ecpi80*). 122
Table 3.14: Sign variation of the estimates of the characteristic variables and dummy variables across years and models; by region of manufacturing, NA: North America, E: Europe..... 123
Table 3.15: Classification of the four models according to adjusted R^2 and F-statistics; manufacturing regions. 123
Table 3.16: Classification of the four models according to adjusted R^2 and F-statistics; manufacturing regions; model 2 eliminated. 124

Table 3.17: Number of observations of each category, sub-periods versus customers. 124
Table 3.18: Regression results for different regions of ownership, model 1, equations (3.3) and (3.4); dependent variable: ln(*ecpi80*). 125
Table 3.19: Regression results for different regions of ownership, model 2, equations (3.5) and (3.6); dependent variable: ln(*ecpi80*). 126
Table 3.20: Regression results for different regions of ownership, model 3, equations (3.7) and (3.8); dependent variable: ln(*ecpi80*). 127
Table 3.21: Regression results for different regions of ownership, model 4, equations (3.9) and (3.10); dependent variable: ln(*ecpi80*). 128
Table 3.22: Sign variation of the estimates of the characteristic variables across years and models; ownership regions. 129
Table 3.23: Sign variation of the estimates of the characteristic dummy variables across years and models; ownership regions. 130
Table 3.24: Classification of the four models according to adjusted R^2 and F-statistics; ownership regions..... 131
Table 3.25: Classification of the four models according to adjusted R^2 and F-statistics; ownership regions; model 2 eliminated. 131
Table 3.26: Hedonic price indices..... 132
Table 3.27: Hedonic price indices; North American manufacturers..... 137
Table 3.28: Pooled price indices for different regions of ownership, models 1 & 2. 138
Table 3.29: Pooled price indices for different regions of ownership, models 3 & 4. 138
Table 4.1: Stylised characteristic satellites of various complexity 146
Table 4.2: Number of satellites produced per sub-period by each manufacturing region for each customer region. 160
Table 4.3: Price comparison between North American and European builders for the same satellites owned by various customers..... 160
Table 4.4: Regressions on North American manufacturers with European customer dummy variable and European, international and other countries' customers with North American producers dummy variable; model 3..... 161
Table 4.5: Regressions on North American manufacturers with European customer dummy variable and European, international and other countries' customers with North American producers dummy variable; model 4..... 162
Table 4.6: Learning curve estimates; dependent variable: gross total factor productivity growth, equation (4.8). 172
Table 4.7: Learning curve estimates; dependent variable: net output productivity growth, version 1. 172
Table 4.8: Learning curve estimates; dependent variable: net output productivity growth, version 2. 172
Table 5.1: Variables included in the principal component analysis..... 203
Table 5.2: Aggregation of countries for the principal component analysis. 203
Table 5.3: Summary of the principal component method; method 1 corresponds to equation (5.6), while method 2 uses equation (5.7)..... 203
Table 5.4: Eigenvectors of the first four principal components per satellite generation; Western World domestic satellite owners (Group 1)..... 204
Table 5.5: Eigenvectors of the first four principal components per satellite generation; Other domestic satellite owners (Group 2). 204

Table 5.6: Eigenvectors of the first four principal components per satellite generation; Africa (Group 3). 207
Table 5.7: Eigenvectors of the first four principal components per satellite generation; Middle East (Group 4). 207
Table 5.8: Eigenvectors of the first four principal components per satellite generation; Asia and Oceania (Groups 5 and 6). 208
Table 5.9: Eigenvectors of the first four principal components per satellite generation; Europe (Groups 7 and 8). 209
Table 5.10: Eigenvectors of the first four principal components per satellite generation; South and Central America (Groups 9 and 10). 209
Table 5.11: Eigenvectors of the first four principal components of 'old' demand variables for the entire sample, 1965-93. 210
Table 5.12: Eigenvectors of the first four principal components of recent variables for the last satellite generation, 1985-93. 214
Table 5.13: International outgoing communication traffic capacity regression; first method (equation 5.6); Groups 1 and 2. 214
Table 5.14: International outgoing communication traffic capacity regression; second method (equation 5.7); Groups 1 and 2. 212
Table 5.15: Stock demand regression results (equation 5.11); first traffic demand predicted results (equation 5.6); North American manufacturers price index, model 3 (table 3.12); Groups 1 and 2. 218
Table 5.16: Stock demand regression results (equation 5.11); second traffic demand predicted results (equation 5.7); North American manufacturers price index, model 3 (table 3.12); Groups 1 and 2. 219
Table 5.17: Stock adjustment pooled results, fixed λ (equation 5.14); first traffic demand predicted results (equation 5.6); All (left) and North American (right) manufacturers price indices, model 3 (tables 3.3 and 3.12). 221
Table 5.18: Stock adjustment pooled results, fixed λ (equation 5.14); second traffic demand predicted results (equation 5.7); All (left) and North American (right) manufacturers price indices, model 3 (tables 3.3 and 3.12). 221
Table 5.19: Stock adjustment results, fixed λ (equation 5.14); first traffic demand predicted results (equation 5.6); North American manufacturers price index, model 3 (table 3.12); Groups 1 and 2. 224
Table 5.20: Stock adjustment results, fixed λ (equation 5.14); second traffic demand predicted results (equation 5.7); North American manufacturers price index, model 3 (table 3.12); Groups 1 and 2. 225
Table 5.21: Stock adjustment results, variable λ (equation 5.17); first traffic demand predicted results (equation 5.6); North American manufacturers price index, model 3 (table 3.12); Groups 1 and 2. 228
Table 5.22: Stock adjustment results, variable λ (equation 5.17); second traffic demand predicted results (equation 5.7); North American manufacturers price index, model 3 (table 3.12); Groups 1 and 2. 229
Table 5.23: Stock adjustment results, by groups of countries, variable λ (equation 5.17); first traffic demand predicted results (equation 5.6); All manufacturers price index, model 3 (table 3.3). 231
Table 5.24: Stock adjustment results, by groups of countries, variable λ (equation 5.17); first traffic demand predicted results (equation 5.6); North American manufacturers price index, model 3 (table 3.12). 231

Table 5.25: Stock adjustment results, by groups of countries, variable λ (equation 5.17); second traffic demand predicted results (equation 5.7); All manufacturers price index, model 3 (table 3.3). 232
Table 5.26: Stock adjustment results, by groups of countries, variable λ (equation 5.17); second traffic demand predicted results (equation 5.7); North American manufacturers price index, model 3 (table 3.12). 232
Table 5.27: Stock adjustment pooled results, variable λ (equation 5.17); first traffic demand predicted results (equation 5.6); All (left) and North American (right) manufacturers price indices, model 3 (tables 3.3 and 3.12)..... 234
Table 5.28: Stock adjustment pooled results, variable λ (equation 5.17); second traffic demand predicted results (equation 5.7); All (left) and North American (right) manufacturers price indices, model 3 (tables 3.3 and 3.12). 234
Table 5.29: Stock adjustment pooled results, variable λ (equation 5.18); first traffic demand predicted results (equation 5.6); All (left) and North American (right) manufacturers price index, model 3 (table 3.3 and 3.12)..... 235
Table 5.30: Stock adjustment pooled results, variable λ (equation 5.18); second traffic demand predicted results (equation 5.7); All (left) and North American (right) manufacturers price index, model 3 (table 3.3 and 3.12). 235

Acronyms

ADCS: Attitude Determination and Control Subsystem

BLS: Bureau of Labour Statistics

BSS: Broadcasting Satellite Services

CNES: Centre National d'Études Spatiales

CPI: Consumer Price Index

CSA: Canadian Space Agency

DBS: Direct Broadcasting Satellite

DCME: Digital Circuit Multiplication Equipment

DOD: Department Of Defense

EG: Experience Growth

EIRP: Effective Isotropic Radiated Power

ELV: Expendable Launch Vehicle

ESA: European Space Agency

ETS: Engineering Test Satellite

FET: Field Effect Transistor

FSS: Fixed Satellite Services

GEO: Geostationary Earth Orbit

GTO: Geostationary Transfer Orbit

HAC: Hughes Aircraft Company

HD-MAC: High Definition MAC

HP-DBS: High Power Direct Broadcasting Satellite

INMARSAT: International Maritime Satellite

INTELSAT: International Telecommunication Satellite

ISDN: Integrated Service Digital Network

ISRO: Indian Space Research Organisation

ITU: International Telecommunication Union

LEO: Low Earth Orbit

MAC: Multiplex Analogue Component

MMAS: Martin Marietta Astro Space

MMS: Matra Marconi Space

MSS: Mobile Satellite Services

NASA: National Aeronautics and Space Administration

NASDA: National Development Agency of Japan

NOP: Net Output Productivity

NOPG: Net Output Productivity Growth

OECD: Organisation for Economic Co-operation and Development

PDN: Public Data Network

PPI: Producer Price Index

PTT: Post Telegraphs and Telephones

R & D: Research and Development

RF: Radio Frequency

SS/L: Space Systems/Loral

SSPA: Solid State Power Amplifier

TDF: Television de France

TFP: Total Factor Productivity

TFPG: Total Factor Productivity Growth

TFPI: Total Factor Productivity Index

TT&C: Telemetry, Tracking and Command

TV: Television

TWTA: Travelling Wave Tube Amplifier

US: United States

VSAT: Very Small Aperture Terminal

Glossary

ADCS (Attitude Determination and Control Subsystem): Subsystems charged with the stabilisation of the spacecraft and its orientation so as to point its antennas towards the earth.

Actuators: Equipment, such as reaction wheels, gyroscopes and thrusters utilised to rectify the attitude of the satellite.

Amplifier: Device utilised to augment the power of a signal received. Non-linearity characterises the efficiency of power amplifiers, i.e. the output to input power ratio diminishes from 100 % to as low as 50 % as output power increases.

Antenna: Generally parabolic-shaped (like a soup bowl) aerial utilised to receive and transmit signals. Antenna gain is a measure of the power radiated by the antenna in a given direction compared with the power radiated by an isotropic (radiating in all directions) antenna fed with the same power.

Apogee: Point on an elliptical orbit that is the farthest to the celestial object it is orbiting. It is situated opposite the perigee point.

Attitude: Direction towards which the satellite is pointing, generally the earth in the case of communication satellites.

Bolpower (Beginning-Of-Life power): Power delivered by the solar panels when the satellite is first operational.

Bus: Synonym of platform.

Carrier: High frequency signal modulated by the communication signal.

C-band: Frequency band characterised by frequencies between 4 and 8 GHz; for commercial satellite communications, up links (earth to satellite) use frequencies between 5.925 and 6.425 GHz and down links (satellite to earth) use frequencies between 3.7 and 4.2 GHz.

Channel: The entire frequency band allocated to a given satellite system is divided into smaller sub-bands, or channels which are treated separately. This contribute to eliminate inter-modulation noise created by amplification.

Drymass: Mass of the satellite depleted of all its fuel. This is generally the mass of the satellite at the end of its life.

Eclipse: Time period when the satellite is hidden from the sun by the earth.

EIRP (Effective Isotropic Radiated Power): Measure of the power of the signal radiated by an antenna.

EOL (End-Of-Life): The end-of-life of the satellite is defined as the time when the designed lifetime elapses, while the actual death of the satellite occurs when it slowly goes out of its assigned orbit as it runs out of propellant or a failure of some sub-systems prevents its main function, i.e. signal transmission.

Footprint: Geographical area covered by a satellite determined by a minimum EIRP value.

Frequency band: Attributed range of frequencies within which the satellite must operate, receive or transmit signals.

GEO (Geostationary Earth Orbit): Geosynchronous orbit situated approximately 36,000 km above the surface of the earth. A satellite in this position will remain located above the same geographical point on the planet.

Geomass: Mass of the satellite once it has reached its assigned geostationary orbit. This is the mass of the dry spacecraft plus the mass of the on-board propellant that will provide the station-keeping thrusts during its lifetime.

Ground segment: Earth stations responsible for the transmission and reception of signals.

GTO (Geostationary Transfer Orbit): Elliptical orbit with an apogee point on a geostationary orbit and a perigee point on a low earth orbit. Orbit that a spacecraft must follow to reach a geostationary orbit.

Gtomass: Mass of the satellite once it has been injected onto the geostationary transfer orbit, and before the apogee thrust that will increase the spacecraft velocity to attain a geostationary orbit. This is the geomass of the satellite plus the on-board propellant necessary for the apogee kick motor. Consult appendix E for details on the launch process.

Harmonics: Harmful higher frequency signals created as by-products after amplification.

HD-MAC: High Definition MAC.

ISDN (Integrated Services Digital Network): Digital switched network supporting transmission of voice, data and images over conventional telephone lines.

Ka-band: Frequency band characterised by frequencies between 26.5 and 40 GHz.

Ku-band: Frequency band characterised by frequencies between 12.4 and 18 GHz; for commercial satellite communications, up links (earth to satellite) use frequencies between 14.0 and 14.5 GHz and down links (satellite to earth) use frequencies between 11.7 and 12.2 GHz.

L-band: Frequency band characterised by frequencies between 1 and 2 GHz.

LEO (Low Earth Orbit): Orbit situated approximately 200 km above the surface of the earth.

MAC (Multiplex Analogue Component): wide band television standard, e.g. C-MAC, D2-MAC.

O-band: Frequency band characterised by frequencies between 60 and 90 GHz.

Payload: Part of a satellite composed of the receiving and transmitting antennas, and all the electronic equipment which supports the transmission of signals, mainly the transponders.

Perigee: Point on an elliptical orbit that is the closest to the earth, or the celestial object it is orbiting.

Platform: Also known as the spacecraft bus, this part of the satellite provides all the necessary support for the operation of the payload.

Receiver: Part of the transponder that receives the signal, filters out the noise and modifies the frequency of the carrier.

Repeater: Synonym of transponder.

RF amplification: The high power amplifier converts its DC input power (the power provided by the electric power supply) into radio-frequency power (the power of the signal).

Satellite: Man-made device orbiting around the earth used to relay signals between regions of the planet.

S-band: Frequency band characterised by frequencies between 2 and 4 GHz.

Sensors: Electronic devices used to monitor the localisation and state of the satellite.

Solar panels: Panels composed of solar cells and solar generators utilised to convert energy emitted by the sun into usable electricity.

Solstice: Time period when the satellite is in view of the sun.

Space segment: The satellite as well as the earth stations monitoring and controlling the spacecraft.

SSPA (Solid State Power Amplifier): Transistor-based power amplifier using field effect transistors (FET) to amplify the signal received.

Stabilisation: Maintenance of the satellite attitude, i.e. pointing towards the earth. Two methods have been utilised so far, spin stabilisation and three axis stabilisation. The former constantly rotate the satellite around one axis, while the latter uses various actuators to correct variations in attitude.

Station-keeping: Maintenance of the satellite into its a pre-assigned box to avoid interference with neighbouring satellites. Thrusters are the main devices utilised for this task.

TT&C (Telemetry, Tracking and Command): Subsystem charged with the monitoring and maintenance of the vital signs of the satellite.

Telemetry: Transmission of measurements and information concerning the satellite operation to monitor the satellite from the ground.

Tracking: Also called navigation and guidance, tracking is used for orbit determination, orbit control and station-keeping. Orbit determination and control maintains the distance from the satellite to the earth (on the operating orbit).

Transmitter: Part of the transponder that recombines the channels, filters out the harmonics created in the amplification stages and transmits the signal.

Transponder: Also known as repeater, this device receives the signal, modifies its frequency, amplifies it and then transmit it back (see section 2.1.1.1 for a more comprehensive explanation).

TWTA (Travelling Wave Tube Amplifier): Travelling wave tubes operate by interaction between an electron beam and a radio wave in order to amplify the signal received.

X-band: Frequency band characterised by frequencies between 8 and 12.4 GHz.

List of Variables

***Complexity*$_{3i}$** [Chapters 3 and 4]: Technical measure of the value of complexity defined as for engineering costing software

***Complexity*$_{4i}$** [Chapters 3 and 4]: Technical measure of the value of complexity defined in an economic semi-log format

ctrp [Chapters 2, 3 and 4]: Proportion of transponders operating between 4-8 GHz

δ [Chapter 4]: Depreciation rate

D(P) [introduction]: Demand for communication satellite capacity

D_1 [Chapter 5]: Dummy variable for the domestic satellite country owners

D_2 [Chapter 5]: Dummy variable for the non-domestic satellite country owners

D3a [Chapters 2, 3 and 4]: Type of stabilisation (1 if 3-axis, 0 if spin stabilised)

D7275 [Chapter 3]: Time dummy variable for the years 1972-75

D7679 [Chapter 3]: Time dummy variable for the years 1976-79

D8081 [Chapter 3]: Time dummy variable for the years 1980-81

D8284 [Chapter 3]: Time dummy variable for the years 1982-84

D8586 [Chapter 3]: Time dummy variable for the years 1985-86

D_{8593} [Chapter 5]: Time dummy variable for the period 1985-93

D8788 [Chapter 3]: Time dummy variable for the years 1987-88

D8990 [Chapter 3]: Time dummy variable for the years 1989-90

D9193 [Chapter 3]: Time dummy variable for the years 1991-93

$D_C(P)$ [introduction]: Demand for communication capacity

D_{is} [Chapter 5]: Dead satellite capacity of country i

D_t [Chapter 3]: Dummy variable for the t^{th} time period

Dtwt [Chapters 2, 3 and 4]: Type of amplifier (1 if TWTA, 0 if mix of SSPA and TWTA)

Dx_{ki} [Chapters 3 and 4]: Dummy variable for the k^{th} characteristic of the i^{th} satellite series

E [Chapter 4]: Experience as a measure of cumulative complexity

ε [Chapter 4]: Price elasticity of demand

ε_i [Chapter 3]: Error term associated with the i^{th} satellite series

eolpower [Chapters 2, 3 and 4]: End-of-life solar array power capability

γ [Chapter 4]: Learning coefficient

gmeirp [Chapters 2, 3 and 4]: Effective isotropic radiated power

G_T [Chapter 2]: Transmission gain of the satellite antennas

gtomass **(m_i)** [Chapters 2, 3 and 4]: Launch mass of satellite

hmpower [Chapters 2, 3 and 4]: Amplifier power

K [Chapter 4]: Capital input

K_{is} [Chapter 5]: Satellite capacity of country i

kutrp [Chapters 2, 3 and 4]: Proportion of transponders operating between 12.4-18 GHz

L [Chapter 4]: Labour input

λ [Chapter 5]: Adjustment coefficient

lifetime [Chapters 2, 3 and 4]: Planned number of years for which the satellite is designed

M [Chapter 4]: Material input

m_i [Chapters 3 and 4]: Launch mass of a satellite of the i^{th} series

mtrp [Chapters 2, 3 and 4]: Proportion of transponders operating between 0.3-4 GHz

nb_i [Chapter 3]: Number of satellites included in the order of the i^{th} satellite series

number **(nb_i)** [Chapters 2 and 3]: Number of satellites ordered in a contract

O_j [Chapter 5]: Other countries' orders of satellites

otrp [Chapters 2, 3 and 4]: Proportion of transponders operating between 8-12.4 and 26.5-60 GHz

p [Chapter 5]: hedonic price index for satellites

$PComp_{in}$ [Chapter 5]: n^{th} principal component of country i

P_I [Chapter 4]: Price of investment

p_i [Chapters 3 and 4]: Price of each of the satellites of the i^{th} series

P_S [Chapter 4]: Hedonic price of satellites

P_T [Chapter 2]: Transmission power of the satellite

Q [Chapter 4]: Quantity of satellite capacity

Q_i [Chapter 5]: International outgoing telephone traffic of country i

θ_K [Chapter 4]: Capital input share

θ_L [Chapter 4]: Labour input share

θ_M [Chapter 4]: Material input share

r [Chapter 4]: Interest rate

rdev [Chapters 2 and 3]: Development time (contract to launch)

σ [introduction, Chapter 5]: Elasticity of substitution

$S(P)$ [introduction]: Supply of communication satellite capacity

$S_A(P)$ [introduction]: Supply of terrestrial and oceanic cable capacity

$S_C(P)$ [introduction]: Supply of communication capacity

service [Chapters 2, 3 and 4]: Type of service (0 if FSS, 1 if FSS+BSS, 2 if FSS+MSS, 3 if BSS, 4 if MSS)

S_i^* [Chapter 5]: Desired stock of communication capacity of country i

S_{if} [Chapter 5]: Stock of alternative media communication capacity of country i

S_{is} [Chapter 5]: Stock of satellite capacity of country i

S_{is}^* [Chapter 5]: Desired stock of satellite capacity of country i

S_{js} [Chapter 5]: Stock of satellite capacity from other countries j

sumtr [Chapters 2, 3 and 4]: Total number of transponders (excluding redundancy)

totbw [Chapters 2, 3 and 4]: Total bandwidth capacity (excluding redundancy)

w_K [Chapter 4]: Rental rate of capital

w_L [Chapter 4]: Wage rate

w_M [Chapter 4]: Price of material

ξ [Chapter 5]: Bandwidth efficiency measure

X_{ji} [Chapters 3 and 4]: Measure of the j^{th} characteristic of the i^{th} satellite series

y [Chapter 5]: Stock

y^* [Chapter 5]: Desired stock

I. Introduction

More than fifty years ago, Arthur C. Clarke (1945) thought of the advantages and possibilities of developing geostationary communication satellite systems. On the potential of satellite systems, he wrote the following:

> *"... the advantages of the space station are as follows:-*
> *(1) It is the only way in which true world coverage can be achieved for all possible types of service.*
> *(2) It permits unrestricted use of a band at least 100,000 Mc/s wide, and with the use of beams an almost unlimited number of channels would be available.*
> *(3) The power requirements are extremely small since the efficiency of 'illumination' will be almost 100 per cent. Moreover, the cost of the power would be very low.*
> *(4) However great the initial expense, it would only be a fraction of that required for the world networks replaced, and the running costs would be incomparably less."*

Today, the geostationary communication satellite systems proposed by this visionary man provide an important part of our day to day communications. As in many high technology environments, military applications lay the ground work for commercial communication satellite systems. The space age started in the middle of the Cold War when the first spacecraft to orbit the earth, Sputnik-1, was launched on October 4, 1957. Three months later, the United States launched Explorer-1. Both satellites would broadcast messages, the former emitted a simple repeated beep, while the latter transmitted a pre-recorded message from the US president. It is only in 1962 that the first real-time communication satellite, Telstar-1 was launched. Telstar-1, the predecessor of modern satellite communications, could transmit telephone and television signals across the Atlantic. So far, all satellites launched were either experimental or intended for military purposes (Curtis, 1994).

It is now 34 years since the launch of EarlyBird, the first commercial communications satellite. Also known as Intelsat I, EarlyBird could carry 240 telephone channels or one television program between Europe and North America. A few years later, Canada's Anik A1, launched in 1972, became the first commercial *domestic* communication satellite. The Anik A satellite series could relay twelve television channels for Canada's domestic market; Within just seven years, the satellite capacity had been multiplied by twelve. The capacity of satellites has continued to evolve and nowadays, satellites incorporate transponders of different frequency bands (hybrid payloads) used for a wide range of communication services. Not only are satellites composed of a greater number of transponders than their predecessors, but their capacity also expands as modulation techniques allow for increasing frequency re-use. The industry that has grown up around the idea of geostationary orbiting satellites, envisaged by Arthur C. Clarke in 1945, has matured into a paradigm of the way in which 'high tech' augments and changes 'old tech'.

I.1 The nature of the industry

Not only did the capacity of the typical communication satellite grow, but their numbers have grown greatly as well. Indeed, an increasing number of satellites are being launched every year: during the 1960s, 8 commercial communication satellites were successfully launched, while during the 1980s, more than 90 spacecraft were launched, and the tendency is expanding with new countries entering the

communication satellite club. As a result, the stock of actively functioning satellites in orbit has continued to increase.

Satellite communication, however, is not the universal panacea that the first engineers thought it would become. Different communication technologies have emerged to compete for similar traffic. For instance, fibre optic cables under the Atlantic are used for the same purpose as satellites but have the advantage of eliminating transmission delays, typical to geostationary satellite communications, that are particularly troubling in the case of telephone traffic. The first transoceanic cable allowed telephone communications between North America and Europe in 1956, much before the launch of the first commercial communication satellite. Intelsat launched its first satellite (Intelsat I) in 1965 to provide further capacity over the Atlantic at a lower cost. Before Intelsat I was launched, the transatlantic submarine cables TAT 1 to 4 had been in operation, but TAT 4 could provide 138 voice circuits while Intelsat I supplied 240 voice circuits. Since then, both terrestrial and submarine cable systems have competed with satellites to provide communication services. With the advent of TAT 10, the third transatlantic submarine fibre optic cable, Intelsat lost the battle for the cheapest circuits (OECD, 1995).

Communication satellites were first introduced to carry long distance telecommunications or provide feed for local television transmitters[1]. Telecommunication services have led the way to data transmission, and jointly with broadcasting, to video-conferencing. Broadcasting has developed into a more user oriented service with the propensity to increase more than ten-fold the number of television channels transmitted directly to users' homes. With the advent of transoceanic fibre optic cables, satellite technology has been increasingly redirected towards broadcasting services that transmit to the end-user. Point-to-point transmissions[2] such as telephone calls are in general better served by systems of cables, while point-to-multipoint transmissions, such as broadcasting, are more appropriate to satellites. Some services rely heavily upon satellites, for instance, direct-to-home (DTH) satellite television services, as competitors to cable broadcasting services, rely entirely on spacecraft transmissions. Further, where no cable connection is possible, as in maritime communications, greater use is being made of satellite services. The commercial communication satellite services market therefore consists of three main categories of services: fixed telecommunications (including voice and data), broadcasting (sound and video) and mobile communication services. Servicing the broadcasting industry remains the major application for satellite services (OECD, 1995, p.31).

Orbiting communication satellites have their place as auxiliaries to ground-based facilities, rather than replacing them as foreseen in Arthur C. Clarke's visionary statement. In 1990, communication satellite traffic represented 60 % of Australia's total telecommunication traffic, 64 % of New Zealand's and 40 % of Germany's

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[1] Most of the literature uses communication and telecommunication in the same sense. In order to avoid confusion in this thesis, the following convention will be adopted: satellite broadcasting will refer to everything that relates to mass transmission whether it is video, television, sound or radio, and satellite telecommunication will refer to everything that is not broadcasting with the exception of radio-localisation services, while satellite communication will generally designate broadcasting and telecommunication services.

[2] Point-to-point transmissions are better served by networks of cables because geostationary satellites introduce a small delay in the communication. This will probably be remedied with the advent of low earth orbit satellites.

(OECD, 1995). Furthermore, in 1990, 3.5 % of US households possessing a television set were equipped with direct reception satellite services equipment, while 59 % of TV households received cable television services. In the same year, 3.1 % of all Japanese television sets received television services directly via satellite. More recently, in 1993, direct-to-home (DTH) broadcasting satellite services reached 12 % of the entire number of television sets (Rusch, 1992). Although these direct broadcasting services represent a small proportion of the entire broadcasting market, their presence is increasingly significant. In addition, countries like the Philippines have a greater incentive to use satellites rather than lay a web of submarine cables.

The satellite supply industry is similar to the business of design and construction of hydroelectric dams; both involve 'bespoke' work, in the way that customers are purchasing a discrete, costly product that has been 'tailored' to suit their needs. In other ways, the satellite industry also shares procedural features that make it more akin to the aircraft industry than, say, to the computer business: it employs a highly skilled workforce; incorporates elements of oligopoly and competition; the technology spillovers from military to civilian sectors once were high but are now less important than they were in the infant stage of the industry; many countries have deregulated their telecommunication industry as they have their airline markets; a laborious road between the initial conception of a space program and its completion may take as much as five years; in Europe, the principle of *juste retour* causes delays and extra cost in the case of European satellites such as Eutelsat. Multinational firms operating production facilities in numerous countries are rare in the satellite industry as is also the case of aircraft (see Mowery and Moran, 1994).

In approaching economic analysis of this industry, then, it is important to bear in mind the departure of the characteristics of the market for telecommunication satellites from those of a competitive industry. There are few players on the side of the vendors: about 20 satellite builders world wide, of which less than half compete internationally, and about three times as many satellite owners. The market is therefore essentially oligopolistic. Further, the communication satellite production industry is also highly vertically integrated, with two US manufacturers providing communication services via satellite operator subsidiaries as well as launch vehicles and ground stations via other subsidiaries. Satellite producers are also horizontally integrated: similarly to the aircraft industry these firms seek to form alliances to spread the high cost of developing new technology (Mowery and Moran, 1994), where the tendency is to form a consortium of specialists capable of producing 'efficiently'.

The data utilised for the present study covers 29 years and includes contracts for commercial communication satellites from 1964 to the end of 1992. This represents the data available at the time of the study and was not updated for the following reasons. First, it would have taken a considerable amount of time to update it accurately. Second, the decision to exclude from this study the contracts signed from 1993 onwards resides in the dramatic change, after this date, not only in the structure of the industry but also in the technology, introduced by the new smaller and cheaper 'constellations' of low-earth-orbit satellites such as the Motorola Iridium and Qualcomm Globalstar programs. On the manufacturing side of the satellite industry, the advent of these constellations of satellites implies the introduction of production lines for the fabrication of more than 60 identical satellites, compared with an average of 2 satellites per contract prior to 1993. Considerable economies of scale can therefore be obtained and the price per spacecraft should decrease dramatically.

Moreover, these satellites require less power for successful transmissions, as they are closer to the surface of the planet, making savings on the technology as well. On the demand side, i.e. the supply of communication satellite services, the launch of these low-earth-orbit world-covering constellations of satellites should give a competitive advantage to their owner and drive some less competitive players out of the market, especially in the field of mobile telecommunications. In addition, from a technology point of view, these satellites are in a class of their own. They orbit the earth on a much lower orbit and, to reach their orbital positions, smaller launch vehicles costing substantially less can be used. Being much smaller and lighter, these satellites can also be launched in bunches, thus further reducing the launch costs. All in all, these low-earth-orbit constellations of satellites will revolutionise satellite communications, and for these reasons, they will be excluded from this work. In any case, as the price considered here corresponds to satellite contracts, they would appear as outliers in this study because although in terms of number of satellites, they contribute a substantial amount, they still represent a very small number of contracts in the database.

I.2 The approach in this study

The objective of this study is to develop a general understanding of the evolution of this high technological sector of the industry, in this case, the world communication satellite industry. The approach of this thesis is to examine is the supply and demand of commercial communication satellites as a capital good. On the supply side, the industry under study is the commercial communication satellite manufacturing industry, whereas, on the demand side, the buyers of this capital good are telecommunication and broadcasting service providers. One of the questions that this thesis will attempt to answer is whether the industry is demand or supply driven, i.e. whether demand is pulling the rapid growth in technical evolution, or is it a result of technological improvements on the supply side. Also, since we observe an increase in the quantity of satellites being purchased over the years, we may ask whether this was due to a demand-shift or a supply-shift. If satellites were a perfect network good, i.e. the more of that good we have then the more valuable is the network and the more expensive it becomes, the demand curve would slope upwards. This is not true of satellites as they are intrinsically a point-to-multipoint device in some of their services. So because of the broadcasting technology and because there exists alternative media to transmit communication signals, we have strong reasons to believe that the demand curve slopes downwards. Assuming that the demand curve slopes downwards, we can then ask what happened to the change in the price of a standard unit satellite. The underlying motivation of this thesis is therefore the conventional 'identification problem', as illustrated in figure I.1.

If $\Delta P < 0$, there must have been a supply shift, but there could also have been a demand shift, which we can only verify once we know the elasticity of the demand curve, *D(P)*. First, we need to measure the change in price, ΔP, correctly using some price performance ratio of satellites, as a change in quality over time, implied by the changing characteristics of satellites, has already been noticed. We will do so by taking the hedonic price index approach.

Bartik (1987) shows that the economic problem in estimating hedonic demand parameters is not a standard identification problem as has often been assumed; Indeed, such a framework leads to biased results, as supported by Epple

(1987). Both authors argue that the supply and demand interaction if treated as standard identification problem (in the same way as Rosen, 1974) yield biased estimates. The basis of Rosen is that the marginal price of the buyer for an attribute of the good being purchased and the marginal price of the seller for the same attribute of the same good both contribute to estimate the hedonic marginal price for that good's characteristic. The problem resides in the fact that ordinary least squares estimation of the hedonic equation will be biased because unobserved tastes in the residual are correlated with the buyer's choice of attributes. To overcome this problem, Epple (1987) proposes an instrumental variable method that uses any variable that shifts the budget constraint of the household because it is correlated with the choice attributes and goods being purchased by the household, but uncorrelated with unobserved tastes. Brown and Rosen (1982) also concentrate on the pitfalls of Rosen (1974).

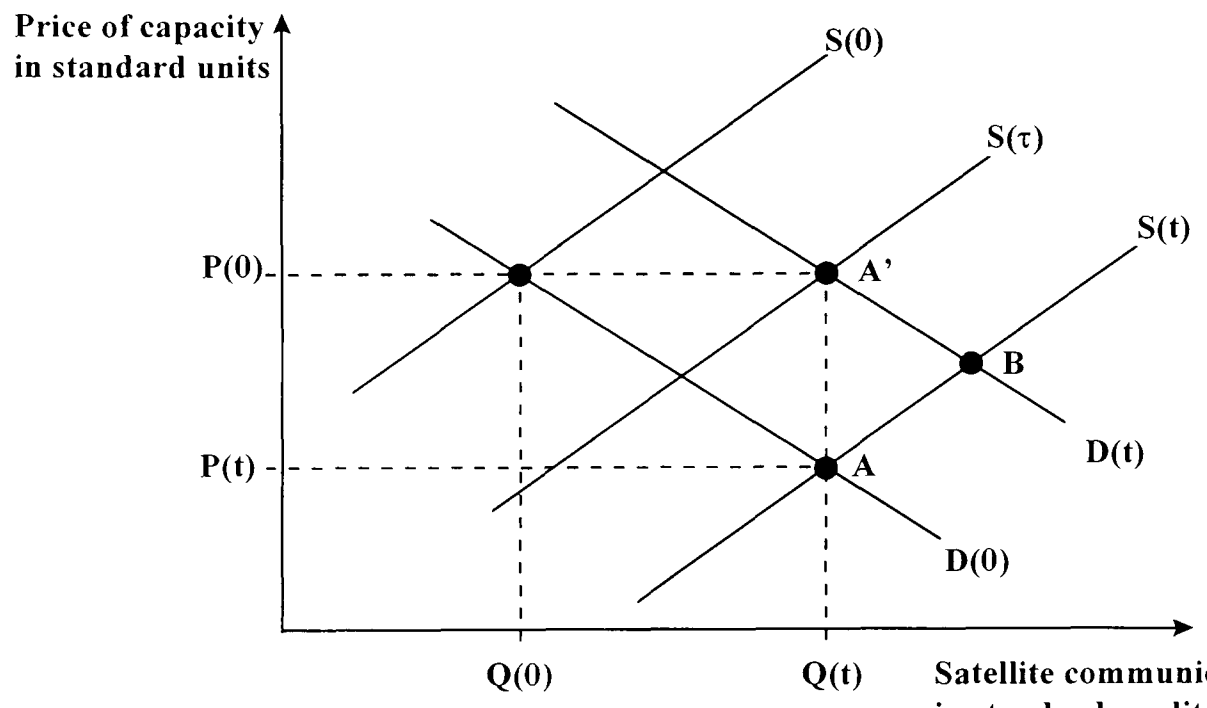


Figure I.1: Identification problem.

Arguea and Hsiao (1993) provide a different method to circumvent the problem of supply and demand interaction in the hedonic model, which consist of relying on cross-sectional data alone. They also provide methods to choose the relevant number of attributes to include in the analysis, arguing that too many variables do not represent consumers taste accurately because they are simpler, and too little variables can lead to mis-specification of the model.

Measuring the price change accurately will inform us as to whether this quality change was related to a supply shift. On the one hand, if the price increases, it can either move along the supply curve or it is due to a shift in supply; the case of the price increase is thus ambiguous because the supply may be very elastic. On the other hand, if the price decreases and the demand curve slopes downwards, as is assumed here, it must have been because of a shift in the supply curve. In the present case, there are three potential sources for a supply shift:

- endogenous technological improvement in the industry due to learning;
- price of inputs going down, i.e. technical progress in other industries bringing the cost of inputs down;
- increasing competition decreasing profits.

The main question to consider when examining the supply side is whether technical progress is present. Suppose for a moment that we have a monopoly to start

with, and then entry causes a drop in the profit-margin by decreasing the supply price. Two questions then spring to mind: Is supply shifting faster than demand because of entry of new firms that narrow the profit-margin? Or is the cost falling because of technical change? Note that we do not observe a plummeting price as is observed for the computer industry. This, however, does not tell us how much of the change in quantity is due to the change in supply. For this, we need to identify the demand function and estimate its elasticity. A possible approach is to suppose one could estimate the demand for communication capacity $D_C(P)$, and the supply function for terrestrial and oceanic cable transmissions, $S_A(P)$; then the demand for communication satellites $D(P) \equiv D_C(P) - S_A(P)$. This assumes that alternative supply technology makes $S_A(P)$ a perfect substitute for the supply of satellites $S(P)$. If satellites are not a perfect substitute for alternative technologies, and this is likely because of the existence of services provided exclusively by satellites, then the supply of communication capacity becomes $S_C = F(S_A, S/\sigma)$, where σ is the elasticity of substitution $0 < \sigma < \infty$. Implicitly, our approach assumes $0 < \sigma < \infty$, and so we try to identify the demand for satellites, $D(P)$, and estimate its elasticity.

If we find that the demand slope downwards, as we expect it does, then marginal cost decreases and we may observe economies of scale and learning. But no big economies of scale are noticed, or even expected, in this industry because of the nature of the product. Indeed, satellites are custom-made to the design specifications of their customers, indicating that each satellite, or series of satellites in the same purchase, is unique. With the technology improvements noticed in the industry, this implies that the spacecraft manufacturing industry is learning, and the demand curve shifts outwards over time. Is this a short run phenomenon or is it more characteristic in the long run? Does this happen because of increasing plant capacity or lower long run marginal costs? This thesis will attempt to discover to what extent is this industry's expansion being driven by supply shifts, and reduction in price/cost of this form of communication channel, vis-à-vis the general price level and vis-à-vis other models, and so displacing those models from existing markets. If supply shifts are found to be important, this study will seek to determine the sources: altered entry conditions, changing competition, or technologically driven cost cutting. If the latter is evident, we will try to evaluate whether this has come from satellite manufacturers, or from underlying technologies that are used in these capital goods. For example, in the computer industry, innovations in micro-processors have driven the capacity and speed of computers. Questions such as whether innovations occurred because the supply-side is more important at the fundamental technology or at the construction level are interesting but will not be addressed here as the data required for such an analysis could not be gathered in the time available.

In general, satellite footprints cover a number of countries, for this reason, demand for satellite communication services emerging from all the countries covered are relevant. To complicate matters, various countries may have different demand curves, and their demand shifts may also be dissimilar. We therefore need to investigate the factors that shift demand in these countries and whether there are global demand drivers in order to determine the slope of the demand curve. Does the change in satellite capacity growth reflect the change in growth of communication services demand? Answering this question will allow us to determine whether satellites are being preferred to alternative technologies that could satisfy the same, or similar services, more cheaply. A further study of the stock adjustment process of

various countries may shed some light as to why some countries adjust their stock of satellite capacity faster than others. It may be that in some countries, a heavy and obsolete infrastructure slows down the process of innovation, while more recent adopters of advanced communication systems buy the new updated technology, and are therefore seen as adjusting faster than others. Furthermore, countries may have similar patterns of adjustment because regional satellite systems service their needs. There may also be a significant difference in the speed of adjustment of countries that first launched domestic satellites, such as Canada and the US, compared with the newer South East Asian entrants. The speed of adjustment may also vary over time and, for example, depend on the backlog of orders of spacecraft manufacturers. There may be cycles of orders because of the increasing lifetime of commercial communication satellites. Many questions need to be answered to fully understand the market for communication satellites and the growth of this capital good.

I.3 The organisation of the thesis

The thesis is divided into two parts. The first part provides a description of the industry. The first chapter introduces the relationships between the main players of the communication satellite industry. After a brief glance at the growth of key communication indicators, the chapter then presents the evolution of the number of satellites over a period of 28 years followed by the contribution of the different types of players in the stock of satellites. In order to understand the constraints in the manufacturing side of the industry, a better understanding of the technology intrinsic to communication satellites is given in a second chapter. The different functions of the satellite components are explained before being quantified by variables. Then the evolution of these technological objects is traced over time.

A third chapter subsequently addresses the first stage of the identification problem, i.e. whether the price has risen or fallen. Although there are problems with supply and demand interaction in hedonic estimation, this chapter will not concentrate on these interactions but rather on one side of the story. The demand-side will be formally examined in chapter 5. Hedonic price regressions will be estimated to establish the shadow price of these satellite qualities, i.e. the customers' willingness to pay for these attributes. Because we are dealing here with the derived demand for a production input, namely the satellite, whose technical characteristics are well understood, the problems of incomplete specification of demand, leading to unobserved taste effects in the residual being correlated with purchaser's choices, is not the serious source of bias that may plague the use of the hedonic approach in the case of consumer goods. We make use of a detailed engineering information about these satellites to specify alternative estimating equations, and we use extraneous information about differences in the technological regimes obtained during various sub-periods, in estimating the model econometrically. Thus, chapter 3 does not enter into a discussion of the interactions between the supply and demand sides, leaving the latter for treatment in the second part.

The second part of the thesis investigates the forces of supply and demand on the satellite industry. A fourth chapter examines the supply conditions and the technology change using information derived from the hedonic regressions of the third chapter. Supply side shifts, invoking technological innovation, entry of vendors and so on, is one part of the story. Price-quantity relations are examined to identify

whether or not such shifts were important. A study of productivity change and mark-up evidence allows to distinguish between entry and innovation/technological change effects on the supply schedule. Total factor productivity indices are calculated for the industry by employing the so-called 'dual approach', which infers the magnitude of efficiency shifts in the production function from the changing ratio of unit costs to unit prices of the output. For the prices, we are able to utilise the hedonic price index estimates from chapter 3, whereas for costs we have constructed a new index based on input prices and cost shares. Chapter 4 then proceeds to examine the movements of the resulting total factor productivity index, and considers its relationship to changes in mark-ups and the effects of learning by doing among the vendors.

In chapter 5, we turn to the demand side. Communication satellites are not the only product manufactured by satellite builders, most prime-contractors also participate in the production of meteorology and earth observation satellites. Depending on the type of output, the level of competition varies from monopoly to oligopoly. Noting the lack of perfect substitutability between satellites and wires/cables technologically, the chapter examines the demand for these satellites using world wide information relating to the evolution of telecommunication and broadcasting services. The demand shifts characteristic to most countries in the world are calculated. Using this measure, a stock demand equation is fitted to determine the desired stock of satellite communication capacity wanted by each country. Then, countries are compared according to their adjustment speed of their stock of satellite capacity. Various functional forms are utilised to determine similarities between countries and whether the adjustment speed has changed over time.

Finally, the concluding chapter summarises the various effects of supply and demand discovered in the evolution of the technology.

Chapter 1

Evolution of the communication satellite industry

1.1 STRUCTURE OF THE COMMUNICATION SATELLITE INDUSTRY 12
1.1.1 Three types of players 12
1.1.1.1 Manufacturers 12
1.1.1.2 Launch providers 13
1.1.1.3 Customers and operators 15
1.1.2 Integration in the space industry 16
1.1.2.1 Vertical integration 17
1.1.2.2 Horizontal integration 18
1.1.3 Other aspects 21
1.1.3.1 Transaction mechanisms 21
1.1.3.2 Insurance 23
1.1.3.3 Competition between different regions of the world 24
1.1.3.4 Alternative technologies and demand 25
1.2 COMMUNICATION GROWTH 26
1.2.1 Telecommunication infrastructure growth 27
1.2.2 Telecommunication traffic growth 29
1.2.3 Broadcasting growth 30
1.2.4 Communication satellite growth 33
1.3 HISTORY OF SATELLITE COMMUNICATIONS 35
1.3.1 General history of the satellite communications 36
1.3.2 Disaggregation by manufacturing 39
1.3.2.1 Evolution of satellite manufacturing 39
1.3.2.2 Concentration of satellite vendors 43
1.3.3 Disaggregation by ownership 47
1.3.3.1 Evolution of satellite ownership 47
1.3.3.2 Concentration of satellite customers/operators 51
1.3.4 Other measures of the evolution of supply of satellites 54
1.4 CONCLUSION 56
ANNEX 1.1 58

1. Evolution of the communication satellite industry

A little more than 30 years ago, in 1965, the first commercial communication satellite, Intelsat I, was launched. It had a life expectancy of 2 years, a mass of approximately 68 kg and possessed one transponder[1] in the C band[2] (Intelsat, 1987). Over time, the size, mass, power, lifetime and signal capacity of communication satellites increased gradually and continuously, filling the payload[3] of launch vehicles as soon as they expanded. Nowadays, satellites have on average more than 20 transponders, a lifetime of around 10 years and a mass that varies between 1500 and 4600 kg. Not only did the quality of satellites improve over time, the number of spacecraft launched every year has also expanded to create an increasingly important fleet above the equator. Intelsat was the first international organisation to launch telecommunication satellites, Inmarsat[4] followed suit in 1981 with two Marecs spacecraft. With the launch of Anik A in 1972, Canada became the first country to utilise a domestic communication satellite.

Before this evolution in quality and quantity of civilian communication satellites took place, the military had built and successfully launched a considerable number of spacecraft. Many years of space communication research and development have led to the commercialisation of satellite communication observed since the launch of Intelsat I. Between the late 1950s and mid-1970s, NASA and the Department of Defense (DOD) launched 28 experimental communication satellites; NASA sought to develop and test space communication for commercial applications such as telephony and television. The only private sector company to participate in the financing of these R&D programs was AT&T with Telstar1 and 2[5]. Even though military R&D played a crucial role in the development of commercial communication satellites, nowadays, the direct transfer of technology between military and civil space applications is minimal; military satellites are often too complex for commercial needs[6].

In the United States, the 1970s were characterised by the emergence of a market for the ownership and operation[7] of domestic commercial communication satellites as well as an expansion of the civilian spacecraft production market. At the same time, the stagnation of the military budget accompanied that of NASA programs.

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[1] A transponder is the part of a satellite that receives the signal, modifies its frequency, amplifies it and transmit it back. All the technical terms in this thesis are defined in the glossary, and will be briefly described in a footnote when first encountered.

[2] The C band handles the transmission of signals in the frequency band situated between 4 and 8 GHz.

[3] The payload is the part of a satellite that supports the manipulations of the signal.

[4] The two Marecs satellites were leased by the European Space Agency (ESA) to Inmarsat which was created in 1979.

[5] Telstar 1 and 2 were the ancestors of the commercial communication satellites Telstar 3 and 4.

[6] For instance, military telecommunication satellites include functions such as sophisticated scrambling and antinuclear propagation effects which are of little use to commercial applications (Euroconsult, 1991, p.51).

[7] In general, operation of a civilian communication satellite is executed by its owner.

Following this rapid early growth, this chapter will show that during the 1980s and 1990s, the growth of the commercial telecommunication market continued, though more slowly than in the 1970s. Despite an increase in production of commercial communication satellites, in the United States, military applications were undoubtedly the most important spacecraft production market with the introduction of many uses such as meteorology, geodesy, navigation/positioning, early warning, general and local observation, electronic intelligence, and so on.

In Europe, the development of the space industry is far more recent; space communication R & D started fifteen years later in Europe than in the United States. Furthermore, European commercial applications, primarily telecommunications, started up about ten years later than in the United States. Thus, it was not until the early 1980s that the European domestic satellite communication operation market truly developed. It will be noticed in this chapter that this late start led to strong growth in the production of civilian commercial communication satellites. This implies a separation of the European and US domestic markets for satellite services. Indeed, there is a difference in the date of introduction of satellite communication services in both regions; early 1970s for North America and beginning of the 1980s for Europe. Moreover, by the time Europe was launching its first domestic telecommunication and broadcasting satellites, North American satellite customers were already replacing and expanding their fleet.

Did the late start of European communication satellite market affect the market share of US satellite builders? This chapter will examine the difference in the number of satellites ordered to different satellite manufacturers, mainly European or North American, and launched by different customers, US, Europe, international consortia and customers from other countries. The most significant difference between European and US spacecraft manufacturers is that military applications, in Europe, did not play the same role of R & D precursor as they did in the US.

More generally, with the augmentation of the number of commercial communication satellites produced, how were the first companies building and operating satellites affected by new entrants in the market? Did these entrants have any impact on the degree of integration, vertical and horizontal, in the whole industry including both manufacturers and operators? And if so, how? For example, firms on the verge of exiting the market may have been taken over by a more successful competitor or an interested satellite operator. This chapter will show that the evolution of the degree of concentration in this industry has decreased, but that the main players in the production market have maintained their first mover's advantage through the whole period. Competition from manufacturers as well as from alternative technologies capable of providing similar services will be studied as well as the effects of a heavy ground infrastructure. For example, questions such as whether these kilometres of networked cables were destined to vanish completely or whether they offered some resistance to this new wireless technology will be answered. Contrary to the production market, communication services providers were slowed by a heavy infrastructure of old technology.

The chapter is organised as follows. In a first part, the chapter concentrates on the characteristics and structure of the different parties involved with communication satellites. The section begins with a description of the players involved in the commercial communication satellite industry, and surveys their degree

of integration. Then follow a brief explanation of the transaction mechanisms, insurance schemes involved and an account of the degree competition within and between regions as well as from alternative technologies such as cable and fibre optics. The second part of this chapter examines the rate of growth of communication satellite services using telecommunication and broadcasting indicators. The chapter then examines, in a final part, the evolution of the number of communication satellites since the beginning of the commercialisation of satellites.

1.1 Structure of the communication satellite industry

In order to understand the evolution of the commercial communication satellite industry, the following information concerning the civil satellite industry is needed: an overview of the players and their relationships with one another, an account of the transaction mechanisms, insurance processes and finally, a description of the competition from alternative telecommunication and broadcasting systems that affect the growth of the telecommunication market as a whole.

1.1.1 Three types of players

In the process of providing telecommunication and broadcasting satellite services to end-users, three main players can be distinguished: the manufacturers who produce the satellites, the launch service providers that put them into orbit and the operators who provide the satellite services to the end users. Only the manufacturers and customers will be considered in the rest of the thesis. The role of launch service providers will be examined in the second section.

1.1.1.1 Manufacturers

The spacecraft manufacturing industry is divided into three levels: prime-contractors produce entire spacecraft; subcontractors, supply equipment and subsystems; and components' manufacturers provide parts for these sub-systems. Space equipment and subsystems are the parts that constitute a satellite; they contribute to the payload or the platform[8] and will be described in greater detail in the second chapter. Space components are the constituents of the different subsystems, and electronic components, such as transistors and capacitors, fall into the component category. Subcontractors and space components' manufacturers will deliberately be ignored as they are beyond the scope of this study, and very little data is available on these firms. This study will thus concentrate on the prime-contractors.

An important characteristic of this industry is the small number of satellite manufacturers involved. Indeed, less than 20 companies throughout the world market currently produce satellites at the prime-contractor level. Furthermore, amongst these prime-contractors, only the following four successfully compete internationally in the market for civilian communication satellites: Hughes Aircraft Co., Lockheed Martin, Matra Marconi Space and Space Systems/Loral[9]. Other companies are either not efficient enough (often too small in size, for example) to offer their products on the

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[8] The platform is the part of a satellite that supports, protects and provide power to the payload.

[9] Lockheed Martin resulted from the merger of the space businesses of Lockheed and Martin Marietta Astro Space. Space Systems/Loral is an alliance of Loral, Aérospatiale, Alcatel Espace, Alenia Spazio and Deutsche Aerospace (Rusch, 1992).

international market, or cannot transfer this kind of high technology abroad due to Government regulations. In order to survive, the smaller satellite builders usually concentrate their production on satellite-related products (transponders, antennas, solar panels, ground stations, etc.), competing in the equipment and subsystems market. For example, Alcatel Espace was prime-contractor of the three Telecom 2 and the four Inmarsat 2 satellites and subcontracted the antennas to Spar Aerospace which has an international expertise in this field (Spar Aerospace, 1992a).

In the early days of commercial communication satellites, most US manufacturers were involved mainly with Government military contracts. This is not the case in Europe, where the military aspect of space is relatively small compared to the US. Most US satellite producers are still involved in military contract work but to a lesser degree than in the 1960s. Commercial applications can gain, and certainly have benefited in the past, from the military expertise of US spacecraft builders.

Hughes Aircraft, Lockheed Martin, Space Systems/Loral and TRW are the main US manufacturers. Spar Aerospace from Canada, which was awarded the contract for the last two Anik programs, is another North American manufacturer included in the study. In contrast, in Europe originally, a greater number of manufacturers were prime-contractors for communication satellites. This number has declined since the late 1980s with the merger of many contractors. In France, Alcatel Espace competes with Matra Marconi Space and Aérospatiale. In the UK, Marconi and British Aerospace are now part of the Matra Marconi Space Group. The Italian company Alenia is part of the consortium Space Systems/Alliance and obtained the contract for the Italsat series. In Germany, Dornier and MBB are now part of Deutsche Aerospace, and ANT in part of the Eurosatellite consortium with its two compatriots. In Japan, Mitsubishi Electric Co. and NEC were prime-contractors for the latest CS and BS series respectively[10]. Further information on merger and alliances will be presented in section 1.1.2.

1.1.1.2 Launch providers

The main purpose of this section is to establish that launch services are not affecting the supply and demand of civil communication satellites. In doing so, many aspects of the launch services will be examined to give a broad picture of this industry. We will dispense with an account of the precise launching aspects in this thesis because these are not essential to the issues affecting supply and demand for the satellite themselves.

Over the years, technology improvements in propulsion, materials and aerodynamics have permitted the launch of satellites increasingly heavy and voluminous, as well as the advent of dual payload launches. More reliable satellite technology and more accurate and powerful launch vehicles have allowed the operational lifetime of satellites to increase on average by two years from one decade to the next: 6-8 years for the first decade, 10-12 years for the second decade and up to 15-20 years more recently.

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[10] This is a brief enumeration of the prime-contractors included in the database available to the author. There are more manufacturers who act as prime-contractors but their contribution may be negligible in the commercial communication satellite field compared to the ones mentioned above. A list of the manufacturers is included in Appendix B.

In the early days of telecommunication satellites, the majority of launches were related to military and scientific applications. The proportion of non-commercial applications has since decreased, to the benefit of commercial applications. According to a recent survey by Euroconsult (1994), 70 % of all launches are still associated with government programs. Because of the relatively small proportion of commercial communication satellite launches, it will be assumed that launch costs are not determined by the supply and demand of telecommunication and broadcasting satellites but more affected by the number of military and scientific spacecraft launched every year. Since government space applications have driven the launch business, launch prices and characteristics will be treated as exogenous in this study.

Until the mid-1980s, NASA had a virtual monopoly on the commercial geostationary launch market using expendable launch vehicles (ELV) such as Titan, Delta and Atlas. NASA developed the space shuttle with the idea of reducing launch costs by providing a recoverable and reusable launch vehicle, an alternative to ELVs that would eventually replace them. In 1978, subsequent to the adoption of Intelsat launch dual-sourcing policy (Intelsat, Annual Reports), Intelsat introduced competition in the launch business by contracting the European launcher Ariane for the launch of some Intelsat V payloads. NASA rapidly responded by allowing the space shuttle to provide commercial launches, dramatically scaling down the operations of ELVs. But NASA soon reversed this decision in the aftermath of the Challenger accident in 1986, by relegating the shuttle almost exclusively to government space business and encouraging the commercialisation of ELVs. Since the end of the 1980s, commercial launches have remained almost closed to all but three principal players: McDonnell Douglas (Delta), General Dynamics Corp. (Atlas) and Arianespace (Ariane), the latter with more than fifty percent of the world market. Today, Titan (Lockheed Martin) rockets solely launch US government spacecraft.[11]

Since 1973, ESA developed Ariane under the management of the CNES to provide an independent access to space for European satellites. Arianespace was created in 1980 to commercialise Ariane launch vehicles (Euroconsult, 1994). Although Arianespace is responsible for the production and marketing of the European launcher, ESA is still in charge of research and development. The success of Ariane relies upon the location of its launch pad in Kourou, French Guyana: being within 5° of the equator, it requires less fuel to put satellites into geostationary orbit, and provides 15 % more payload capacity than the American ELVs whose launch pads are situated farther from the equator[12].

So far, most commercial telecommunication and broadcasting satellites have been operating from geostationary (GEO) orbits. Only very recently, low earth orbit (LEO) telecommunication satellites such as the Motorola Iridium series have appeared; but none are included in this study because the sample spans from 1964 to 1992, by which time, contracts were not finalised for any of the LEO communication spacecraft. The 'distance' involved in space transportation for delivery of satellites to

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[11] France and the United States are however not the only launch providers in the world, Japan, China and Russia also provide launch services for geostationary satellites, but their contribution to the commercial communication satellite market is minimal. More information about the launch business can be found in Euroconsult (1994).

[12] The reduction in the satellite mass increases exponentially with the latitude of the launch pad. Appendix E provides general principles involving various launch vehicles, but consult Maral and Bousquet (1994, chapter 11) for a thorough explanation on launchers.

operational geostationary orbit is therefore similar for all the satellites included in this study and transport costs related to distance are thus irrelevant to this study.

As a general rule, prices of launch services are based in part on satellite mass (table 1.1). Although it may be treated as exogenous for the purpose of this thesis, the launch industry, nonetheless, is crucial to the communication satellite industry, and a brief description of the main characteristics and players follows.

Table 1.1: Average price of commercial launch services according to the mass of geostationary satellites (Source: Euroconsult, 1994, p. 368).

Satellite mass	Launch service price (millions of US$)
500-800	20-45
800-1500	45-55
1500-2500	65-85
2500-4500	85-100

There seem to be significant fixed launch costs, because the average cost per kilogram falls with the mass. Perhaps this has affected the evolution of more massive satellites, but some factors may reduce the impact of these fixed costs on the supply and demand of commercial satellites. The mass of civil communication satellites has increased over time and follows the expansion of launchers' capacity. Launch vehicle research and development aimed at increasing the capacity of launchers, to be able to put into orbit more that one satellite at a time, has more than doubled the launch rate in some cases[13]. Whether satellite improvements have pushed the increase in launch capacity or the potential profits ensuing dual launches have driven the augmentation in satellite size and mass goes beyond the scope of this thesis. Unfortunately, launch costs are generally not disclosed and were not available to author. As a consequence, this very interesting question will have to be left unanswered, launch services will have to be treated as exogenous.

1.1.1.3 Customers and operators

The communication satellite purchasing market features three kinds of customers: civilian Government, military applications and commercial customers. Those of the first type (national space agencies like NASA, CSA, NASDA, ESA, CNES[14]) generally are prime-contractors for the first project of a series, e.g. the first Ku band (12/14 GHz) satellite. Governments frequently finance entire remote sensing programs. Security in military programs obliges countries to build satellites within the country boundaries; and, like Government programs, no monetary profits are expected from the operation of such satellites. The contracts awarded to the manufacturers are generally 'cost plus'. In contrast to these two types of customers, commercial customers must make profits in order to survive in the market. Commercial customers prefer to use fixed-price rather than cost-plus contracts[15]. In order to remain

[13] Because the satellite bay of most launch vehicles has a cylindrical shape, and that an increasing number of commercial satellites are box shaped, it is possible to pile two satellites on top of one another in the launcher as well as mini experimental satellites on the sides. Indeed, dual launches are possible on board the latest Ariane launchers and the space shuttle.

[14] Please consult the list of acronyms for the exact terminology of these commonly used abbreviations.

[15] Contracts are generally not as black and white as fixed-price and cost-plus contracts imply; incentive elements in the form of performance payments, penalties/bonuses for late/early delivery and so on, are the norm. Beaudry (1994) gives an account of incentive contracts utilised in the commercial communication satellite industry.

competitive, commercial communication satellite builders must rent their transponders at the comparative price of alternative technologies such as fibre optics and earth links. In addition, private operators demand the shortest delivery schedules, are the most demanding in terms of price, incentive payments and penalties. A list of the customers included in this thesis is provided in appendix B.

Within the commercial type of customers, three can be distinguished: domestic customers, regional and international organisations. Governments are the main instigators for international and regional organisations. For instance, the US Government played a central role in the development of Intelsat (international), and ESA provided the foundation for the Eutelsat series (regional). Intelsat purchases satellites, launches them and then leases or sells the capacity to satellite service users, which usually are Intelsat's representatives in each member state; For instance, British Telecom is the UK representative to Intelsat. Intelsat's main source of revenue is their international voice service. They also provide digital services, occasional use television[16], domestic telecommunication services, international television lease and international business services. But Intelsat is only one type of operator of satellite services. Similar organisations to Intelsat exist at the regional level, e.g. Eutelsat for Europe and Arabsat for the Middle East. The third category of customers who provide domestic satellite services, are country Post, Telegraphs and Telephones departments (PTT) or private organisations. In Europe, France Telecom, Société Européenne des Satellites and British Sky Broadcasting mainly provide satellite broadcasting services, and particularly, direct-to-home television services. With the recent tendency towards liberalisation, domestic commercial satellite communication markets have changed: some countries in Europe have seen US satellite service providers such as AT&T enter their telecommunication market. This liberalisation has also promoted the destruction of state monopolies in this field.

Customers or satellite operators have entered/exited the market, take-overs and mergers occurred and as a consequence, ownership of some spacecraft has varied over the years. According to the OECD (1995), few satellite systems that were initiated in the 1970s remained in the hands of the same owners: Fairchild sold half its share of American Satellite Company (ASC) to Contel 1985; GTE merged with ASC Contel; Hughes acquired the Westar satellite system from Western Union and the SBS spacecraft from IBM. A particular example of a well travelled satellite is the Canadian satellite Anik D2, which was transferred to GE Americom, moved from 111.5 °W to 82 °W, and renamed Satcom 4R when Satcom 4 failed prematurely in October 1991, but was returned to Telesat in 1993 (Euroconsult, 1994, p.225). It was then sold to Arabsat, moved to 19 °E, and renamed Arabsat 1D (Baylin, 1994) to supplement Arabsat 1C before the launch of Arabsat 2.

1.1.2 Integration in the space industry

Both vertical and horizontal integration characterise the space industry; indeed, it has strong links with the aerospace, missile and defence manufacturing industries, as well as with the telecommunication and broadcasting services industries.

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[16] Occasional use generally means special events such as the Olympics, the Super Bowl, media overage of catastrophes in remote parts of the world, and so on. For example, Intelsat provided world-wide coverage of the 1988 Winter Olympics from Calgary; seven Intelsat satellites broadcast 19 channels of Olympic television programs (Intelsat, 1988).

1.1.2.1 Vertical integration

Chronologically, a satellite is ordered, designed, and built; then carried to the launch base from where the launch vehicle carries it into orbit. From then on, ground stations take over, first to test the satellite, and then to operate the space program using ground-based data treatment. Thus, there exist four major independent stages in the typical communication program's operation: production, launch, testing and operation.

Vertical integration of these stages characterises the activities of US communication satellite vendors. Indeed, a shift from the role of satellite supplier towards that of in-orbit satellite capacity provider is starting to appear, due to increased involvement of satellite manufacturers in terms of risk-sharing, i.e. in-orbit delivery, high degree of incentives, equity investment or lease financing. Hughes Aircraft is highly vertically integrated, and was the first company to offer a quasi-complete space service: satellite, through the Space and Communication group, ground station and data analysis through Hughes Communications Inc., the largest communication operator. Hughes incorporated Western Union and its Westar satellites, and purchased the IBM SBS spacecraft to increase its fleet of Galaxy satellites. Hughes also have financial interests in AMSC, DirectTV Inc. and JCSat, the Japanese satellite service provider. Martin Marietta, now Lockheed Martin, is another example of a vertically integrated firm. It is the third largest US communication operator through GE American Communication Inc., with the Satcom satellites, and the second most important satellite builder through Martin Marietta Astro Space (Euroconsult, 1994). As Hughes, Lockheed Martin also has interests in international satellite service providers via Satellite Japan Corp. and SES/Astra.

By 1991, over half of the US domestic satellite capacity was owned by these two companies, Hughes with 33 % (1991 values) and General Electric with 23 % (OECD, 1995). One of the major advantages for these two manufacturers is that they are customers to themselves, whenever one of their communication company branches needs new satellites, the contract is automatically awarded to the division specialising in satellites. General Electric's management agreed to merge GE Aerospace, which includes GE Astro Space, with Martin Marietta Corp. in the early 1993. Because Martin Marietta (now Lockheed Martin) manufactures the Titan launch vehicle, which is mainly devoted to scientific and military applications, we may see this joint company offering integrated programs in the near future[17]. Other satellite manufacturers also are vertically integrated: for instance, TRW have interests in the related service company TRW Pacificom. In addition, Lockheed along with MBB and Matra Marconi Space (MMS) own part of the Motorola Iridium satellite system to be completed and launched by 1998.

Vertical integration, however, is not limited to satellite prime-contractors; space and ground equipment manufacturers also have their share in the satellite services market. AT&T produces ground equipment and provides satellite services via AT&T Skynet/Tridom using the Telstar family of satellites; and GTE, another ground equipment manufacturer provides satellite services via GTE Spacenet.

This integration strategy does not necessarily guarantee success. In the early 1980s, Ford organised Ford Aerospace Satellite Services Co. but failed in its attempt

[17] Especially since Lockheed was awarded the very lucrative contract of manufacturing the series of Motorola Iridium satellites.

to diversify into satellite operations as well as services, and eventually sold its rights to AT&T. British Aerospace had similar intentions with the Orion international satellite communications system, but, unfortunately, its activities as a satellite operator are limited to participation to the International Private Satellite Partnership set up to operate Orion. In contrast to the US, in Europe, companies are far from being as vertically integrated. Nevertheless, some integration is noticeable between prime-contractors and their subcontractors of space equipment and between prime-contractors and satellite service providers. Here are a few examples: apart from the shares of British Aerospace in the satellite service company Orion, Alenia and Matra Marconi Space also have equity in this company. Qualcomm Globalstar is related to the American/European consortium Space Systems/Loral, which was awarded the contract for the production of its satellites.

More indirectly, Intelsat also is part of vertically integrated organisations. It is owned by world-wide signatories such as Telesat of Canada and Comsat of the US, which are in turn, owned by satellite manufacturers. Since March 1992, Spar Aerospace has been a major shareholder of Telesat which is also a shareholder of Intelsat. When Intelsat's Board of Governors makes a decision about a space project, Spar influences Telesat's vote. As a consequence, satellite producers will partly direct decisions of their customers and increase their chances of winning a contract. Spar Aerospace, who also owns part of Telesat Mobile Inc. (TMI), was awarded the contract for the development of the Canadian MSat satellite ordered by TMI[18].

It is interesting to ask why such a high level of vertical integration is observed. Perhaps similar reasons to that of commercial aircraft apply in the case of commercial communication satellites? The most obvious example is spill-over from military technology; although true in the early days of satellite design, nowadays military spill-over is less frequent. Other reasons are possible economies of scope in design and the ability to avoid risks related to the uncertainty of demand forecasting. As these greatly vertically integrated firms are customers to themselves, they have the ability to accommodate schedule slippage in launch dates, and even in design specifications. For instance, ground station development may provide a cheaper solution to an expensive problem encountered in satellite design.

1.1.2.2 Horizontal integration

Horizontal integration has also played a key role in the de-fragmentation of the industry both in Europe and the US. In the US, for instance, Lockheed and Martin Marietta have joined forces in the latest merger of prime-contractors. On the customer/operator side, American Satellite Company (ASC) was sold to Contel which later merged with GTE. In Europe, prime-contractorship is divided between platform and payload specialists. Recently, Europe has seen three important mergers between platform manufacturers and payload specialists. In 1989, the German companies Dornier System, specialist in payload manufacturing, and MBB, a payload contractor, merged to form Deutsche Aerospace (DASA). In Italy, Selenia Spazio, a payload specialist, and Aeritalia Gruppo Sistemi Spaziali, a platform manufacturer, combined their activities to form Alenia Spazio in late 1990. Finally in early 1991, the French platform prime-contractor Matra Espace, consolidated with the British payload

[18] Most of the information associated with the vertical integration of satellite manufacturers was extracted from the OECD report on satellite communication (1995).

specialist Marconi Space Systems, to form Matra Marconi Space (MMS). The British platform manufacturer, British Aerospace, has since been absorbed by Matra Marconi Space. European builders have had to eliminate the excessive fragmentation of their space industry, in order to become more competitive on the international market against their tightly integrated US rivals.

Following a similar trend, Aérospatiale (platform specialist), Alcatel Espace (payload specialist), Alenia Spazio and Deutsche Aerospace are participating in the European and American consortium Space Systems/Loral. Space Systems/Alliance, as it is known in Europe, owns 49 % of the American space builder Loral. As in the aircraft industry, space companies form international alliances or consortia to spread the risk associated with the satellite business (Mowery, 1992). As part suppliers, they are forced to provide financing (floating equity or venture capital). Furthermore, the main co-operative ventures aimed at exports have been transatlantic rather than intra-European. For example, the Arabsat contract was awarded to Aérospatiale as prime-contractor in co-operation with Loral which supplied the payload. Alcatel provided part of the payload, notably some C band receivers, TWTAs and power amplifiers, as part of a subcontract from Loral (Euroconsult, 1993a).

A second international alliance exists within Europe only, under the name of Eurosatellite, and consists of Aérospatiale, MBB, Alcatel Espace, Telefunken Systemtechnik, ANT Nachrichtentechnik, and ETCA. With the contribution of MBB, Aérospatiale is manufacturing the Spacebus platform which is an attempt to compete with the very successful HS platforms of Hughes Aircraft and the GE platforms of Martin Marietta. Eurosatellite produced the TVSat, TDF and Tele-X satellites which all have a similar design in an attempt to benefit from economies of scale. US and European satellite builders must also form alliances to spread the immense work load of the new LEO mobile telecommunication mega-projects. These involve constellations of small satellites for continuous coverage. Examples are Iridium (Motorola) and Globalstar (Qualcomm), respectively requiring 66 and 48 satellites.

With this greater concentration in the supply of communication satellites, there is a growing tendency towards a duopoly in Europe (Space Systems/Alliance and Matra Marconi Space); Whereas the tendency is still more oligopolistic in the US, with Hughes, Lockheed Martin, Space Systems/Loral, and smaller satellite manufacturers competing with one another. One of the main problems of the European space industry in general (apart from Arianespace which has been successful), is its fragmentation. France, in particular, multiplied the number of mini-subsidiary companies of government agencies in order to promote the expansion of the space sector (Euroconsult, 1991). Space companies are thus penalised by the unfair competition they face from these privileged highly subsidised agency companies. As a result, the European space market is almost closed. European companies have been aware of this situation for many years and since the late 1980s they have been trying to improve the financial structure of the industry by several mergers. Euroconsult (1991), however, fears that change in the financial structure of the satellite manufacturing industry is occurring too slowly and that the degree of integration sought is insufficient. On the one hand, Neven, Röller and Waverman (1993) showed that in Europe, only 4 satellite manufacturers would survive at the minimum efficient scale (10 satellites or so). On the other hand, some prime-contractors feel that there is room for only one integrated supplier, in order to develop a position as strong as Arianespace and Airbus on the world market (Euroconsult, 1991, p.20).

An alternative to alliances or consortia, is teaming, which is based on opportunities arising from political, technological, schedule and delivery factors rather than from cost. Although the designs are interrelated, manufacture of payloads (electronics), platforms (structure) and antennas (microwave engineering) remain very different tasks. Companies with particular know-how are teaming together in order to increase their chances of winning contracts; each company providing one or more subsystems to form the most efficient bidding package. Mowery (1992), found a similar reason encouraging international joint ventures in the aircraft industry; among other things, the definite advantage of incorporating enhanced technological capabilities of other firms. This encourages the specialisation of different manufacturers in specific subsystems. Spar Aerospace, for example, has developed an expertise in payload and antenna manufacturing. Spar therefore usually subcontract the platform to another firm such as Hughes Aircraft. It would appear that the larger the company, the easier it is to team with another company. For instance, Hughes Aircraft and Spar Aerospace co-operated to build one of the MSat satellite pair launched in 1994. In Europe, Alcatel and Matra Marconi Space have co-operated in joint prime-contractorship for the production of the Telecom 2 satellites by providing the payload and the platform respectively. Similarly to the aircraft industry (Mowery, 1992), this sharing of responsibilities in the production of satellites allows to spread the fixed costs of design between the different partners.

Intelsat contracts have encouraged international co-operation in satellite manufacturing by favouring bids that contained a greater diversity of international equipment suppliers. Because of its internal structure, Intelsat must take decisions in conjunction with all its member states; as the voting power corresponds to the share of annual investment in the organisation, more important investors have a greater decision power. For instance, Hughes Aircraft purchased a large part of the C band and Ku band receivers for its Intelsat VI series from Alcatel (Euroconsult, 1993).

Pan-European programs such as Eutelsat were manufactured by a number of European companies following the 'juste retour' system typical to ESA. We suspect that such geographical constraints in the fabrication of satellites may cause delays and higher costs as they do in the market for European commercial aircraft (Mowery and Moran, 1994). Albeit the formation of the transatlantic alliance Space Systems/Loral and the high US content in international satellites, European satellite manufacturers have so far failed to enter the US domestic market for commercial communication satellites. According to Mowery and Moran, alliances of this sort allowed European aerospace consortia to penetrate the US domestic aircraft industry. This barrier, which seems impassable to European satellite manufacturers, has been surmounted by their aircraft counterparts, which generally are parent companies; Aérospatiale, Alenia, British Aerospace and Deutsche Aerospace (MBB and Dornier) all have space applications (spacecraft) and aerospace (aircraft) divisions. In the period 1983-1989, space application sales of US aerospace (spacecraft and aircraft applications) industry have been higher than the civil aircraft sales (Euroconsult, 1993b, p.100). So the space sector is not negligible compared with the aerospace industry as a whole.[19]

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[19] *Aerospace* is usually employed as a generic term for 'machines that fly'. Satellites are in orbit around the earth, so in a certain way, they fly as well. The literature does not make a clear distinction on the use of *aerospace*, whether it includes the space sector that is. As convention in this thesis, *aerospace* will designate the aircraft industry unless otherwise stated by adding 'as a whole' or 'entire' to the word aerospace.

1.1.3 Other aspects

A few more details concerning the satellite industry have been identified and will be explained briefly in the following. These are the most common transaction mechanisms utilised between manufacturers and customers of commercial communication satellites, the type of insurance involved in this industry, the competition between different parts of the world on the international market and finally, alternative technologies that compete with communication satellites.

1.1.3.1 Transaction mechanisms

The laborious road between initial conception of a space program and its completion takes approximately three to five years. This is because it almost always involves new technology, which must satisfy specifications the highest of which are known as 'military'. Uncertainties related to the satellite industry incite customers to be careful in the choice of a manufacturer. Customers can reduce the risk associated with such uncertainties by choosing an efficient selection mechanism like the first-price sealed-bid auction. After the customer has issued his request for proposal to three to five manufacturers, the latter usually have 30 to 90 days to produce a proposal (Miller, 1993). In some cases companies may have knowledge of a forthcoming project earlier than the official request for proposal and may in fact spend three to twelve months preparing a proposal[20]. This situation might occur, for instance, when customers consult manufacturers in the process of defining a request for proposal to obtain feedback about feasibility and new technologies. In addition, although there are usually no entry fees to submit a proposal for commercial satellite contracts customers will sometimes impose a payment of a few thousand dollars to ensure only serious bids are received[21]. Furthermore, the cost of the proposal also depends on the level of detail requested by the customer. For example, Martin Marietta has spent around 1m US$ for Intelsat proposals. For less sophisticated customers (i.e. customers with a small or no technical team), the cost falls to a few hundred thousand dollars.

Most customers normally receive the various bids from the manufacturers and select a winner without further interaction with the bidders. Some more sophisticated customers may have a different way of dealing with bidders. With Intelsat programs, once the bidder as been notified that his proposal lies in the 'competitive' range, the rest of the bidding procedure is divided into three main stages. First, Intelsat sends a questionnaire to the different bidding firms. The principal then organises an oral meeting with the different groups (technical, managerial and financial) of each manufacturer involved in the proposal. Finally, manufacturers are asked to make a best and final offer. Subsequently three customer's evaluation teams corresponding to the manufacturers' groups mentioned before, examine each part of the proposal in details and suggest a winner to the decision group. Sometimes, the last stage of the process is replaced by an English auction among three or four bidders[22].

The bidding process possesses three distinct dimensions: technical performances, schedule and cost. In the space industry, the bid variables are known as

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[20] Source: Shelley Bay, Hughes Aircraft.

[21] For one contract, the Turkish Government charged an entry fee of approximately 12,000 US$, source: Bernard P. Miller, Martin Marietta Astro Space.

[22] Source: Donald L. Bridwell, Intelsat.

the 'work-breakdown-structure'. The *technical performance* must be compliant to the customer's requirements for the proposal to be considered for the rest of the evaluation. The *schedule* must be reasonably compliant and when those two stages meet the requirements of the customer, the manufacturer then submits the lowest *price* possible. The different bidding prices associated with satellite programs remains secret because of the protective law concerning private information. Indeed, there is a special clause included in each satellite bidding contract which stipulates that proprietary information cannot be revealed, to anyone without the consent of the bidder. Only the winning price can be revealed and as a consequence, there is no information available for the other bidders to indicate why their bid failed.

Each bidder is aware of the following three contract characteristics before submitting their bid. First, the majority of commercial telecommunication contracts awarded to firms are fixed-price in cost. The winning firm may be penalised for several reasons if it does not respect the terms of the contract he signed. Second, to ensure the winning firm has a strong enough incentive to produce a satellite of sufficient quality, the customer includes a performance payment and a corresponding damage clause with a penalty for malfunction in the contract. Third, the customer includes a delivery time clause which determines the penalty the manufacturer must pay for a late delivery of the system. Manufacturers bid on technical characteristics, schedule and price. The customer sets the percentage of the bid price which will represent the performance payment and the penalty rate associated with delays and malfunctions. So out of the six contract variables, only three are set by the principal.

When evaluating a bid, most customers ensure each proposal received is technically sufficient. Intelsat, for example, has a complete engineering team of the same technical skills as manufacturing staff to accomplish this. The first stage of the procedure is a pass or fail test for quality. Then the customer weights every technical element to construct an overall technical evaluation. Production time is usually estimated at 36 months, but as in many other fields, there exist problems concerning schedule and the uncertainty and credibility of the production time proposed. Not only does the evaluation team examine the final delivery time, but also the complete management of the schedule: when the design phase is planned to be completed and the production phase to start, the dates of the preliminary and critical design reviews are set. The final evaluation stage assesses the cost/financial potential of the proposal. Everything is then analysed in terms of economic value (real currency, present value, revenue stream). For instance, if one firm offers to deliver the satellite three months before the others, economic value may be the rent of the money or the opportunity cost of that money. Outside tangential features in the cost analysis such as the effect of mass and design of the satellite on the launch vehicle price are also considered: e.g. the lighter the satellite, the lower the price of the launcher.

For a company such as Intelsat, the international content of the bid also plays an important role in the decision making. Within Intelsat, the managerial group submits recommendations from their own skilled technical staff to the Board of Governors. The Governors represent 130 countries or signatory companies; each of these have their own technical staff who independently assess the proposals. Decision may therefore not always be a commercial process but rather a political one. For example, European signatories' lobby might form a coalition in favour of the project which attributes a higher percentage of subcontracting work to European manufacturers. For most sophisticated customers, the decision is therefore more often

a consensus of commercial and political interests rather than a simple vote. Smaller customers cannot afford such an exhaustive organisation and adopt a more commercial evaluation process for the various bidders.[23]

Another main difference between small private enterprises and big institutions, is that the latter are more risk-averse concerning new technology. Private enterprises are willing to take risks and are therefore more open to innovative technology because it is likely to perform better and have a greater capacity. Private firms are therefore beneficial to the space industry for they allow innovation and encourage R&D. In their absence, innovation would occur at a slower pace because major institutions mostly employ previously tested technology, as new technology involves more testing and costs, in addition to carrying greater risk.

1.1.3.2 Insurance

Manufacturers share a proportion of the risk involved in the satellite business, with schemes such as performance payments, including damages clauses as well as penalties for malfunction and late delivery penalties. Customers share the rest of the proportion of the risk on the success of the satellite but also assume the uncertainties linked with the launch. In order to attenuate the effects of the risks related to the above-mentioned new technology, launch failures and space damage, manufacturers and customers take out insurance policies.

There exist many different types of insurance associated with the satellite business: launch, initial operations and in-orbit. *Launch* insurance is usually taken out by the customer to alleviate the financial uncertainty linked with a launch failure destroying the launch vehicle and its contents, or simply failing to reach orbit. This usually covers part of the cost of a new satellite and a new launch service. *Initial operations* insurance protects the customer from a malfunction that may occur in orbit but not as a consequence of the launch and before the operating phase begins. For example, antennas may fail to deploy as they did for the Anik-E2 satellite in 1991 (Dotto, 1992). Finally, *in-orbit* insurance provides protection from malfunctions during the operating lifetime of a satellite. Some components may stop operating for different reasons and, despite the redundancy incorporated in the design of satellites, operational capacity of the satellite may decline over time. For instance, some satellites may be victim of magnetic storms and rendered useless as a consequence. Manufacturers protect themselves against such uncertainties by taking insurance policies on the success of their spacecraft, as *initial operations* and *in-orbit* insurance.

As an alternative to expensive insurance policies, some customers self-insure by ordering more satellites than necessary and keeping these extra spacecraft as ground spares until, and if, they are needed. Governments and the military have the potential to self-insure, and as a consequence, only 30 % of the launches are actually insured (OECD, 1995). Some other customers prefer or are forced to take out insurance policies on the success of the mission, of the launch and the lifetime of the satellite. Remember that Government programs still account for around 70 % of all launches. This therefore suggests that the 30 % of insured launches mentioned by the OECD (1995) are linked with commercial satellite launches. Insurance rates have

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[23] Beaudry (1994) studies the bidding-for-contracts procedure utilised in the commercial communication satellite industry in greater details.

varied considerably over the years, until the first half of the 1980s, the average rate of insurance was 10 %. The rate of insurance rapidly increased to an average of 25 % in 1986, after three subsequent years of greater losses than premiums[24]. Premiums have since decreased to an average rate of 20 % of the sum insured.

1.1.3.3 Competition between different regions of the world

As defence expenditure has declined and military satellite technology diverged from civilian technology, US Government support to the latter has fallen. Hence, US manufacturers' dominant position has become less of a function of direct and indirect Government support. Nevertheless, this past support still has some beneficial effects, in particular, it allows US suppliers to achieve economies of scale beyond the reach of European companies. The immense capital of parent companies, such as General Motors Corp. who took over Hughes in 1985, or General Electric making RCA their Astro Space Division in 1986, allows these suppliers to take more risks than other suppliers in the space market. Intelsat or Inmarsat satellite procurement contracts with substantial performance payments[25] are generally awarded to big manufacturers. Other manufacturers (Fairchild Space Co., Rockwell International Corp., TRW Inc. and Lockheed Missiles & Space Co.) who have been involved with military contracts (NASA and Department of Defense) are thus having difficulty gaining a foothold in the civilian communication satellite production market.

Not only is there competition between domestic firms, but also between international rivals, although most contracts are awarded to US satellite suppliers. The main difference between US and European manufacturers is that the Europeans have almost never[26] supplied the US market, whereas US manufacturers have already built six domestic European satellites. Moreover, European firms seem to be losing what little overseas market they had to the profit of US companies. As of December 1992, even though European suppliers were prime-contractors for 25.1 % (in value) of all the commercial communication satellites to be launched, in number this represents only 15.8 % of the total market[27]. Are European satellites largely overvalued by important R&D subsidies, or are they generally better, higher quality satellites? Arguments in favour of subsidies stipulate that this will contribute to a build up of the European market share in value. Their access to the international market has been restricted not only by the imbalance of US and European Government purchases but also by the structural deficiencies within European manufacturers. Whether technology has a role to play will be examined in the third chapter.

Where open market conditions apply, US manufacturers have been the most successful at attracting contracts; this may be one of the reasons why European countries have been reluctant to fully liberalise the communication satellite service market[28]. A major weakness of the European civil communication satellite production

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[24] Consult OECD, 1995, p.45, for an evolution of the insurance market.

[25] Performance payments are also called incentive payments and are paid to the manufacturer once the satellite is in orbit and fully operational. They are commonly up to one third of the value of Intelsat or Inmarsat satellite procurement contracts. See section 1.1.1.2 for more details.

[26] A single US satellite included in the database available to the author was built by a European company.

[27] These values are calculated using the Rusch (1992) database.

[28] The OECD (1995) suggests that state-owned monopoly suppliers provide a favourable market for Europe's space segment suppliers and counter the economies of scale which US producers get from their military market.

market, is the important risk it faces regarding dominant US industries and the rapid growth of the Japanese industry for electronic components and space systems. European manufacturers hesitate to buy highly subsidised European electronic components and equipment developed on agency credits, because they are judged too expensive, not flight qualified[29], subject to long delays and unreliable in long period orbits (Giget, 1992). Since most agencies' financing comes from their members, this rejection of European components is likely to drive down the amount of subsidies for R&D expenditures. This disengagement would be fatal to European satellite manufacturing industry R&D, since there is no alternative financing available. In addition, the European production market does not benefit from considerable support from military R&D and the resulting synergy between commercial and military applications, as do US manufacturers; nor as for the Japanese market, from a world dominance of electronics. This lack of confidence in European space devices clearly favours the development of mainly Japanese space sub-systems industries to the detriment of European firms. Europe might enter a vicious circle where its domestic companies will not develop an efficient enough sector of the industry.

1.1.3.4 Alternative technologies and demand

Not only do manufacturers have to compete against each other to obtain contracts, they must also ensure they offer a competitive product to alternative technologies such as fibre optics, cable networks and earth links. Communication systems consist of a mixture of different transmission technologies (cables, microwave, fibre optics, satellites) that complement and substitute each other. For some uses and locations, different technologies are competitive substitutes but for some others, one technology may have a distinct advantage. Hence, companies must rent transponders at the comparative price of alternative substitutes. Often, physical aspects can eliminate these competitors. For instance, in large countries such as Canada or the USA, the sole use earth links are physically impossible due to the immense distances to cover. A further example is the multi-island state of the Philippines where fibre optics or coaxial cables solutions are impractical across islands. Satellite links between islands complement terrestrial networks on land.

However, as the cost of fibre optic technology decreases and its capabilities improves, satellites may not indefinitely keep their place at the side of cable systems, either for video distribution, transoceanic communication or even shorter-haul data communications. Villain and Chenard (1993) have observed that investment in fibre networks now exceeds investment in satellite constellations in the US and Japan, as it does on transatlantic and transpacific trunk routes. In addition, the OECD (1995, p.48) postulates that annual circuits costs of transoceanic cables between US and Europe have decreased faster than that of Intelsat; the annual circuit costs of the transatlantic submarine cable, TAT-10, falling below two thirds of that of Intelsat VIIA. This diminution is partly due to the fact that cable-based systems have twice the operational lifetimes of satellites. According to Euroconsult (1994), since 1988, when the FCC relaxed the rules requiring parity between satellite and cable, transoceanic cable systems have secured 70 % of the US overseas public switched network (PSN) traffic world wide and approximately 60 % of the world traffic.

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[29] Electronic components are 'flight-qualified' when they have been tested to ensure a certain level of quality. The highest qualification is usually referred to as 'military specification'.

Since the price of fibre optic cables is more expensive when laid across oceans than when land based, the comparison between satellite and fibre for terrestrial point-to-point applications may prove to be even more favourable to cable. Thus, the advent of new low earth orbit constellations of satellites, such as Iridium and Globalstar, launched in groups, deployed in mosaics and produced *en masse*, which, benefiting from substantial economies of scale, should prove a better competition to fibre optic cables. Communication would be significantly improved by getting rid of the echo which characterises telecommunication via geostationary satellites[30].

The OECD (1995) suggests that the provision of services to end-users, or point-to-multipoint services, are the major areas of growth for commercial telecommunication satellites. Network connectivity, or point-to-point services, should be left to ground systems which are more efficient in this particular case. As a consequence, direct broadcasting and mobile satellite services are the way to the future in the case of commercial communication satellites.

1.2 Communication growth

In this section, some of the communication characteristics of various countries included in this study will be examined in detail. This part will concentrate on the telecommunication and broadcasting indicators as a preamble to the demand side analysis (chapter 5). Rates of growth of various telecommunication country characteristics will be examined and the countries compared.

Table 1.2: Country groups.

Group	Category	Countries*
1	Western World satellites	CAN, FRA, DEU, ITA, JPN, LUX, NOR, ESP, SWE, GBR, USA
2	Other countries satellites	AUS, BRA, HKG, IND, IDN, KOR, MYS, MEX, SAU, THA, TUR
3	Africa	DZA, BEN, BWA, BFA, BDI, CAF, TCD, COM, COG, CIV, ETH, GAB, GHA, GIN, KEN, LSO, LBR, LBY, MDG, MRT, MUS, MAR, NER, NGA, RWA, SEN, SLE, ZAF, SWZ, TZA, TGO, TUN, UGA, ZMB, ZWE
4	Middle east	BHR, BRN, DJI, EGY, IRN, ISR, JOR, KWT, LBN, OMN, QAT, SYR, ARE, YEM
5	Asia	BGD, KHR, CYP, LAO, MAC, MDV, MNG, MMR, NPL, PAK, PHL, SYC, SGP, LKA, VNM
6	Oceania	FJI, PYF, KIR, NCL, NZL, PNG, SLB, VUT
7	Western Europe	AUT, BEL, DNK, FIN, GRC, ISL, IRL, MLT, NLD, PRT, CHE
8	Eastern Europe	HUN, POL, ROM, YUG
9	South America	ARG, BOL, CHL, COL, ECU, GUF, PRY, PER, SUR, URY, VEN
10	Central America	BHS, BRB, BMU, CRI, SLV, GTM, HND, JAM, NIC, PAN, LCA, TTO

*United Nations abbreviations are used here, appendix C provides full names of countries

As for any database, the data provided by the ITU is far from being perfect. Time series do not run for the entire time period and some gaps can be found in between. When possible, a simple regression was fitted to the data to try to fill in the gaps and approximate the extremities of the time series. Sometimes, too little country

[30] Because of the great distance a signal has to travel (twice the distance to the geostationary satellite, 70,000 km), there is a delay between transmission and reception. The echo comes from the fact that the received signal is amplified as noise at the other end of the line and transmitted back to the first caller. On a short distance telephone call, this signal transmission all happens to quickly to perceive an echo, but the same problem exists.

data was available for such interpolation and extrapolation, and the country was eliminated from the study. Thankfully, most of the countries owning satellites, with the exception of Hong Kong, provided good enough data to the ITU. Moreover, because of the considerable number of countries in the world, they needed to be separated into groups. Following the results of a simple cluster analysis[31], countries have been separated into 10 categories. As expected, the G7 countries were outlined as single clusters, but have been grouped for the purpose of this study. The cluster analysis, however, did not reliably distinguish countries without domestic satellite systems, so they will be divided by region. Table 1.2 shows the 10 groups formed.

1.2.1 Telecommunication infrastructure growth

First and foremost in this series of growth measures, is the number of main telephone lines in operation. Growth rates have been calculated for two periods, 1975-85 and 1983-93 to evaluate the difference in the trend across time and countries. Appendix D contains the growth rates calculated from the time series provided by the ITU World Telecommunication Indicators. Table 1.3 illustrates the growth rate of main lines in operations for these two decades in a condensed format which separates the information into 3 of the 10 groups described above.

Table 1.3: Growth of main telephone lines in operation (Source: ITU World Telecommunication Indicators).[32]

Growth	1975-85			1983-93		
Groups	1	2	7	1	2	7
below 0.05	SWE		CHE	SWE		DNK
	JPN		ISL	USA		CHE
	LUX		DNK	JPN		NLD
	USA			GBR		AUT
				FRA		FIN
0.05-0.1	CAN	AUS	BEL	NOR	AUS	ISL
	GBR		NLD	LUX	BRA	BEL
	ITA		PRT	ITA	HKG	GRC
	NOR		AUT	CAN		IRL
	DEU		GRC	DEU		
	ESP		FIN	ESP		
0.1-0.15		HKG	IRL		SAU	
		MEX			MEX	
		IND				
0.15-0.25	FRA	THA	MLT		IND	PRT
		IDN			MYS	
		BRA			KOR	
		TUR				
0.25-0.5		MYS			IDN	
					THA	
above 0.5		KOR			TUR	
		SAU				

Comparing the six columns of table 1.3, we observe that Great Britain and France both show a decrease in the growth of the number of main lines in operation,

[31] A simple 'centroid' cluster analysis was performed following the construction of a distance matrix using all the variables relevant to the demand for communication satellites.

[32] Only the domestic satellite owners and Western Europe are presented in this chapter, consult appendix D for a full account of all countries included in this study.

while Luxembourg experienced an increase. Furthermore, a serious decline between the two decades can be observed for France. Note that all group 1 countries (the rich western world countries owning domestic satellites), with the exception of France in the first sub-period, have a yearly growth value below 0.1. Most of their infrastructure was already in place prior to 1975, and they update it as the need arises. Comparing these results and those that will follow with the study by Antonelli (1995) on the adoption of electronic switches in the telecommunication infrastructure provides interesting parallels. In Antonelli's study, Japan, USA and Sweden also appear to be falling behind in terms of the rate of growth of telecommunication intensity (telecommunication intensity is measured using the overall infrastructure of the system, including the number of main lines and the general transmission equipment). Some countries having launched satellites at a later date (in the 1990s), Korea and Malaysia in particular, have experienced a decreasing growth rate of their telephone infrastructure from 1975 to 1993, whereas for other countries in the same group, Thailand and Turkey, growth rates have increased for the telephone infrastructure. This result is surprising when compared with the rate of diffusion of electronic switches calculated by Antonelli. Indeed, in this classification, Turkey, Thailand and Korea are all 'forging ahead' while Malaysia is 'falling behind'. We agree that the extent of adoption of electronic switching does not equate the number of main lines, but the classification of Korea in the leading group while its main line growth is decreasing suggests that because it had a very strong growth in the first decade, in the second decade, a lesser number of main lines was needed and the country could concentrate its investment on upgrading its switching equipment to electronic switches. In order to verify this claim on telecommunication investment, its growth for the two decades in question is illustrated in table 1.4.

Table 1.4: Growth of telecommunication investment (Source: ITU World Telecommunication Indicators).

Growth Groups	1975-85			1983-93		
	1	2	7	1	2	7
below 0	LUX ESP	IDN BRA	ISL BEL	NOR		IRL
0-0.1	GBR CAN JPN FRA ITA	AUS	DNK NLD CHE PRT IRL AUT FIN GRC	CAN USA SWE GBR FRA	AUS THA MYS	DNK FIN
0.1-0.25	USA DEU NOR SWE	MEX CHN IND		ITA ESP JPN DEU	KOR IND BRA	CHE AUT GRC ISL BEL NLD
0.25-0.5		TUR HKG			HKG TUR	PRT
0.5-1		KOR		LUX	MEX	
above 1					IDN	

As we cannot distinguish the share of telecommunication investment allocated to each part of the infrastructure, it is very difficult to explain the diminution

of the growth rate of investment on South Korean telecommunication infrastructure with the decline in the growth rate of the number of main lines, while this country has been replacing electromechanical with electronic switches at a faster rate than most western countries. In contrast, Japan and Italy increased their investment in telecommunication but this investment has not been entirely spent on the augmentation of main lines as their growth has not changed substantially in the last two decades. This investment, however, has been reflected in an increase in the growth rate of electronic switches; According to Antonelli, Japan is forging ahead in the adoption of electronic switches, while Italy is considered a fast adopter in this area. Luxembourg and Spain have also substantially increased their rate of investment growth in telecommunication (from a negative growth to above 0.25 for Spain and above 0.5 for Luxembourg). While Antonelli does not mention Luxembourg, Spain, in his study, appears in the fast adopters of electronic switches. Luxembourg went from below zero to above 0.5, while at the same time, the rate of growth of main lines has decreased. This presupposes that a substantial amount of investment has been utilised elsewhere. This fact is probably the result of an update of the infrastructure to implement state-of-the-art equipment. We doubt that this investment increase is the result of the purchase of a series of domestic satellites because these spacecraft are essentially designed for direct-to-home (DTH) television broadcasting, and not for telecommunication services. If the ITU incorporated broadcasting into their investment figures, this would explain this sudden growth but we doubt that they do so unless they also provide telecommunication services.

In contrast, USA and Sweden decreased their investment rate in telecommunication but have maintained their level of growth in main lines in operation. This implies that another part of the infrastructure has stopped growing as fast as previously. Presumably, this decline can be attributable to Antonelli's electronic switches; but unfortunately, only in the US, where he classifies this country as falling behind in the extent of adoption of electronic switches. Sweden, on the contrary, falls into the category of fast adopters. So, change in electronic switching equipment, in general, does not seem to be related to this stagnation in investment. In contrast, Canada, Great Britain and France maintained their level of investment growth. Furthermore, in Canada, as for Korea, the same rate of growth is observed over the two decades in the case of main lines in operation, so as to maintain their communication system and grow as the need arises. On the contrary, France and Great Britain, however, have experienced a diminution in the rate of growth of the number of main lines in operation, especially France.

1.2.2 Telecommunication traffic growth

Another way to assess the use of investment is to cross-examine the change in traffic in the two decades under scrutiny. Earlier in this section, the need for telecommunication services was mentioned as a potential cause for the steady growth of telecommunication investment and its ensuing infrastructure. In the next table, the rate of growth of international outgoing telephone traffic is examined (table 1.5).

According to tables 1.4 and 1.5, some countries' investment growth does not appear to follow the growth rate of telecommunication usage, not the international outgoing telephone traffic anyway, as for many countries, this rate of growth has declined. Luxembourg international traffic, for example, has the same level of growth in the two decades, but its investment has considerably increased. In most countries of

group 1 (rich countries with domestic satellites), the growth rate of international outgoing telephone traffic has remained relatively constant over these two decades. Also, in the rest of Western Europe, with the exception of Finland and Greece which both experienced a drop in rate of growth of international traffic, the situation was more or less similar over these two decades.

Table 1.5: Growth of international outgoing telephone traffic (Source: ITU World Telecommunication Indicators).

Growth Groups	1975-85			1983-93		
	1	2	7	1	2	7
0.1-0.25	LUX		CHE AUT	FRA SWE NOR LUX DEU GBR	SAU BRA	NLD FIN CHE DNK GRC BEL AUT
0.25-0.5	NOR ITA ESP CAN*	BRA	GRC FIN	ITA ESP CAN	AUS MEX	MLT ISL
0.5-1	JPN USA	IDN AUS	PRT	USA JPN	TUR IDN	PRT
1-2		IND MYS* HKG* TUR			KOR HKG THA MYS IND	IRL
above 2		SAU				

*1976-86

Contrary to the evolution of the infrastructure, which has not increased rapidly for the past two decades in Japan and the United States, the usage of this infrastructure in terms of number of international outgoing telephone calls as grown much faster. Even faster still is the growth of international telecommunication in Hong Kong, Malaysia and India over the same period. Apart from Hong Kong, these countries have had a greater rate of growth of the infrastructure as well. In the second group of countries with domestic satellites, Saudi Arabia, Brazil, Australia and Turkey have all experienced a drop in the growth rate of international traffic, while in the far east, Indonesia, India, Hong Kong and Malaysia show an augmentation in this rate of growth. Except Hong Kong, which has a lower level of growth in terms of main lines, the other countries are forging ahead. All the countries with a growth rate greater than 1 in the second time period, with the exception of India, are all launching their first domestic satellite in the 1990s. Turkey, is also part of this group but had somewhat reached a maximum growth rate in the previous decade. In the Middle East, some small country members of Arabsat have experienced a considerable reduction in the growth rate of international traffic.

1.2.3 Broadcasting growth

As all the previous figures exclude the broadcasting aspect of general communication services, we have put together a list of the countries which provide

Direct-To-Home (DTH) satellite television services. As a comparison, we also provide the list of countries that are equipped with cable television services. In the subsequent two tables (tables 1.6 and 1.7), the number of cable television subscribers as well as the number of DTH satellite receivers are compared as a percentage of households, for the year 1993. Because of the lack of a consistent time series on the subject, growth figures cannot be calculated, and the year 1993 is used. Times series of these figures are included in appendix D.

Table 1.6: Number of cable television subscribers as a percentage of households in 1993 (Source: ITU World Telecommunication Indicators).

1993\Groups	1	2	3	4	5	6	7	8	9	10
0-10%	ESP GBR FRA	HKG* THA TUR IND		QAT	PHL			ROM** POL	CHL COL*	SLV
10-25%	JPN	CHN*					MLT AUT	HUN		LCA*
25-50%	NOR DEU SWE						DNK FIN IRL		ARG*	
50-75%	USA CAN	KOR		ISR*			CHE			BMU
75-100%	LUX		CAF				NLD BEL			

*1994
**1992

Table 1.7: Estimated number of DTH satellite receivers as a percentage of households (Source: ITU World Telecommunication Indicators).

1993\Groups	1	2	3	4	5	6	7	8	9	10
0-1%	ITA FRA ESP	HKG THA CHN TUR IND*	TCD TGO SWZ SLE	JOR	MMR MNG SYC* PHL MDV* CYP	FJI SLB	MLT BEL		SUR	HND* LCA*
1-5%	CAN LUX USA	MYS IDN KOR	TUN				FIN CHE NLD			
5-10%	NOR SWE						IRL PRT DNK	POL		JAM
10-20%	JPN GBR DEU							HUN		BMU
20-100%					MAC		AUT			

*1994

Some countries like the US and Canada provide both cable and satellite TV services. In some countries, such as Great Britain, satellite dishes are more common than cable television decoders; but in countries which first introduced domestic satellites to be used as feeds for national television stations, Canada and the US for instance, cable is more widespread than satellite receivers. Country size may have been to the origin of the spread of the combination of satellite feeds and cable. In

North America, the majority of the population is generally agglomerated around towns, which are located at some distance from one another. Ordinary ground wireless transmission of television signals thus requires a greater number of feed antennas to relay the television signal from one place to the other. In smaller countries, like Great Britain, ground wireless communications are still feasible with a fewer number of relay antennas. The North American satellite-feed/local-cable infrastructure has therefore slowed the adoption of DTH satellite services, compared with the relatively empty canvas of Europe. As a general rule, in countries with an important cable infrastructure, DTH satellite receivers should be more scarce than in countries where cable only services a small proportion of the population. Unfortunately, in small countries where television can be easily transmitted using ground antennas, neither satellite dishes nor cable services are widespread. Countries such as Spain and France in Europe spring to mind.

Luxembourg is a very distinct case, possessing the highest proportion of cable television services in Europe, the country has decided to launch a series of domestic satellites, certainly not to provide services to its own inhabitants, because the cable infrastructure is so widespread, but to provide satellite services to its neighbouring countries. In fact, Luxembourg has a lower spread of satellite receivers than the UK, which, with Germany, has the highest proportion of personal satellite dishes per household in the world. Even Japan, which first tested and introduced direct-to-home satellite services, with its satellite BSE launched in 1978, has a lower than average proportion of households services by satellite television services. In Europe, broadcasting services were first introduced with satellites such as TVSat and TDF (Germany and France). Note, however, that France, which launched its own fleet of TDF satellites to provide DTH satellite television services, possesses a far lower number of satellite receivers than Germany, which ordered the same number of satellites to be built jointly with the French spacecraft, and has even lost one satellite during its launch. Following these satellite innovations in broadcasting, France is still lagging behind Germany in terms of satellite receivers. Yet, both countries have launched a further fleet of satellites to provide satellite television services: DFS-Kopernikus in Germany and Telecom in France. Elsewhere in Europe, Norway and Sweden have an average number of cable and satellite television service subscribers, compared to the rest of the sample. These two countries purchased the two BSB-Marcopolo satellites intended for DTH broadcasting when British Satellite Broadcasting collapsed in 1990[33]. At the time of the purchase, Sweden also had a Tele-X satellite, which is of the same family of spacecraft as TVSat and TDF.[34]

From the second group of domestic satellite owners, Korea appears in the same category as Canada and the US in terms of penetration of cable and satellite receivers. In contrast to these two old owners of domestic satellites, Korea is relatively new to this space communication concept. A similar situation, however, occurs on both sides of the globe: the important cable infrastructure present slows down the adoption of DTH satellite television services. We postulate that with the recent launch of far east satellites, the penetration of satellite receivers will increase dramatically in countries such as Thailand, Hong Kong and Malaysia, which do not have to fight the inertia caused by a heavy cable infrastructure.

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[33] The two BSB-Marcopolo spacecraft were renamed Thor (Norway) and Sirius (Sweden) after being sold.

[34] More information concerning these satellites is provided in appendix A.

1.2.4 Communication satellite growth

Finally, as one of the media utilised to transmit telecommunication and broadcasting signals, communication satellites will be examined. Table 1.8 illustrates the chronology of acquisition of domestic communication satellites.

Table 1.8: Order of adoption of domestic satellite technology.

	Country	Symbol	Continent	Contract	Launch	Domestic system
Leaders	Canada	CAN	North America	1970	1972	Anik-A
	United States	USA	North America	1972	1974	Westar
	Japan	JPN	Asia	1974	1977	CS-1
	Indonesia	IDN	Asia	1975	1976	Palapa-A
Fast followers	India	IND	Asia	1978	1982	Insat-I
	France	FRA	Europe	1980	1984	Telecom-1
	Saudi Arabia	SAU	Asia	1981	1985	Arabsat-1
	Germany(W)	DEU	Europe	1981	1987	Tvsat
	Australia	AUS	Oceania	1982	1985	Aussat-A
	Brazil	BRA	South America	1982	1985	SBTS-A
	Mexico	MEX	North America	1982	1985	Morelos
	Sweden	SWE	Europe	1982	1989	Tele-X
Slow followers	Luxembourg	LUX	Europe	1985	1988	Astra*
	Italy	ITA	Europe	1985	1991	Italsat
	United Kingdom	GBR	Europe	1987	1989	BSB**
Laggards	Spain	ESP	Europe	1989	1992	Hispasat
	Hong Kong	HKG	Asia	1990	1990	Asiasat***
	Turkey	TUR	Asia	1990	1993	Turksat
	Thailand	THA	Asia	1991	1993	Thaicom
	Korea, Rep.	KOR	Asia	1991	1995	Koreasat
	Malaysia	MYS	Asia	1991	1995	Measat

*Astra-1A, formerly Satcom-Ku3 was sold to SES by Americom
**Sold in 1991 to Sweden and Norway
***Asiasat-1, formerly Westar-6, was recuperated, refurbished and re-launched

The boundaries of the four categories are roughly 1975, 1985 and 1990, corresponding to gaps in the series of orders by new adopters. Comparing this classification with the results obtained by Antonelli (1995, p.50-51), we find some similarities in adoption of new telecommunication technology. Indeed, Canada and the US appear to be the first countries to adopt electronic switching as well as to launch domestic satellites. Japan appears to be a laggard in term of the extent of adoption of electronic switches but has launched satellites since the mid-1970s. In Indonesia, however, one of the first countries to launch a domestic satellite, adoption of electronic switches appears to be non-existent in 1987. It is surprising that a country would launch the latest satellite technology but neglect the ground infrastructure. It is possible that the nature of the terrain (a great number of islands) necessitates the use of satellite technology, and the subsequent investment deprived the country of further improvements on the ground infrastructure. In other countries in the far east, Hong Kong, Malaysia, South Korea and Thailand, the adoption of electronic switches *en masse* by 1987 has pre-empted the order of communication satellites, in the early 1990s. In contrast, even though it launched its first domestic satellite in 1985, Australia does not appear to have followed the wave of adoption of electronic switches that their fellow westerners have.

So far, growth rates of investment, infrastructure, traffic and usage of the communication system have been examined. Last but not least, the growth rate of the

variable that we want to explain, the satellite capacity owned by each country, is examined in tables 1.9 and 1.10. Note that only the first two groups of countries are domestic satellite owners, while the other eight groups own part of satellites launched by international and regional organisations. These measures are calculated using a database built from the Rusch (1992) database and the ITU Space Radiocommunication Stations database. Ownership of Intelsat satellites is included in these tables and as a consequence, countries that do not possess domestic satellites appear to possess an equivalent number of satellites.

Table 1.9: Growth of the owner net stock of satellites; 1975-85.

1975-85\Groups	1	2	3	4	5	6	7	8	9	10
0-0.25		BRA	SEN						BOL	GTM
			MRT						ECU	JAM
			MAR						PER	NIC
									COL	CRI
									VEN	PAN
									CHL	BRB
									ARG	TTO
0.25-0.5	CAN	MEX	CIV	GAB	ISR	VNM	NZL			
		MYS	ZMB	DZA	JOR	PHL				
		AUS	TZA	TUN	LBN					
		SAU	KEN	ETH	EGY					
		KOR	UGA	LBY	SYR					
			ZAF	CAF	YEM					
			GHA	MDG						
			NGA							
0.5-1	GBR	IDN		KWT	CYP		IRL	YUG		
	ESP			IRN			PRT			
	DEU						DNK			
	ITA						AUT			
	LUX						BEL			
	NOR						NLD			
							GRC			
							CHE			
1-2	SWE	TUR		OMN	LKA		ISL			
	USA	THA			SGP		FIN			
					PAK					
above 2	FRA	IND								
	JPN									

Canada and the US appear to be lagging behind in terms of satellite capacity, but this is due to the fact that these two countries were the first to launch domestic satellites and have a high investment share in Intelsat. Brazil and Mexico both have increased their rate of growth in ownership of satellite stock, but most other members of the domestic satellite group have experienced a decline in that growth rate. These two countries both have ordered a second fleet of satellites in the early 1990s. Australia ordered its second fleet of satellites slightly earlier, but has decreased the number of spacecraft purchased (from 3 to 2 satellites in the second order). All these countries appear to have a decreasing level of growth because this examined the net stock of satellites on either sides of 1985. So if the first fleet of satellite appears to die before 1995, then ordering a second fleet of satellite in between only appears to be maintaining the stock, if the same capacity is ordered, obviously. If, for instance, the fleet was launched in 1985, then, the growth rate appears greater than normal for the first decade, and smaller for the second decade, as the first generation of satellite dies.

However, since for most countries, the first domestic satellites were launched in or around 1985, previous ownership of satellites was via Intelsat, for which spacecraft are launched regularly. Following this preliminary study of satellite growth, the next section examines the temporal evolution of the stock satellites in greater detail than the two yearly growth measures calculated in the preceding paragraphs.

Table 1.10: Growth of the owner net stock of satellites; 1985-95.

1985-95	1	2	3	4	5	6	7	8	9	10
below 0		KOR			LKA BGD SGP PHL	PNG FJI				
0-0.1	CAN USA	MYS AUS	MDG ETH ZMB ZAF TZA CAF KEN TCD UGA	IRN ISR OMN	PAK VNM CYP	NZL	GRC AUT DNK CHE ISL FIN	YUG		
0.1-0.25	GBR NOR	IDN SAU IND	COG NGA LBY DZA BFA CIV NER TUN GAB GIN GHA SEN	ARE SYR JOR LBN EGY QAT KWT YEM			BEL NLD IRL PRT MLT		CHL PRY BOL ECU ARG PER COL URY VEN	JAM NIC HND CRI BHS PAN BRB TTO SLV
0.25-0.5	JPN SWE FRA	BRA TUR	MRT MAR							GTM
0.5-1	ESP									
1-2	ITA DEU	THA	LBR							
above 2	LUX	MEX								

1.3 History of satellite communications

Since the mid-1970s, the international communications satellite market has been shaped by the production of North-American domestic satellites. Intelsat, and to some extent the US military, have been the major players in the development of the space industry throughout the world. With such first few programs as Intelsat I to IV and Anik A, US space firms were the pioneers of space commercial communication. North American companies have continually improved the quality of their spacecraft and during the early 1990s, systems like Intelsat VII and Hispasat (Spain) have marked the appearance of the largest satellites launched so far. In this third part of the chapter, the temporal evolution of satellite communication from the point of view of numbers of satellites is examined. Does the number of satellite produced and utilised differ across divers regions? Which manufacturers are chosen by which customers to build these satellites? In an attempt to answer these questions, this section of the chapter is structured as follows: First, the evolution of the cumulative flow and stock of commercial telecommunication and broadcasting satellites to date is presented; Second, the stock of satellites under observation is disaggregated in terms of manufacturing and ownership; Then, concentration indices are calculated from the

number and value of satellites produced by space manufacturers and launched by satellite operators; and finally, as a preamble to the second chapter, the cumulative flow and stock of satellites are represented by different measures of capacity.

1.3.1 General history of the satellite communications

Before the 1970s, the satellite production market of the western world was entirely dominated by the requirements of Intelsat and the US military. In 1972, Canada was the first country to launch a domestic civil commercial communication satellite system, with the Anik A series. Over the period covered by this study, 1964-1992, the number of satellites ordered to satellite manufacturers has increased at a non-steady pace. Consequently, the flow of orders is relatively unstable over time, so the cumulative number of orders will be presented (see figure 1.1). In this graph (and in the rest of the chapter as well), the cumulative number of satellites, is measured as a total per year. Variations within each year are not represented, as everything is standardised at the beginning of the year. Furthermore, the vertical lines shown in the graph illustrate the end and beginning of cycles of purchases of commercial telecommunication and broadcasting satellites to manufacturers and will be used in most graphs in this thesis as a reference point. The graph shows a halt in the rate of orders in 1971, 1975 and 1984 as well as an increase in the rate of purchases, illustrated by a change of slope, in 1979 and 1988.

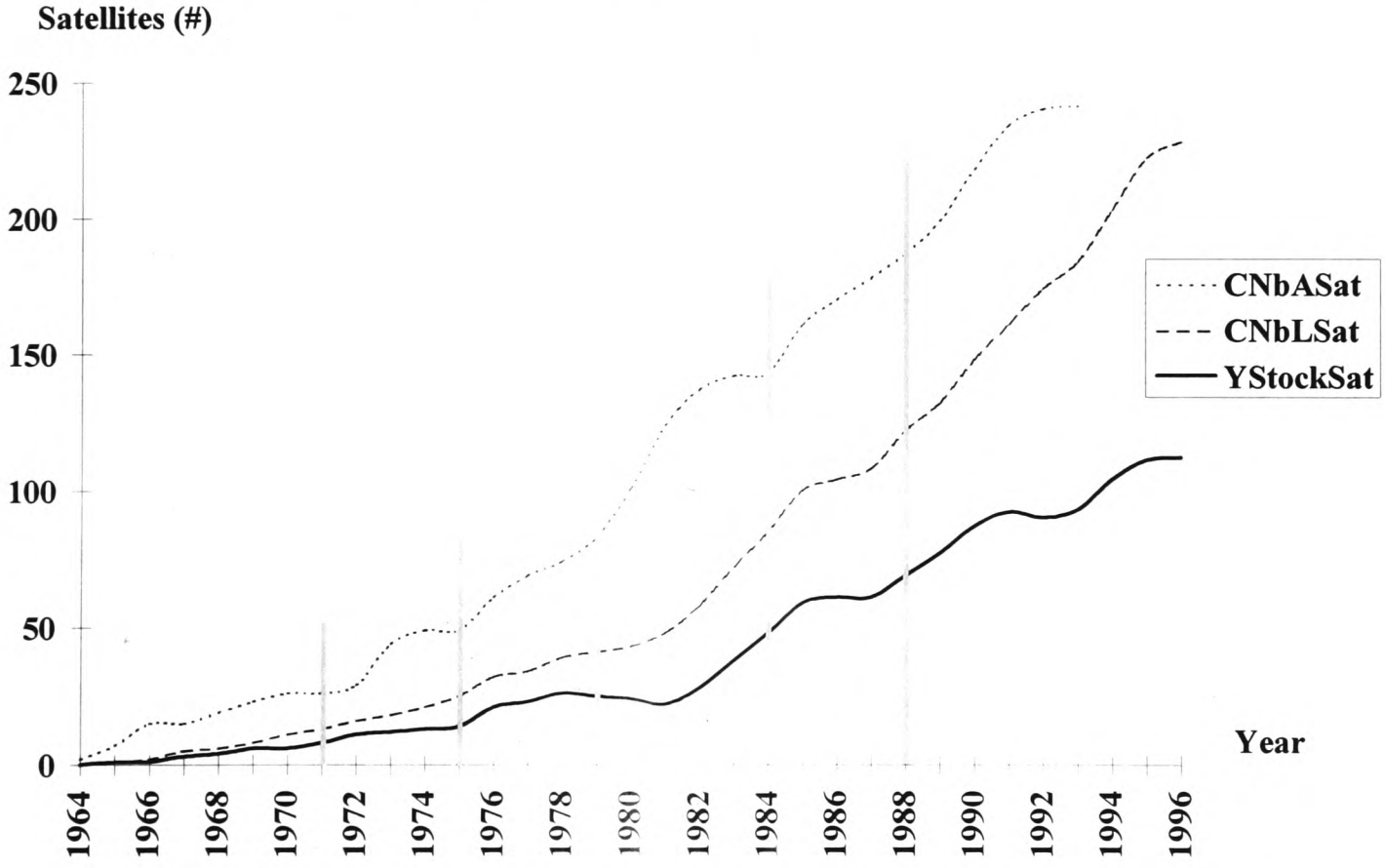


Figure 1.1: Stock (solid line) and cumulative number of awarded (dotted line) and launched (dashed line) commercial communication satellites; yearly.[35]

Comparing these curves show that the evolution of the cumulative number of launches and the in-orbit stock of satellites are smoother than the cumulative number

[35] Note that the data available to this study exclude Russian and Chinese satellites altogether, albeit the fact that Russian satellites represent a substantial part of the market as the country has launched more satellites than all the other countries put together. Although this thesis omits an important part of the market, the Chinese and Russian satellite communication industries are not organised as businesses, so in some sense, we are not dropping a lot of information essential to the competitive market.

of orders would suggest; this is because spacecraft of the same program are launched over a period of some months rather than all at once. Hence, the cycles illustrated in figure 1.1 are modified and attenuated when plotting the cumulative number of satellites delivered for launch and the stock of in-orbit satellites. A small decrease in stock of in-orbit satellites occurs approximately two years after the corresponding stagnation identified by the cycle of orders.

From this graph, it is believed that the civilian communication market follows cycles; and two different cycles can be distinguished, which alternate approximately every four to five years. Villain and Chenard (1993) mention a first cycle starting in the first half of the 1980s, and recurring in the mid-1990s, which corresponds to the old members of the satellite community replacing their fleets. Their second cycle occurs approximately five years later, starting towards the end of the 1980s, and they forecast it to recur in the beginning of the next century. They measure these cycles in terms of number of satellites launched, regardless of when they were ordered. Following their predictions, this should leave a few lean years at the end of the century which should correspond to the 1985-86 stagnation. In the present case, the first cycle observed in figure 1.1 corresponds to a flow of orders starting in the early 1970s, and recurring in the mid-1980s, which corresponds to Villain and Chenard second cycle of launches. While the second cycle represents the flow of orders beginning in the late 1970s, and recurring in the late 1980s to early 1990s, i.e. the first cycle of launches described by Villain and Chenard. Cycles arise from the fact that 6 to 10 years after its launch, an existing satellite is approaching its 'end-of-life'[36] and requires replacement. Note that the recurrence period of cycles increases with time because satellite lifetime increases. The first cycle recurred 6-8 years later, the second cycle recurred 10-12 years later and the third cycle should recur 15-20 years leading into a fourth cycle. Obviously, distinctions between cycles become less clear as new countries order satellites for the first time.

In the next few paragraphs, an account of the highlights of each cycle will be presented: the countries involved, which satellites were launched and the link between cycles will be examined. Appendix A provides an exhaustive list of all the satellites relevant to this study. In the beginning, the number of satellites ordered per year has increased at a relatively low pace: the first few satellites ordered being for the first four Intelsat series, Intelsat I (1964), II (1965), III(1966) and IV(1968 and 1969). Just before the first stagnation of purchases in 1971, domestic markets for communication satellites, mainly for broadcasting purposes, started with the Canadian satellite series Anik A, shortly to be followed by US domestic systems.

In the early 1970s, the next cycle illustrated in figure 1.1 introduced more domestic communication satellites, comprising the first three American Westar, Satcom and Comstar, and the first Indonesian Palapa system. Marisat and Marecs, the first maritime mobile communication satellites, were also ordered during that period. In addition, Intelsat expanded the fourth series by ordering the Intelsat IVA family. During the same period, experimental satellites laid the ground work for the space technology improvements that characterised future generations of communication satellites. Symphony was the first European experimental communication satellite. Then followed OTS and Sirio, which aimed not at demonstrating the possibilities of

[36] The end-of-life of a satellite corresponds to the end of its planned lifetime.

space communication, but at enabling Europe to master its own technology by developing three-axis stabilisation and introducing new frequencies. Further afield, the United States co-operated with Japan in the production of the first Engineering Test Satellite (ETS) to allow Japan to acquire basic satellite technology.

The subsequent period, 1976-79, saw the expansion of the Canadian and Indonesian domestic communication satellite fleets with the Anik B, C and D programs and the Palapa B satellites. Moreover, the US domestic market acquired new systems with Galaxy and SBS, and India purchased its first domestic fleet of communication satellites. Intelsat started to replace its satellite fleet, introducing the Intelsat V series. Following the experiments of the previous period, Europe finally ordered Eutelsat I (European Communication Satellites, ECS), its first fleet of commercial communication satellites built in Europe through ESA. After successful experiments on direct broadcasting satellite services (with BS 1) earlier in the decade, Japan ordered two BS 2 satellites for the first commercialisation of DTH broadcasting services.

Between 1980 and 1984, the market for civilian telecommunication and broadcasting satellites grew at the fastest pace noticeable during the entire period examined. As mentioned earlier, this cycle should be a recurrence of the 1972-75 period, where operators of satellite services expanded and replaced their fleet. During that time, Western Union purchased a further three Westar satellites, and so did GE with Satcom. Telecommunication Satellite Corporation of Japan (TSJC) ordered two CS 2 satellites, the commercial follow up to the experimental CS spacecraft launched two cycles ago. Intelsat ordered the Intelsat VA and VI families of spacecraft to continue replacing obsolete satellites. AT&T purchased another series of satellites, Telstar 3, but this time commercial purposes were intended. Apart from these program continuations, new comers purchased their first commercial satellites. A consortium of Arab countries ordered its first three Arabsat 1. In Europe, France, Germany and Sweden provided their domestic communication markets with three Telecom 1 and two TDF, two TVSat and three DFS-Kopernikus as well as one Tele-X satellites respectively, their main purpose being broadcasting for standard and direct service purposes. Further afield, Australia also acquired its first domestic fleet with Aussat A, Brazil purchased SBTS A (Brazilsat) and Mexico ordered Morelos.

The next period consists of the re-emergence of the 1976-79 cycle, with the prolongation of many programs such as Anik E (Canada), Insat 2 (India), BS 3 (Japan) and Eutelsat II (Europe). Although there appears to be a clear separation in the cycles, some satellite operators expanded earlier than they replaced their fleet, so they ordered satellites sooner than customers which maintain a more or less constant capacity in-orbit. Those are Japan with CS 3, France with Telecom 2 and Australia with Aussat B. In this cycle, Intelsat purchased its seventh series of satellites. Following the success of Marecs spacecraft for maritime communications, Inmarsat ordered four Inmarsat II satellites. Furthermore, the Far East saw the apparition of Superbird and JCSat in Japan as well as Asiasat 1 in Hong Kong. In Europe, a few new comers entered the market: the UK with BSB-Marcopolo (later sold to Norway and Sweden); Italy with Italsat; and Luxembourg with Astra 1[37].

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[37] Astra 1A was previously part of the Satcom fleet and was sold to SES (Société Européenne de Satellites) because of over capacity problems (more details in section 1.3.2.1).

Finally, the last period of orders, 1989-1992, is a mixture of recurring satellites from two periods before, such as Telstar 4 (US), SBTS B (Brazil), Solidaridad (Mexico) and Arabsat 2 (Arab countries); expansion of satellite systems from the last period, such as Astra 1B, C, D (Luxembourg), Italsat 2 (Italy), Asiasat 2 (Hong Kong), PAS 2, 3, 4 (US), Intelsat VIIA, VIII and Inmarsat III; and new comers such as Measat (Malaysia), Thaicom (Thailand), Koreasat (Korea), Turksat (Turkey), Orionsat and Afristar(US), MSat (US and Canada) and Hispasat (Spain).

These cycles are rather clearly separated before the 1990s, but taking into consideration the last period of the sample, the recurrence of satellite series every two cycles seems to slowly disappear. Intelsat is present is all the sub-periods, constantly improving, upgrading, replacing and expanding its satellite system. As more countries develop their domestic markets at different points in time, with different needs and demand growth, these cycles are bound to be attenuated, indeed even disappear completely. This enumeration of purchased satellites is by no means exhaustive, and many satellites were not mentioned for divers reasons: either they did not figure in the databases available to the author, the data was incomplete, the author could not find the relevant information, or the author did not know of their existence[38].

1.3.2 Disaggregation by manufacturing

In the previous section, a general enumeration of the satellites ordered at different points in time provided a useful insight on the possible periodisation of this industry. Is this also true for different regions producing spacecraft? A closer look at this evolution of commercial communication satellites from the manufacturers' view point will provide further information on the supply of communication satellites. Satellite producers will be separated into three regions, Europe, North America and the rest of the world. Japan will be included in the latter category because of the lack and incompleteness of the data concerning its satellites. North American manufacturers will be further disaggregated by singling out the three main manufacturers, Hughes Aircraft, Martin Marietta and Space Systems/Loral. Then, the change in concentration indices over the years will be examined for each region.

1.3.2.1 Evolution of satellite manufacturing

Before the first halt in orders in 1971, all commercial communication satellites had been built by US prime-contractors. In addition, from 1964 to 1975, US spacecraft manufacturers were prime-contractors for 39 of the 41 commercial communication satellites, and they dominated production until the 1980s. Figure 1.2 illustrates the breakdown of the number of commercial satellites by prime-contractors regions. US manufacturers' share of the market represents the majority of contracts, and mostly three US manufacturers compete for this part: Hughes Aircraft, Martin Marietta and Space Systems/Loral. Remember that the latter is owned at 49 % by a European consortium, so even if SS/L is awarded contracts, some subcontracting work is bound to end up in Europe. Before 1975, Hughes Aircraft was awarded the contracts for Intelsat I, II, IV and IV, Anik A, Westar and Comstar while RCA[39], obtained the contract for the Satcom series.

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[38] Appendix A includes an enumeration of all the satellites included in this study.

[39] RCA is now part of Lockheed Martin.

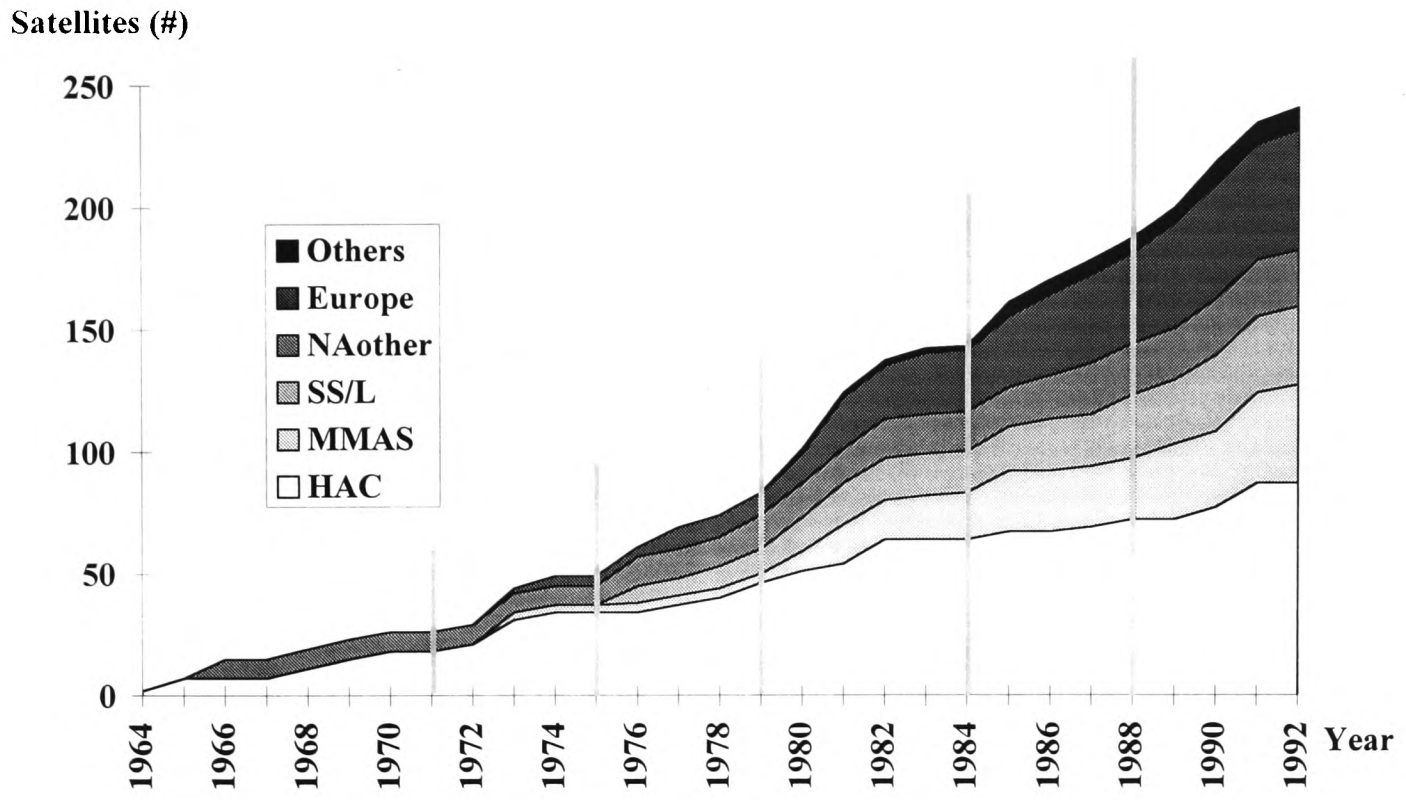


Figure 1.2: Cumulative number of awarded satellites produced in the different regions of the world, with a breakdown of US manufacturers.

During the next cycle, Hughes obtained the contract for the Galaxy, Palapa B and SBS series as well as for a further series of Anik satellites with the C family. Telesat did not put all their eggs in the same basket and ordered Anik B from RCA and Anik D from Spar Aerospace (Canada). In this cycle, Space Systems/Loral (Ford Aerospace at the time) manufactured the Intelsat V. At the same time, in Europe, British Aerospace obtained the contract of the first domestic European Communication Satellites (Eutelsat I) after its success with OTS and Marecs satellites in the previous period. Between 1980 and 1984, Hughes regained the Intelsat contract with the sixth series, continued updating Westar, SBS and Telstar satellite programs and obtained orders from the new comers Aussat A and Morelos. RCA continued producing Satcom satellites and manufactured two new US domestic programs, Gstar and Spacenet. On the other side of the Atlantic, in France, Matra built the first French domestic communication satellites, Telecom 1. Aérospatiale produced its first export, Arabsat 1, and, with the help of MBB[40], built TDF, TVSat and Tele X satellites[41]. ANT, in conjunction with MBB, obtained the contract for three German DFS-Kopernikus satellites. Canada built the first series of Brazilsat, making it its first and only export as a prime-contractor; the second series was later built by Hughes. In Japan, Melco left its position underneath the wing of US manufacturers, and built a second series of CS satellites. In the next cycle, 1985-88, Japanese customers ordered JCSat from Hughes, Superbird from Ford Aerospace (now SS/L), and BS 3 from GE Astro Space in conjunction with NEC. But these were not the only exports of US manufacturers, Hughes also built two BSB-Marcopolo satellites, as well as a further series of Aussat with the B program, and upgraded Westar 6 for it to become Asiasat 1; GE Astro Space built Satcom Ku3 which was later sold to SES to become Astra 1A. In Europe, Alenia built its first commercial domestic system with Italsat;

[40] Within the framework of Eurosatellite.

[41] All these satellites have a similar design presumably to benefit from economies of scale in their production.

Matra built the second series of Telecom satellites; British Aerospace obtained the contract for Inmarsat II; and Aérospatiale manufactured the Eutelsat II program of satellites. Finally, in the last period, Hughes obtained many more export contracts with Brazilsat B, Astra 1C, D, Solidaridad (Mexico), Thaicom (Thailand) and Measat (Malaysia). Martin Marietta obtained its share of exports with Astra 1B, Inmarsat III, Koreasat and Asiasat 2. Matra Marconi Space built the Spanish satellites Hispasat, and British Aerospace produced the Orion satellites. The rest of the manufacturers continued building the continuation of the same series of satellites.

From the previous paragraphs, Hughes is without any doubt the most important commercial manufacturer. As some satellites are missing from the database available to the author, the real market share of Martin Marietta is greater than it appears on this graph; the data available for the Satcom family was grossly incomplete regarding the second families of satellites, and was omitted as a consequence. North American manufacturers included in the category *NAother* are: Spar Aerospace, which was awarded the contract for Anik D and E; TRW, which was prime-contractor for the Intelsat III satellites then reverted to Government line of work; and Defense Systems Inc. (DSI), which manufactured Afristar 1. Figure 1.1 illustrated the evolution of the number of satellite contracts at the time of purchase. Because a family of satellites is launched gradually, the corresponding graph using the launch date as the reference is presented in figure 1.3 to examine whether there is a significant difference in the cycles. As in figure 1.1, cycles are shifted right by 1-3 years in the case of the stock and cumulative launches.

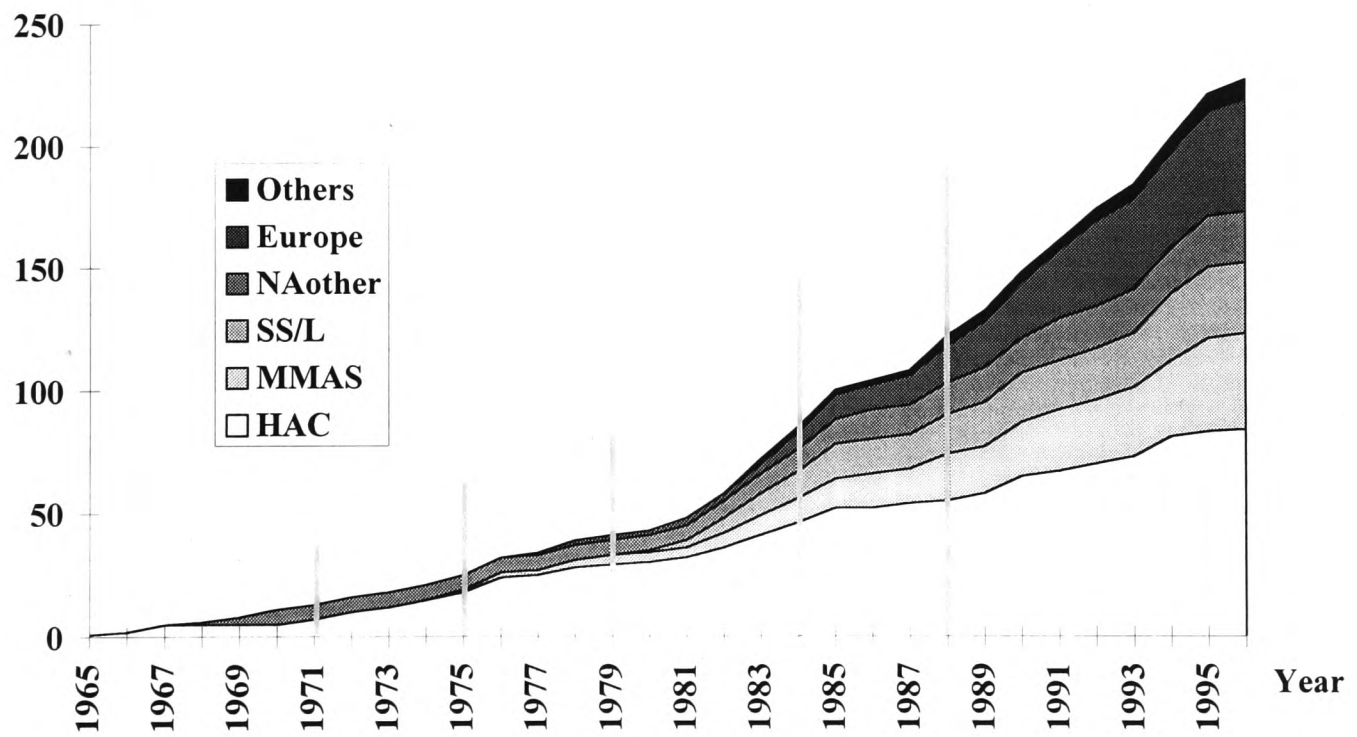


Figure 1.3: Cumulative number of launched satellites produced in the different regions of the world, with a breakdown of US manufacturers.

Before 1975, Hughes Aircraft provided 11 HS-333[42] flight units out of the total market of 49, both experimental and commercial. Hughes Aircraft was favoured

[42] HS-333 and HS-601 platforms are structures of satellite onto which the payload is fixed, refer to the second chapter for a more thorough explanation of the technology.

by most customers not only because of its important size compared to the other companies but also for its experience in space military projects. RCA was much smaller at the time, and concentrated more on ground radio diffusion systems, while TRW focused their expertise on military programs. As mentioned before, the majority of satellites were in most part built by US manufacturers (even those with non-US prime-contractors) during this period for they were, with their vast military programs, one of the few leading figures in space technology. Europeans, in trying to justify their high satellite prices, have argued that US space firms have strongly benefited from military R&D (Giget, 1992). Since most military contracts are cost plus, it has been suggested that they may have financed commercial R&D under military R&D expenditures. For example, Intelsat I and II were largely derived from NASA Syncom satellite, Intelsat III was strongly based on NASA ATS series and the Intelsat IV family was a derivative of the US military Tacsat satellites (Owens, 1990).

During those years, telecommunication satellites ordered outside the US were partly manufactured by firms other than US space companies. This is because it was, and still is, common practice for some countries to require subcontracts for some components to be awarded to their domestic firms when a contract was awarded to US satellite builders. For example, in 1970, Telesat Canada awarded the contract for Anik A satellite system to Hughes Aircraft, which in return, subcontracted the production of the satellite structure to the Canadian manufacturer Spar Aerospace (Spar Aerospace, 1992b).

From 1964 to 1988, US satellite suppliers were prime-contractors for 145 of the 204 civil communications satellites delivered. In percentages of sales value, US manufacturers lost around a fifth of their market share from the mid-1970s to the benefit of Europeans and to a lesser extent, to Canadian and Japanese firms. The US thus held 60.8 % of a market evaluated at US$ 9.4 billion over the period 1976-1988[43].

During the 1980s, Europe saw the emergence, as prime-contractors, of many companies which used to be subcontractors of the major US industries, stealing 32.2 % of the market share. Euroconsult (1991) suggests that Europe's expansion in the telecommunication market benefited from the fact that a new generation of systems was being introduced at the time; as they stated, it can be an advantage to enter a mature market equipped with hardware from a previous generation at the time when it needs replacing. European space manufacturers were actually encouraged by high R&D subsidies from Government agencies (ESA and CNES) to develop space expertise and production capability of communication satellites. Involvement of European Government agencies in the development and promotion of space technology, and support for expansion of space manufacturers, has been better managed in Europe than in the United States in the last decade (Giget, 1992).

European R&D subsidies, plus experience gained from US satellite manufacturers subcontracts allowed non-US firms to enter the world civil communication production market, and destroy the monopoly of US satellite builders, in particular that of Hughes Aircraft. Hughes, by subcontracting, has permitted European and Japanese manufacturers to develop a technological lead in some essential subsystems of telecommunication satellites. The apparent limiting factor in

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[43] The figures are calculated from the database available to the author, mainly Rusch (1992).

the market share of European manufacturers however, is the fact that prime-contractors are usually responsible for design and fabrication of the spacecraft platform while the payload, which represents a higher share in the contract, is subcontracted. For instance, Aérospatiale and British Aerospace were prime-contractors respectively for Arabsat and Inmarsat II, but Hughes Aircraft provided the payload for both satellite systems. As a consequence, this measure of European market share expresses an excess market power, and overstates the European share of the world production market of civil communication satellites in terms of industrial activity.

Moreover, the competition from terrestrial technology, such as fibre optic networks, clearly hurts the satellite domestic market and created a surplus of transponders that slowed down North American domestic satellite production. As a result, in the late 1980s, the non-US domestic market has been helped by second-hand satellite sales from the overcrowded US fleet. US companies sold at bargain prices transponders to be used by Europe, Asia and South America. For example, Satcom K3 and K4 became respectively Astra 1A and Intelsat K. Westar 6 was launched in 1978, salvaged by NASA, refurbished by Hughes Aircraft, renamed Westar 6-S, then Galaxy VI, and re-launched in 1990 as Asiasat 1 (Euroconsult, 1994).

Hughes Aircraft and Martin Marietta, the two market leaders since the early 1970s, appeared to be even more dominant than they were during the second (1976-84) and third (1985-93) decades of commercial communication satellite production. As of December 1992, Hughes Aircraft had 19 satellites on order and had sold 18 three-axis stabilised HS-601 platforms. Further, Martin Marietta has been awarded the potentially very lucrative contract of Intelsat VIII, thus gaining its first major contribution to the Intelsat market. In contrast, Ford Aerospace saw their position degrade considerably since the 1980s, when they were awarded the largest satellite constellation, the Intelsat V and VA series. Over this period, British Aerospace, Deutsche Aerospace and the Canadian and Japanese manufacturers lost more than half of their market share.

1.3.2.2 Concentration of satellite vendors

Even though, prime-contractors are getting more concentrated following the recent tendency towards acquisitions and mergers discussed in section 1.1.2, this is not so at the subcontractor level (Euroconsult, 1992). Many years of dispersion of know-how throughout different countries accompanied by frequent modifications in responsibility for systems and sub-systems, due to complicated system financing and national preferences, have prevented the build up of firm expertise in Europe (Euroconsult, 1991). A convenient way to evaluate the change in degree of concentration of these vendors over time, is to examine the evolution of Lorenz curves. Figures 1.4 to 1.7 illustrate the evolution of concentration in the world commercial communication satellite production industry in terms of number of satellites produced and value of the contracts obtained. Five time periods were chosen from the previous classification: the first two sub-periods were grouped together to form the period 1964-75, and the last four sub-periods, 1976-79, 1980-84, 1985-88, 1989-93. In the cases where there are not enough manufacturers in the first sub-period, 1964-79 is shown instead of 1964-75 and 1976-79.

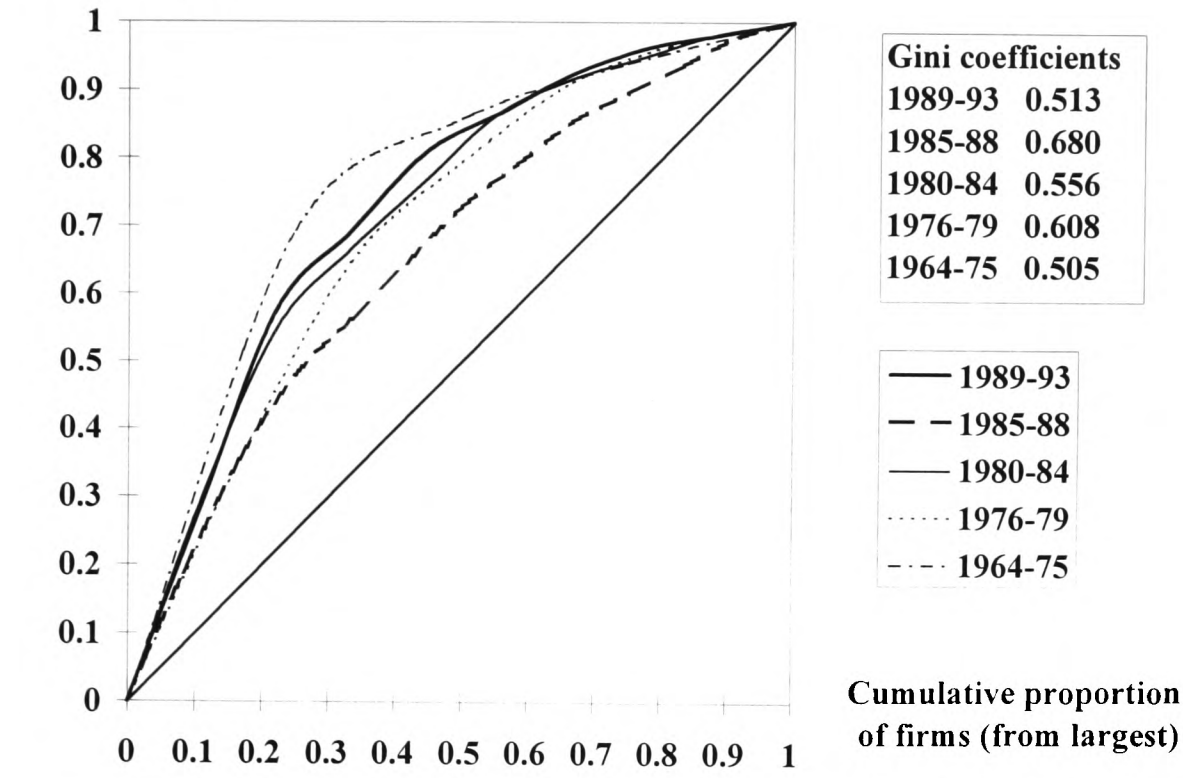


Figure 1.4: Lorenz curve, manufacturers; number of awarded satellites.

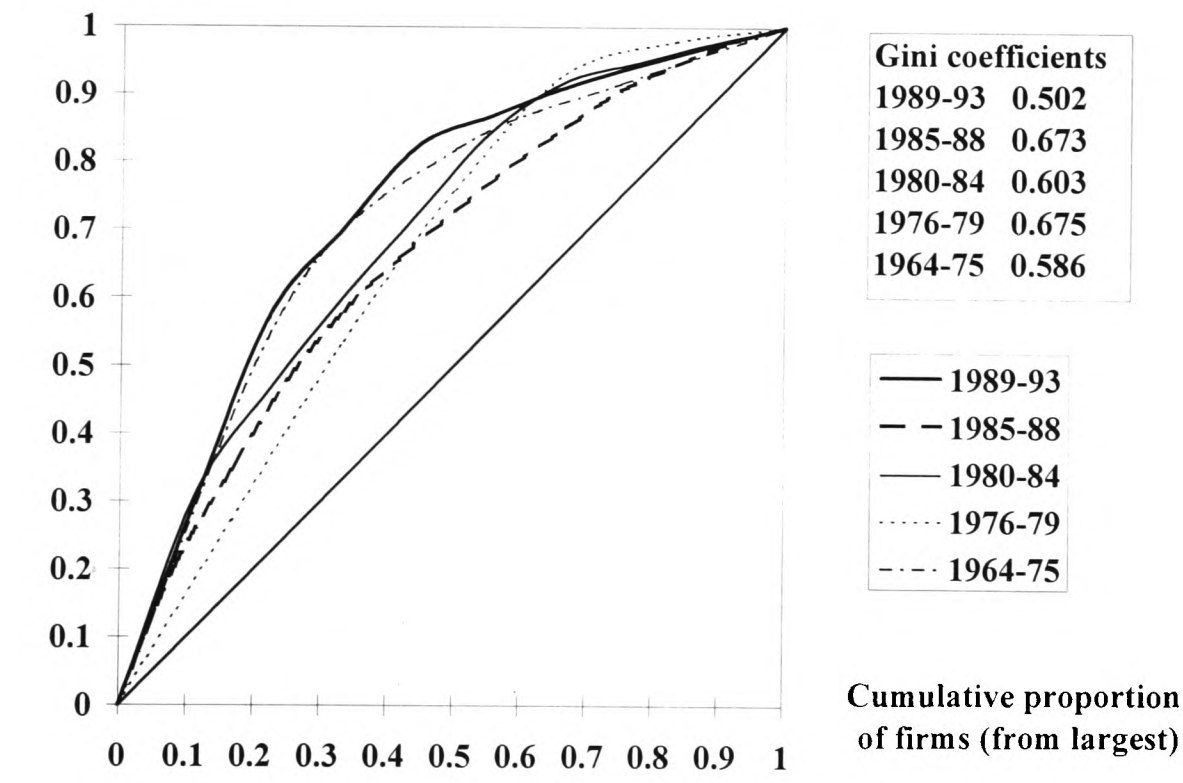


Figure 1.5: Lorenz curve, manufacturers; value of awarded satellites (constant US dollars, 1980 = 100).

Figures 1.4 and 1.5 show that both Lorenz curves of the sample period extremities have the smallest Gini coefficients, thus implying that firms were less homogeneous in terms of output; i.e. between 1976 and 1988, the most important satellite builders lost part of their market share to the benefit of smaller firms. Although the Gini coefficients appear very similar, there is however a difference between the first and last sub-periods. On the one hand, in the early days of commercial satellite design, few suppliers had enough expertise to build satellites, and those who had, acquired this experience from military contracts. It is not until the 1970s that military activity started to decline. Manufacturers that had concentrated on military contracts in the 1960s started to enter the market for the production of

commercial communication satellites. On the other hand, the late 1980s and early 1990s have seen a number of mergers that have contributed to reduce the number of prime-contractors, especially in Europe, hence the increase in industry inequality, demonstrated by the Gini coefficient. Until 1984, the Gini coefficient is greater when the concentration is measured in terms of value than in terms of number. This suggests that the most important satellite producers charge more for their satellites than the smaller manufacturers. This raises the important issue that bigger satellite builders are more experienced and produce better quality satellites that are more expensive for the customer. Quality is an essential characteristic of high technology goods and will be addressed in more details in the next chapters.

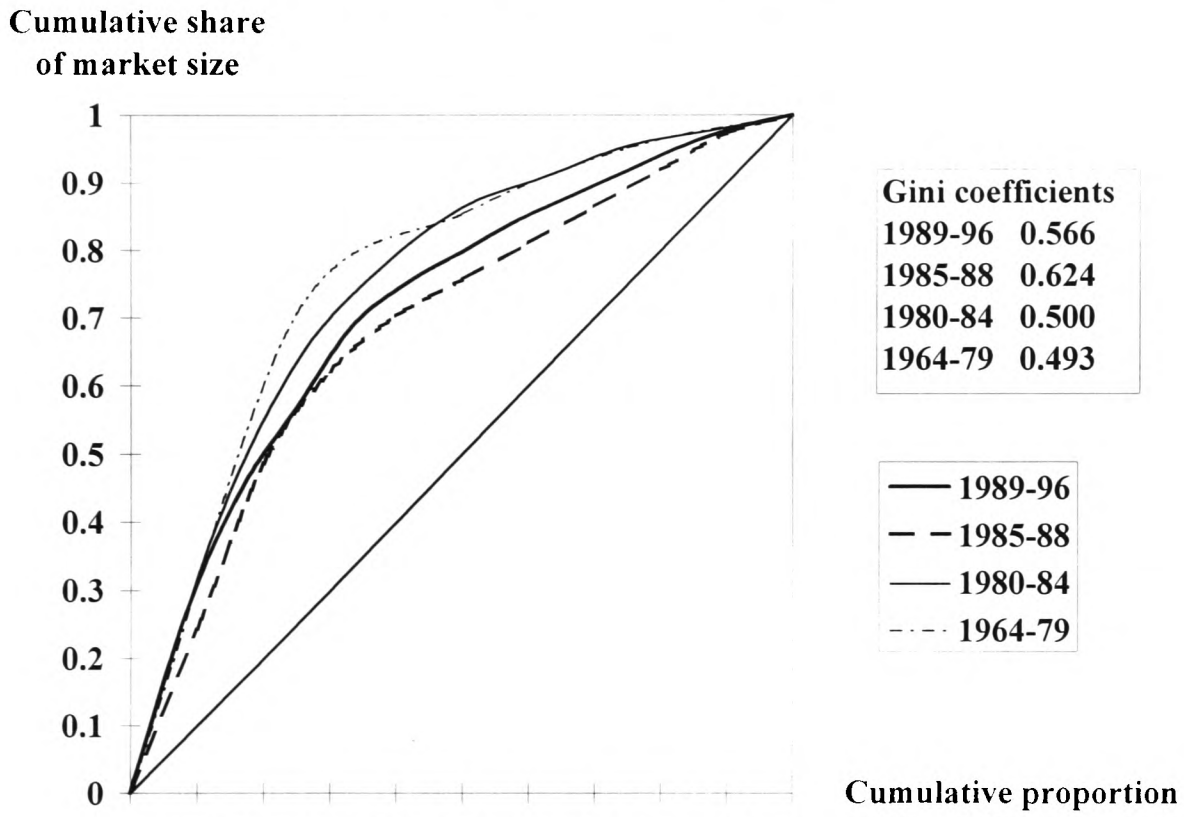


Figure 1.6: Lorenz curve, manufacturers; number of launched satellites.

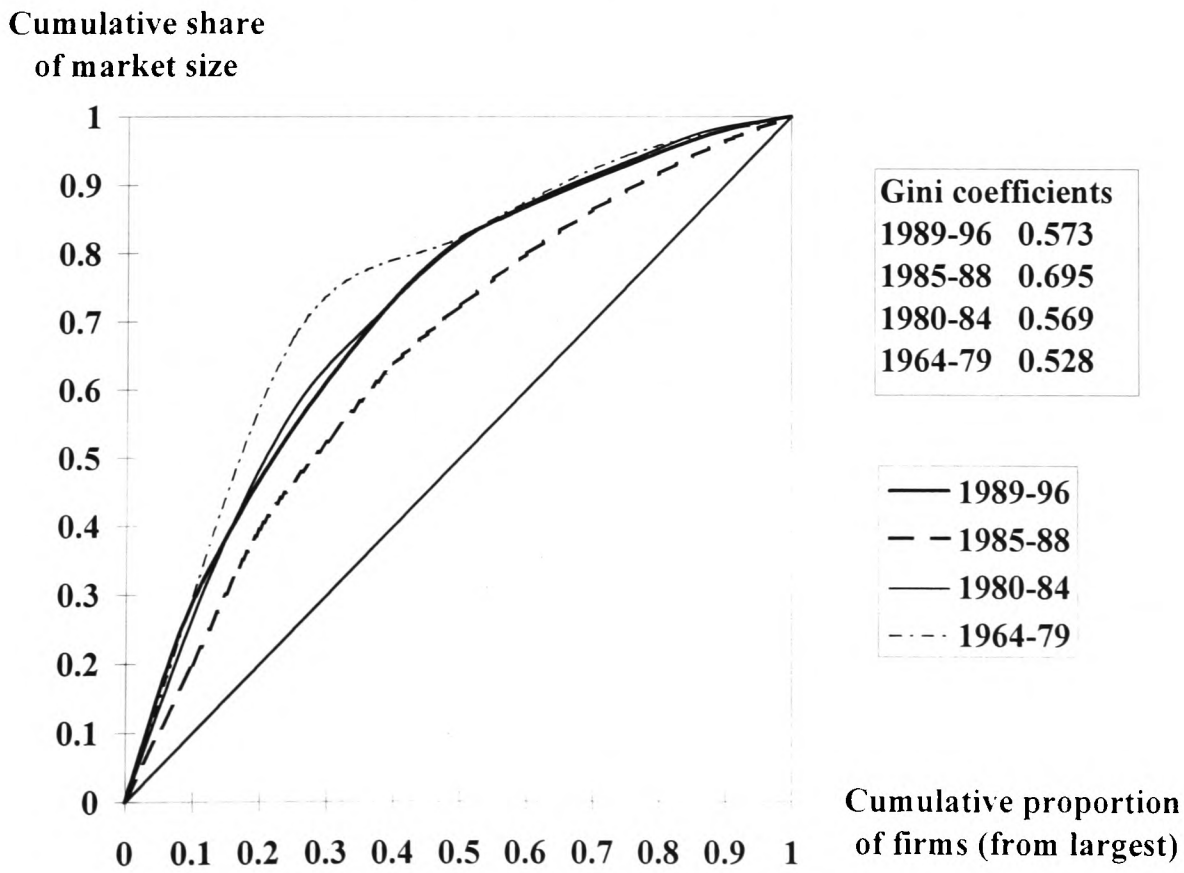


Figure 1.7: Lorenz curve, manufacturers; value of launched satellites (constant US dollars, 1980 = 100).

Following the same convention as previously adopted, concentration measures are examined using delivery dates (see figures 1.6 and 1.7). From the point of view of launched output, the industry exhibits a more consistent decrease in inequality between firms from the beginning until 1985-88 than was illustrated by award dates. Recall that 3 years is the average time lapse between contract and delivery. As a consequence, some of the contracted output appearing in the later part of the sub-period 1985-88, for instance, will be counted in the sub-period 1989-96 for delivered output. This is consistent with the hypothesis that as demand for communication satellites increased, the number of manufacturers building them also increased. Since the end of the 1980s, however, greater competition from alternative technologies, mainly fibre optics, has driven firms towards mergers and acquisitions.

Because Lorenz curves are concerned with the *relative* concentration of the industry, a measure of *absolute* concentration is needed to be able to compare the satellite industry with other industries, such as the aircraft industry. Figures 1.8 and 1.9 illustrate the evolution of the concentration ratio calculated using the Herfindahl index. Again, the same representations are shown: number and value of awarded satellites. As a convention, in the following graphs, thick lines represent sub-period concentration ratios, while thin lines characterise yearly concentration ratios. In addition, three Herfindahl indexes were calculated: North American producers (dotted line), European manufacturers (dashed and dotted line), and the all the satellite vendors of the world (solid line).

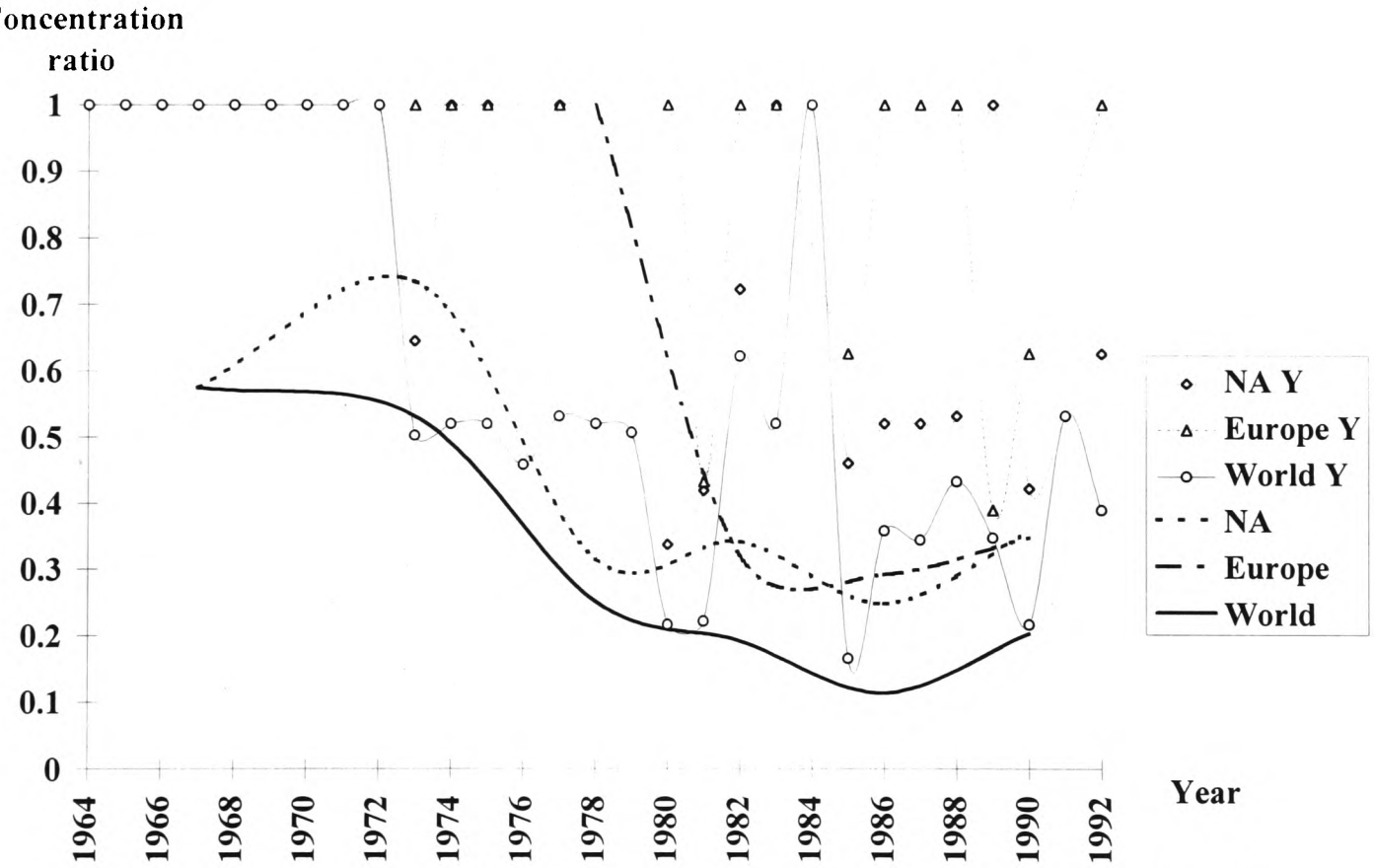


Figure 1.8: Evolution of the Herfindahl index, manufacturers; number of awarded satellites.

It is interesting to note the decline in concentration in Europe as more companies enter the market, but also the small augmentation resulting from recent mergers. More important still is the roughly similar level of concentration obtained from the mid-1980s, in European and North American regions of production. Note that the observed increase in North American concentration ratio in the early 1970s, is due to the temporary disappearance of TRW as a prime-contractor for commercial satellites. TRW has more or less concentrated its activities on military contracts, apart

from a few exceptions (TDRSS, for instance), since it was awarded the Intelsat III contract. The launch date version of the Herfindahl index is included in the annex at the end of this chapter. Once again, the discrepancy between award and launch dates cause the higher level of the latter concentration ratio, in the early 1970s in particular.

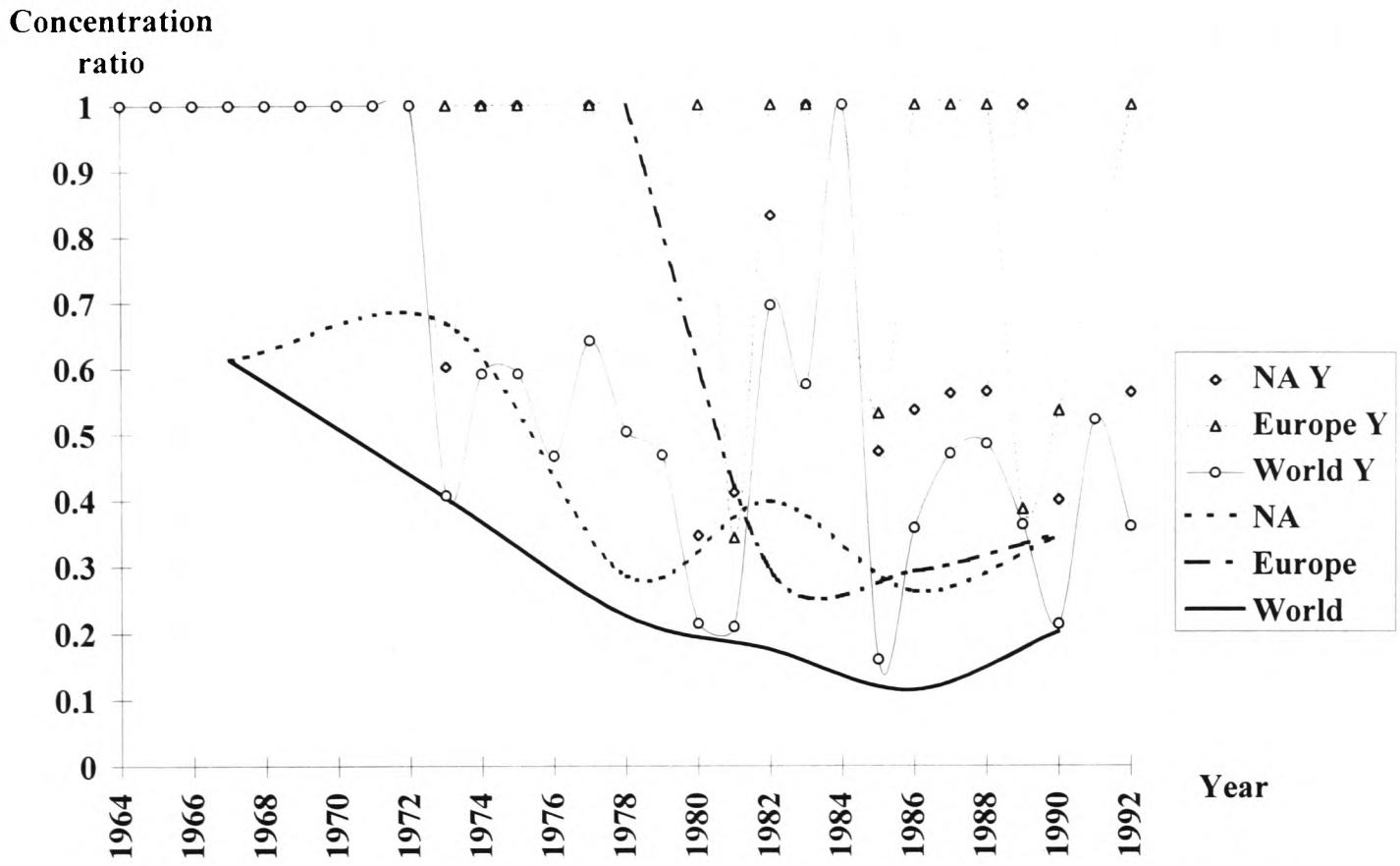


Figure 1.9: Evolution of the Herfindahl index, manufacturers; value of awarded satellites (constant US dollars, 1980 = 100).

1.3.3 Disaggregation by ownership

Different world regions require different satellite services. In this section, we will thus examine various ownership regions in order to determine the potential discrepancies in purchasing behaviour. The same presentation structure used for the disaggregation of vendors applies here: an account of the number of satellites ordered and launched will be presented by region of ownership, then, concentration ratios will be calculated for commercial communication satellite operators.

1.3.3.1 Evolution of satellite ownership

The number of satellites purchased by Intelsat has increased steadily over the years as is portrayed by figure 1.10. Note that the international category includes Inmarsat satellites as well, but since their number is small compared to the Intelsat fleet, it is fair to say that this category represents the evolution of Intelsat spacecraft.

From 1972, the US domestic market picked up, and has increased steadily since, apart from a sharp rise in the first part of the 1980s. Europe's domestic market for commercial communication satellites only started in early 1980s with the Eutelsat program. Before that, European industries concentrated on experimental communication satellites. In the rest of the world, the number of domestic satellites has increased at a slower pace, excluding booms in the first halves of the 1980s and 1990s.

From the point of view of deliveries, or launches, the increase in the number of satellites is more gradual (figure 1.11). The augmentation in spacecraft number corresponding to the early 1980s, is clearly delimited in figure 1.11. This trend was

interrupted by the Challenger accident, which had the consequence to halt all commercial launches using the space shuttle for two years, but picked up at a slower pace in 1988. Indeed, the stagnation in launch numbers is more or less attributable to this tragedy in the case of international, European and US satellites, as during those years, no variation appears in the rate of increase of contracts as shown in figure 1.10.

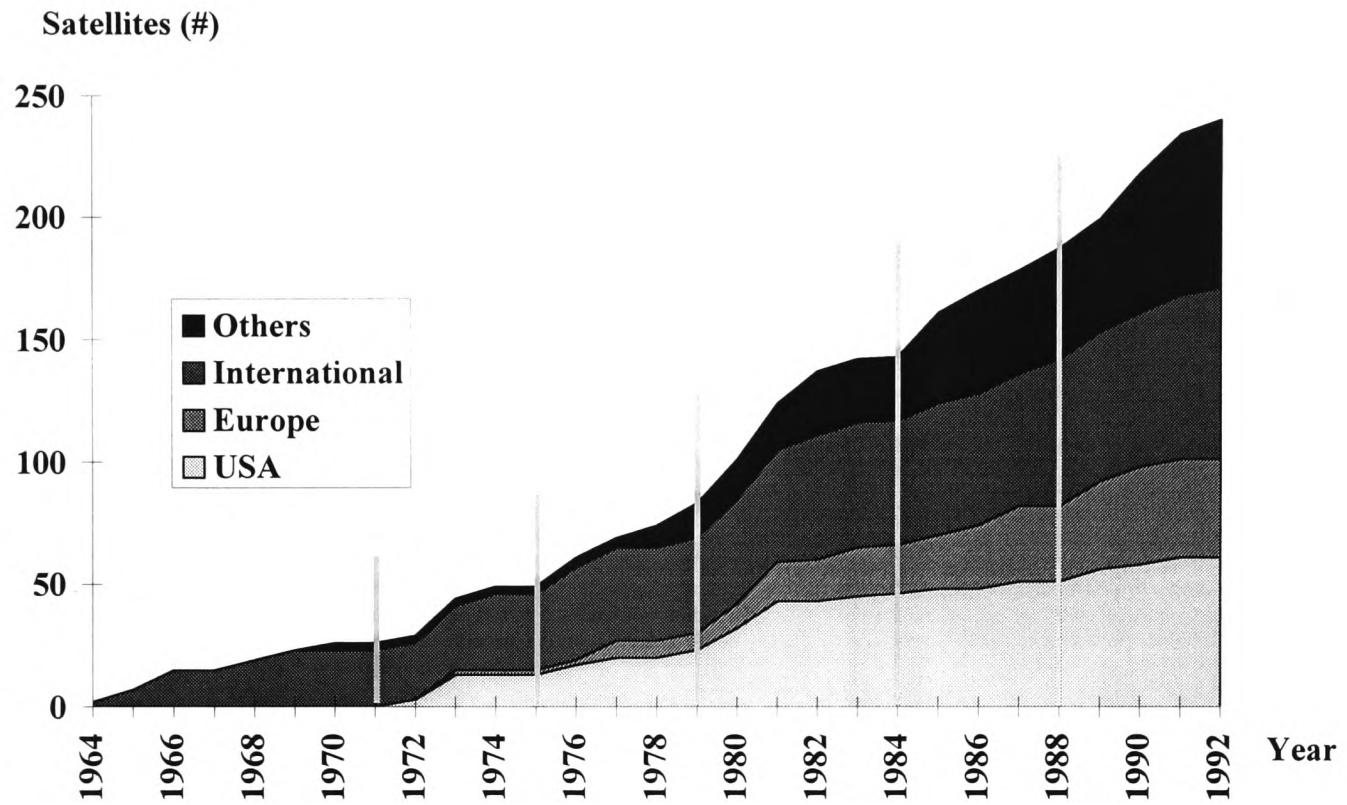


Figure 1.10: Cumulative number of awarded satellites per region of ownership.

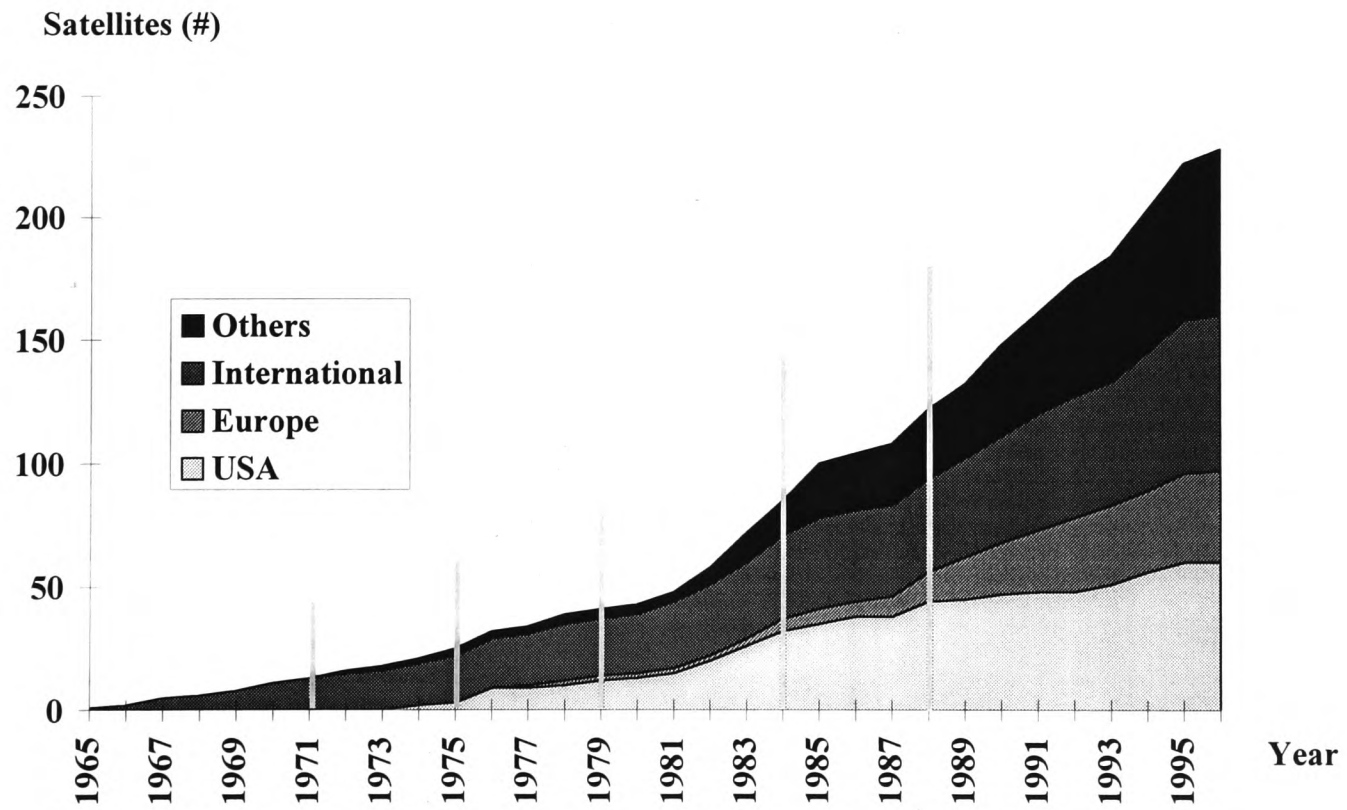


Figure 1.11: Cumulative number of launched satellites per region of ownership.

The situation is more ambiguous in the case of satellites from other countries where the rate of purchase grew to a halt in 1984; the observed stagnation in launches is therefore due to the contribution of both factors: the shuttle accident and the decline in orders prior to the explosion. In the years following this tragedy, the fast increase in

number of satellite launches is mainly due to the expansion of European systems and that of the rest of the world because the number of Intelsat and US domestic satellites increased at a very low pace during that time. A possible explanation for this slow augmentation is the growing competition from fibre optic cables which made their apparition in the US and its surrounding oceans. This created an excess capacity of circuits which forced many US companies to sell their already ordered satellites[44].

Decisions of satellite operators to order new satellites depend essentially on the present and future status of their in-orbit fleet, i.e. the stock of satellites in orbit. Figure 1.12 illustrates the stock of commercial communication satellites over the years. Note that this figure illustrates the stock of satellites according to designed lifetime, the real lifetime being unavailable. Indeed, the real length of life of a satellite may differ from its designed lifetime because of the margin of extra fuel on-board. Moreover, this graph does not take into consideration either satellites that failed or partially failed before the end of their planned life.

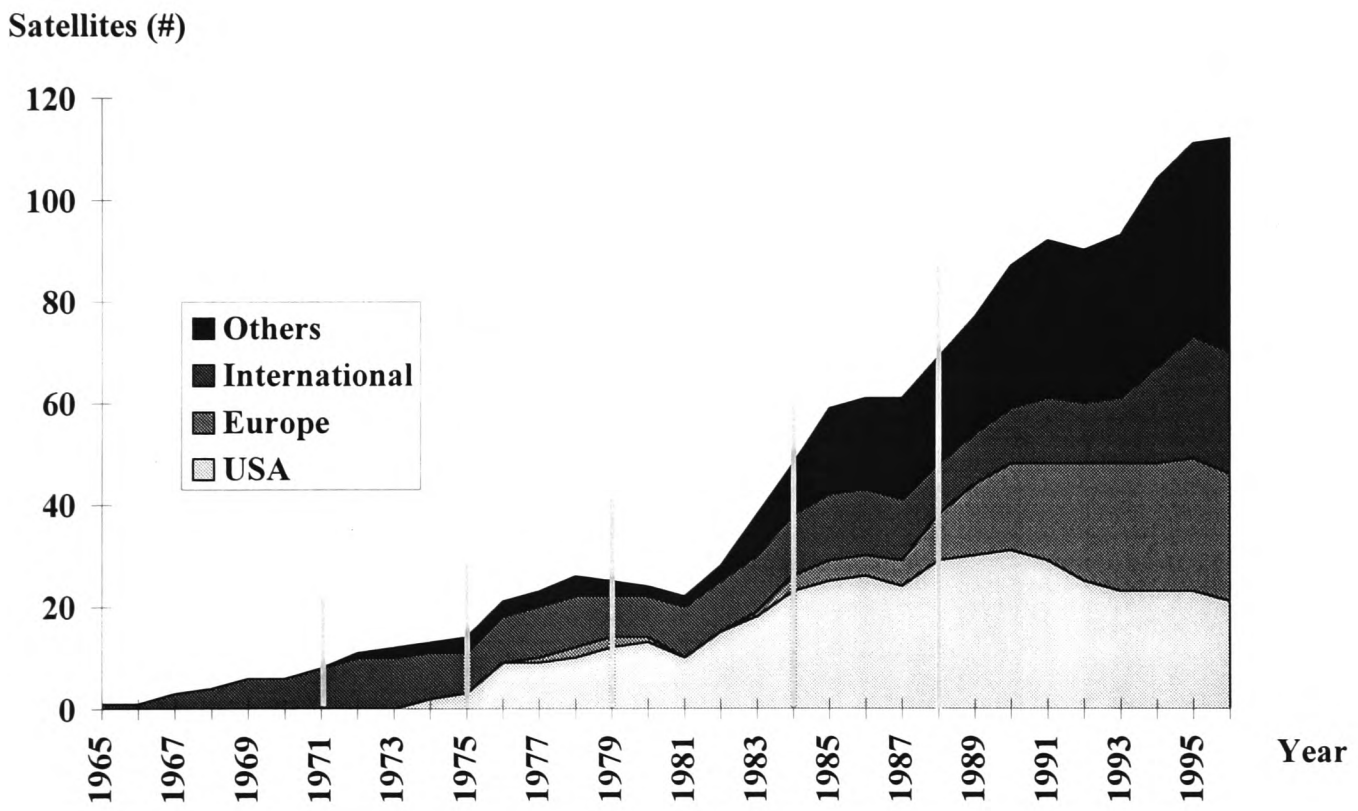


Figure 1.12: Stock of in-orbit satellites by region of ownership; numbers.

From 1973 to 1975, the stock of Intelsat satellites declined, but increased again afterwards to stay more or less constant until a small augmentation in the mid-1980s, and another diminution in the later part of the 1980s. This last decline is probably the consequence of the introduction of submarine fibre optics cables. In the US, the stock of domestic satellites increased more or less steadily until the end of the 1980s and has declined ever since. Ground competition from fibre optics is ferocious in the US and this may be the cause of the decline in US domestic commercial communication satellites. In fact, the United States is the only region where the stock of spacecraft has decreased in the 1990s, all other regions experience a rise in stock at that time. In Europe, the stock of experimental satellites had time to completely die out before the generation of commercial communication satellites following these experiments were launched. Then, the stock increased slowly until 1987, but afterwards, Europe experienced a rapid growth that stabilised around 1993. It is in the

[44] Refer back to section 1.3.2.1 for more details on the satellite second hand market.

rest of the world that the stock of communication satellites augmented the fastest; since the beginning of the 1980s, an increasing number of countries (Brazil, Mexico, India, Hong Kong, Australia, Malaysia, Thailand, Korea and Turkey) have joined the space age, and launched commercial satellites for their domestic communication markets. Many more countries are currently planning domestic systems, such as Argentina, Israel, Iran and Papua New Guinea.

Figure 1.12 represented the evolution of the stock of satellites in terms of numbers in orbit, the value in orbit is illustrated in figure 1.13. Even when measured in constant US dollars (1980 = 100), the value of in-orbit stock increased faster than when measured in numbers. This presupposes an augmentation in the quality of satellites for which customers are willing to pay more. The next chapter will examine the evolution of the technology in an attempt to lay the ground work for the third chapter, which will formally study the relationship between price and quality of commercial communication satellites.

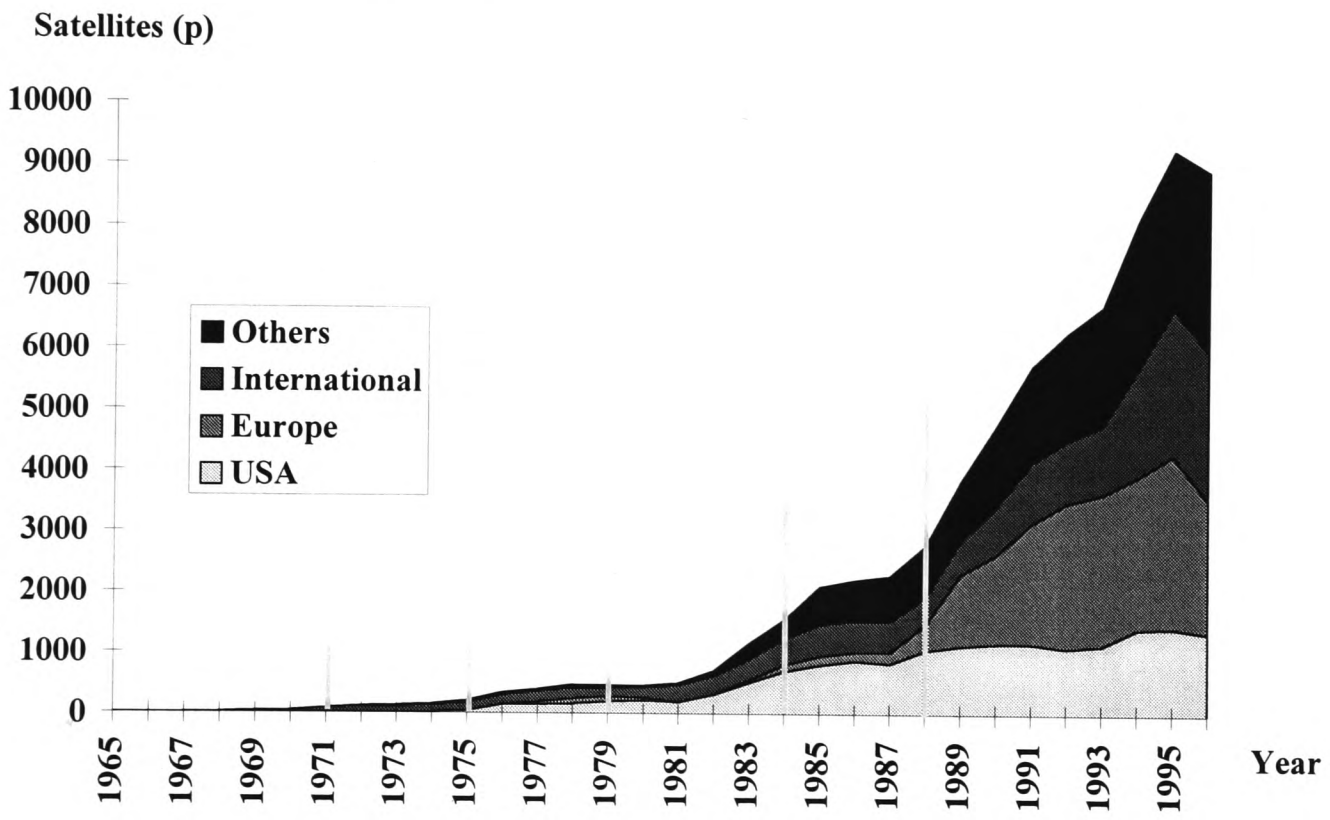


Figure 1.13: Stock of in-orbit commercial communication satellites; value (constant US dollars, 1980 = 100).

The OECD disaggregates customers by the following classification (which differs slightly from the one adopted in this thesis[45]): Governments, Space agencies and Intelsat/Inmarsat/Eutelsat/Arabsat, privately owned partially by governments, independent private companies. As of June 1992, governments and state-owned companies provided 43 % of the orders for commercial satellites to be delivered between 1992-1997, international and regional organisations such as Intelsat, Inmarsat, Eutelsat, and ESA provided another 22 %, 17 % went to companies either owned by space segment suppliers or by companies in which they have significant equity, and finally, the remaining 18 % went to independent private companies (OECD, 1995, p.42). Only around 40 % of the world market for communication satellite hardware is fully competitive. Representing the evolution of this

[45] Only Intelsat and Inmarsat are truly international as they cover most of the globe. For our purposes therefore, Eutelsat and Arabsat are classified in Europe and other countries respectively.

classification of customers would overload this chapter and the reader would not gain much more from it, so it is left out.

1.3.3.2 Concentration of satellite customers/operators

In this section, the same procedure that was used for manufacturers will be applied. In other words, Lorenz curves will be plotted for the number and value of awarded and launched satellites. In addition, the Gini coefficient will be calculated (see figures 1.14 to 1.17).

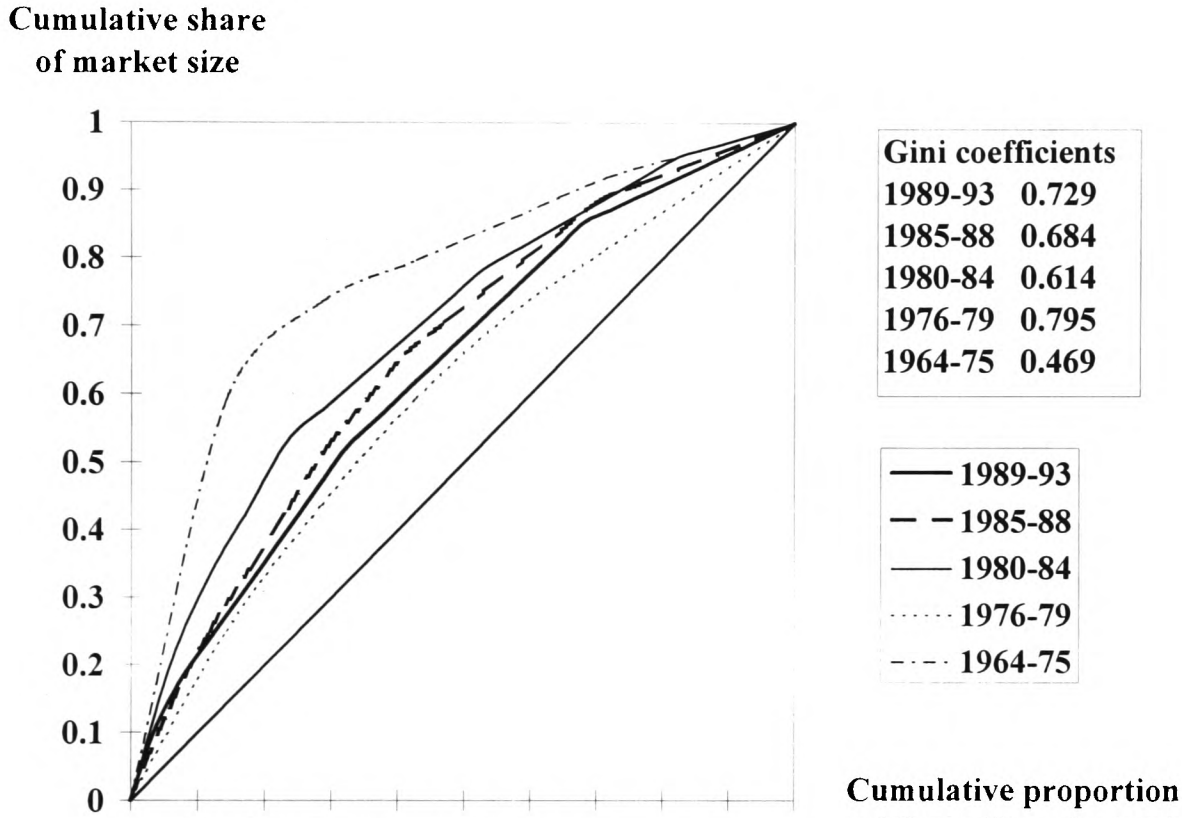


Figure 1.14: Lorenz curve, customers; number of awarded satellites.

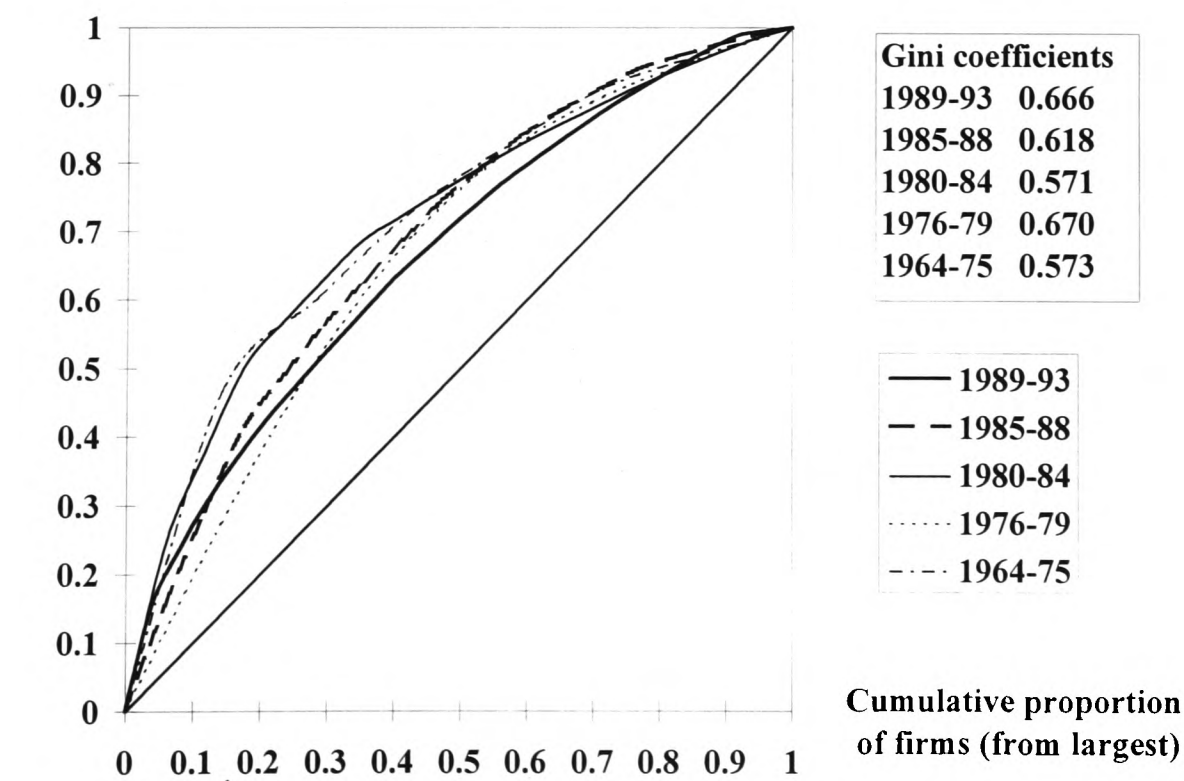


Figure 1.15: Lorenz curve, customers; value of awarded satellites (constant US dollars, 1980 = 100).

In the first sub-period, 1964-75, the most important customer, Intelsat in this case, appears to possess a bigger share in number than in value of satellites. Because Intelsat generally orders many satellites at a time, between 4 and 8 spacecraft per order, this suggests that some economies of scale may be present in this case. The subsequent two graphs, figures 1.16 and 1.17, represent the evolution of the same measure of concentration from the point of view of deliveries.

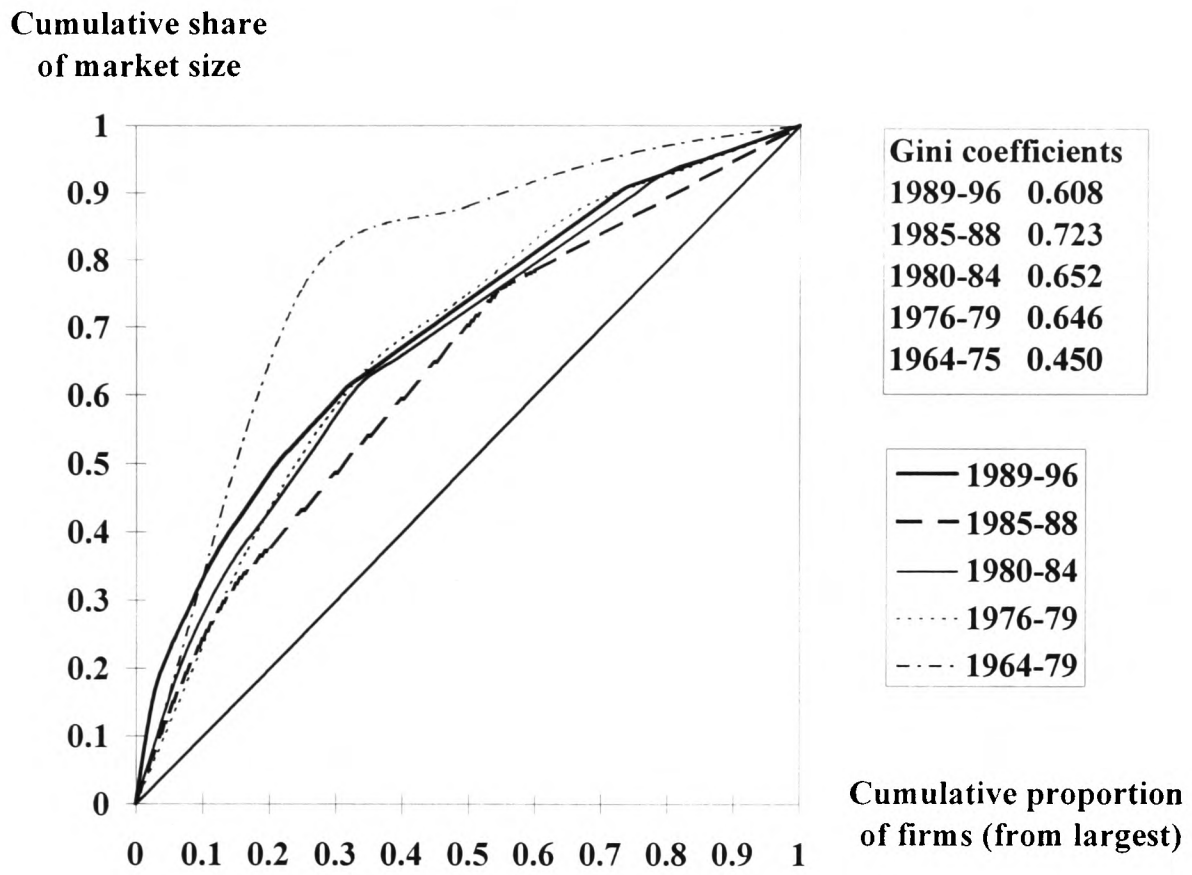


Figure 1.16: Lorenz curve, customers; number of launched satellites.

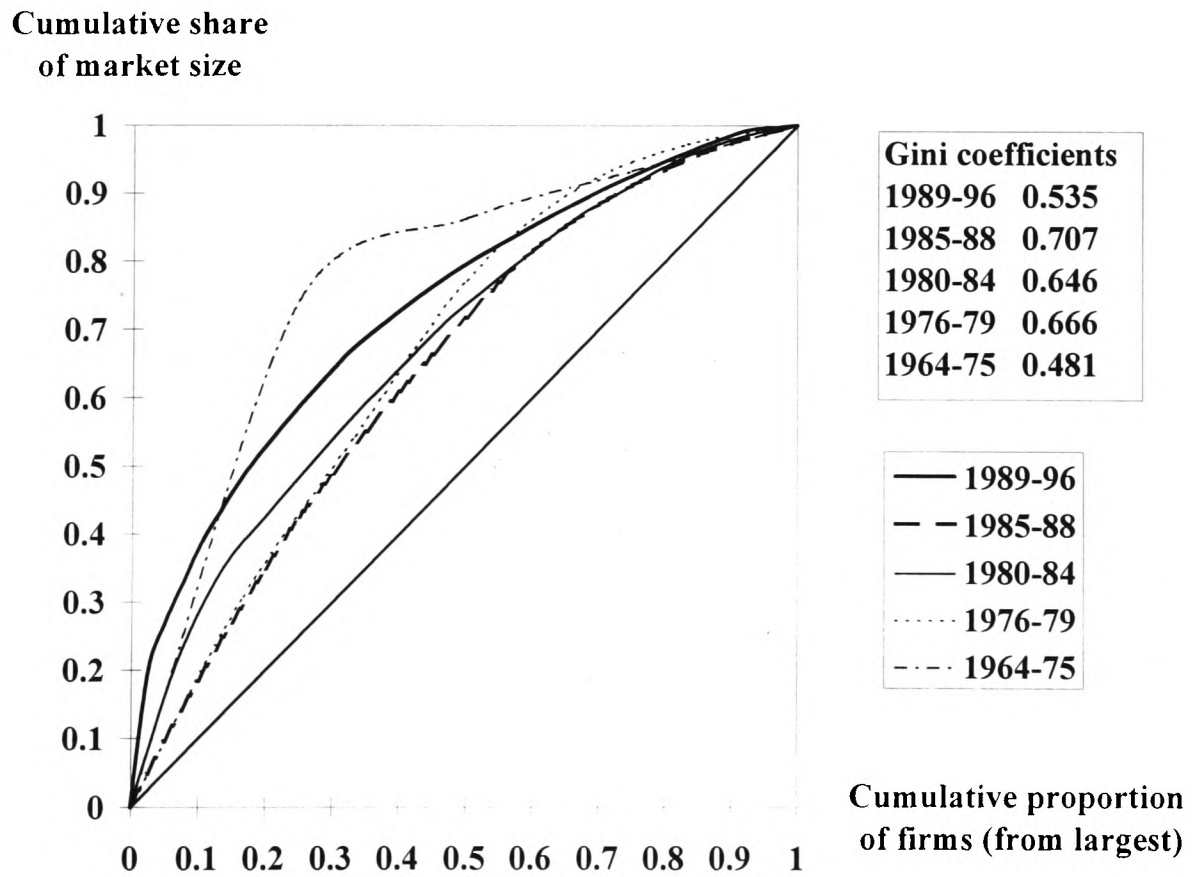


Figure 1.17: Lorenz curve, customers; value of launched satellites (constant US dollars, 1980 = 100).

In the two graphs (figures 1.16 and 1.17) representing launch measures, the sub-period 1985-88 shows the least inequality among satellite operators, while the first sub-period shows the most inequality. As in the case of manufacturers, the two

extremities of the sample have the smallest Gini coefficients, indicating that customers have disproportionate market share. At the beginning of the sample period, the majority of satellites were ordered by Intelsat, which, as described above, generally buys many satellites at a time. Finding a proper explanation as to why the last sub-period presents more inequalities among customers is more puzzling. Possible reasons are that liberalisation in telecommunication services has encouraged not only mergers and acquisitions among satellite operators but also caused failures resulting in firms exiting the market. A more plausible explanation though, relies on fierce competition from alternative technologies that may have caused some communication service providers to invest in fibre optics, rather than satellites, to supply their customers. In addition, although the Gini coefficient is higher for value measures in the first two sample periods, the difference is not as considerable as it was in the case of awarded satellites. The discrepancy between value and number measures being attenuated over the delivery period contradicts the hypothesis of economies of scale previously postulated. Indeed, by measuring concentration ratios in terms of orders concentrates customers into a particular time period while they were present during a longer time. To examine customers in a more detailed fashion would require looking at Lorenz curves measured in terms of the stock of satellites. Unfortunately, we do not possess all the information necessary to perform such a study. It was previously explained that satellites are transferred, leased and sold to other parties in the course of their lives. Although, we have a few examples this 'second-hand' market, the full necessary survey is lacking.

Absolute measures of concentration are presented below as figures 1.18 and 1.19 illustrate the evolution of the concentration indices for ownership of satellites in different regions of the world. The same conventions that applied in section 1.3.2.2 are in use here. International organisations have been omitted from these graphs because only two are present throughout the sample period, Intelsat and Inmarsat.

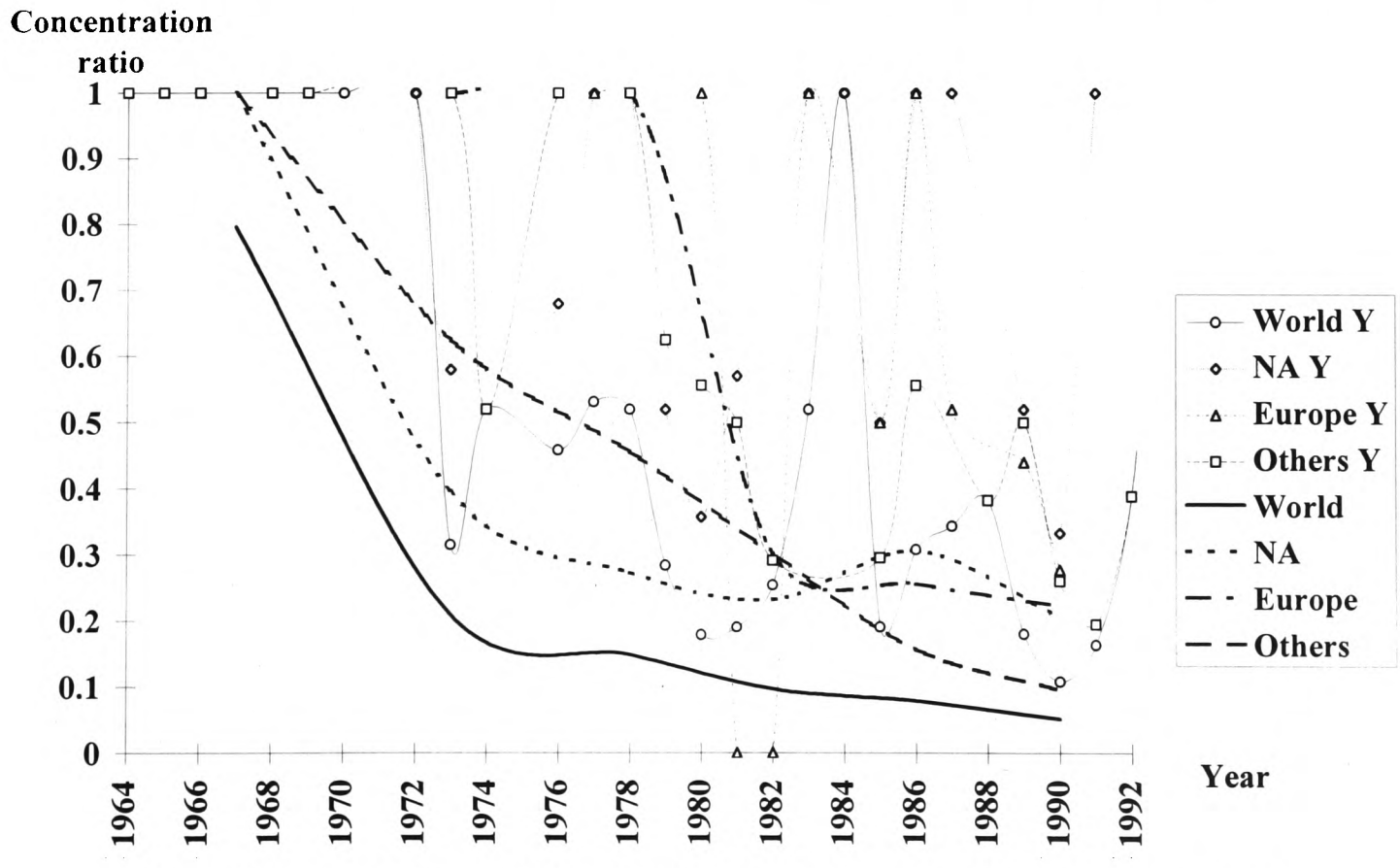


Figure 1.18: Evolution of the Herfindahl index, customers; number of awarded satellites.

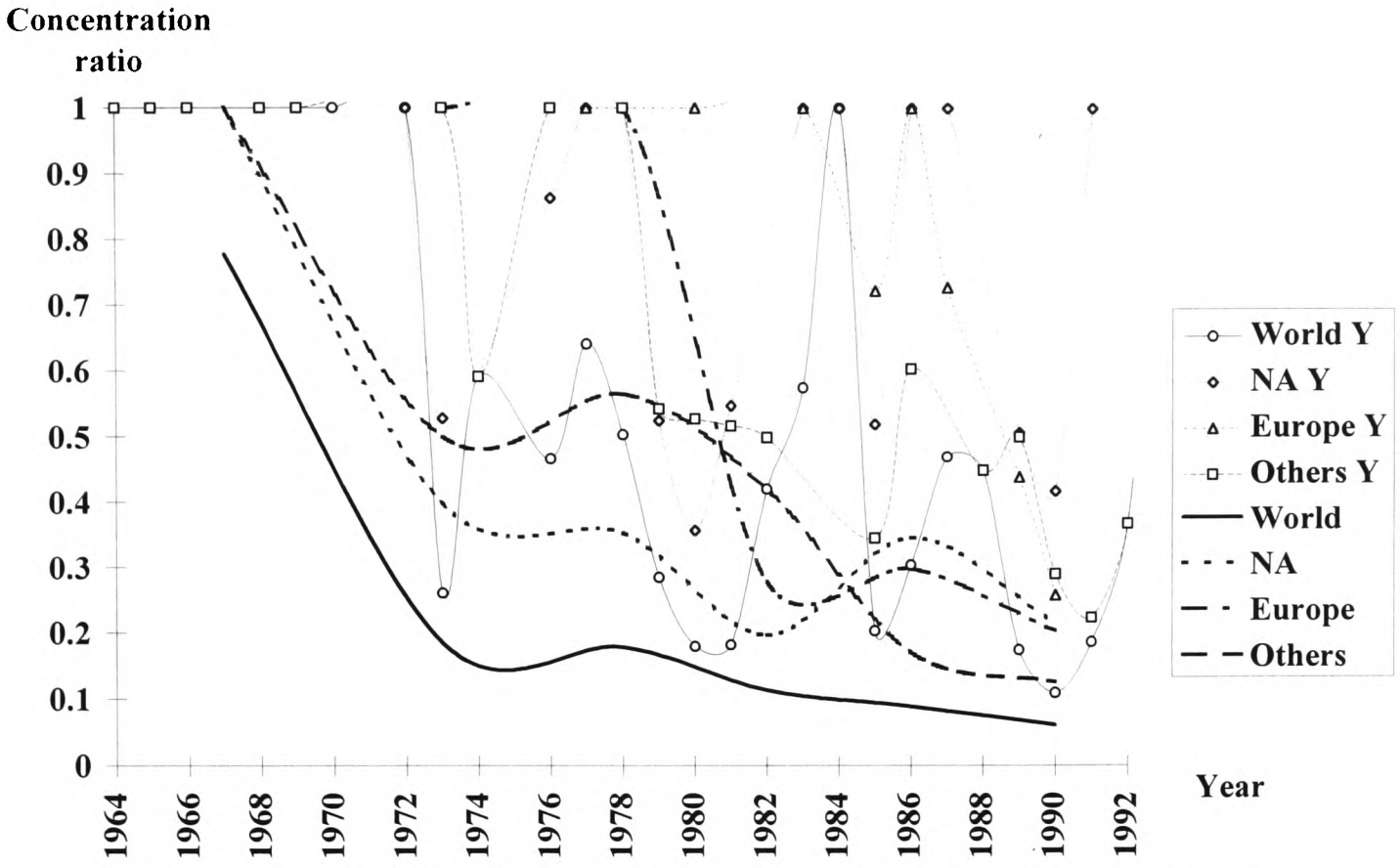


Figure 1.19: Evolution of the Herfindahl index, customers; value of awarded satellites (constant US dollars, 1980 = 100).

Notice that there is a significant difference between the Herfindahl index of other countries customers compared with US and European owners. In the former, the decrease in concentration corresponds to the entry of new countries into the satellite age, while in the two latter regions, there is little geographical area not already covered by satellites. In other words, entry of domestic satellite operators is much more difficult in well-established communication service markets such as the US and European markets, whereas it is relatively easy in virgin territories, where communication systems are provided solely by Intelsat that is. Graphs depicting the same evolution of the concentration indices but from the view point of launch dates are included in the annex to this chapter.

1.3.4 Other measures of the evolution of supply of satellites

In previous sections, satellite industry growth has been measured by number of satellites ordered or launched. But the evolution of the number of satellites through out the years may not be the best measure to assess supply and demand changes. As the number of transponders per satellite varies with various satellite designs, and increases with time, circuit capacity augments as well. A potentially better measure of demand change may thus be the number of transponders itself (figure 1.20). The capacity of each satellite is essential in the assessment of its revenue, but the problem is how to compare capacity over the entire era.

Again, using the number of transponders as a measure of capacity may not be as accurate as expected, because the characteristics of transponders vary even within the same satellite. Satellite operators charge steeper tariffs for transponders with higher radiated power as it is expected that broadcasting satellites with a greater radiated power reach a greater number of potential customers in a larger area, thus possibly generating more revenue (OECD, 1995). Figure 1.21 therefore represents a third attempt at measuring the evolution of demand using total bandwidth. This

bandwidth measure is the most accurate measure of supply so far, but again, this type of measure has its flaws.

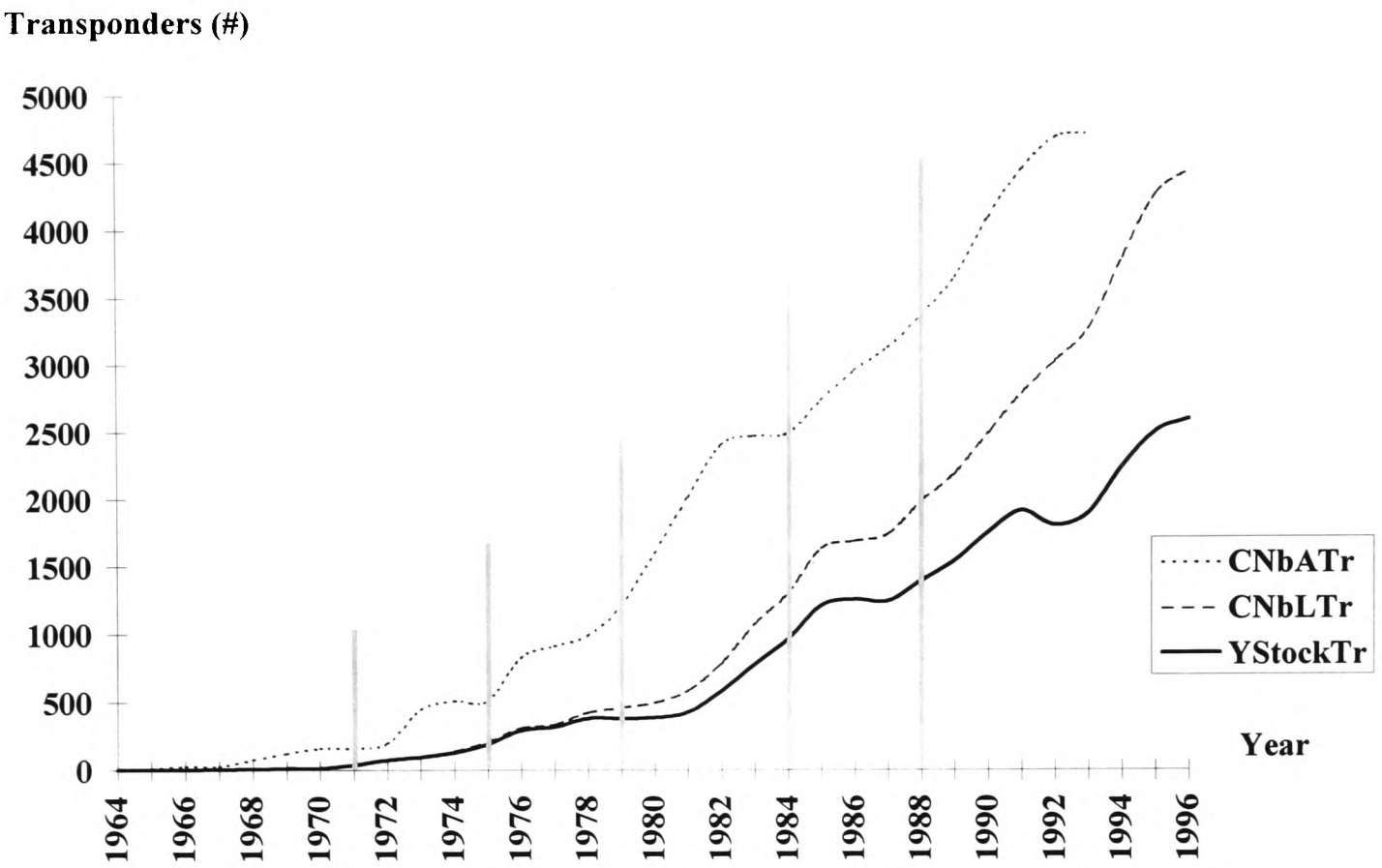


Figure 1.20: Stock of capacity (solid line) and cumulative quantity of ordered (dotted line) of launched (dashed line) capacity; number of transponders.

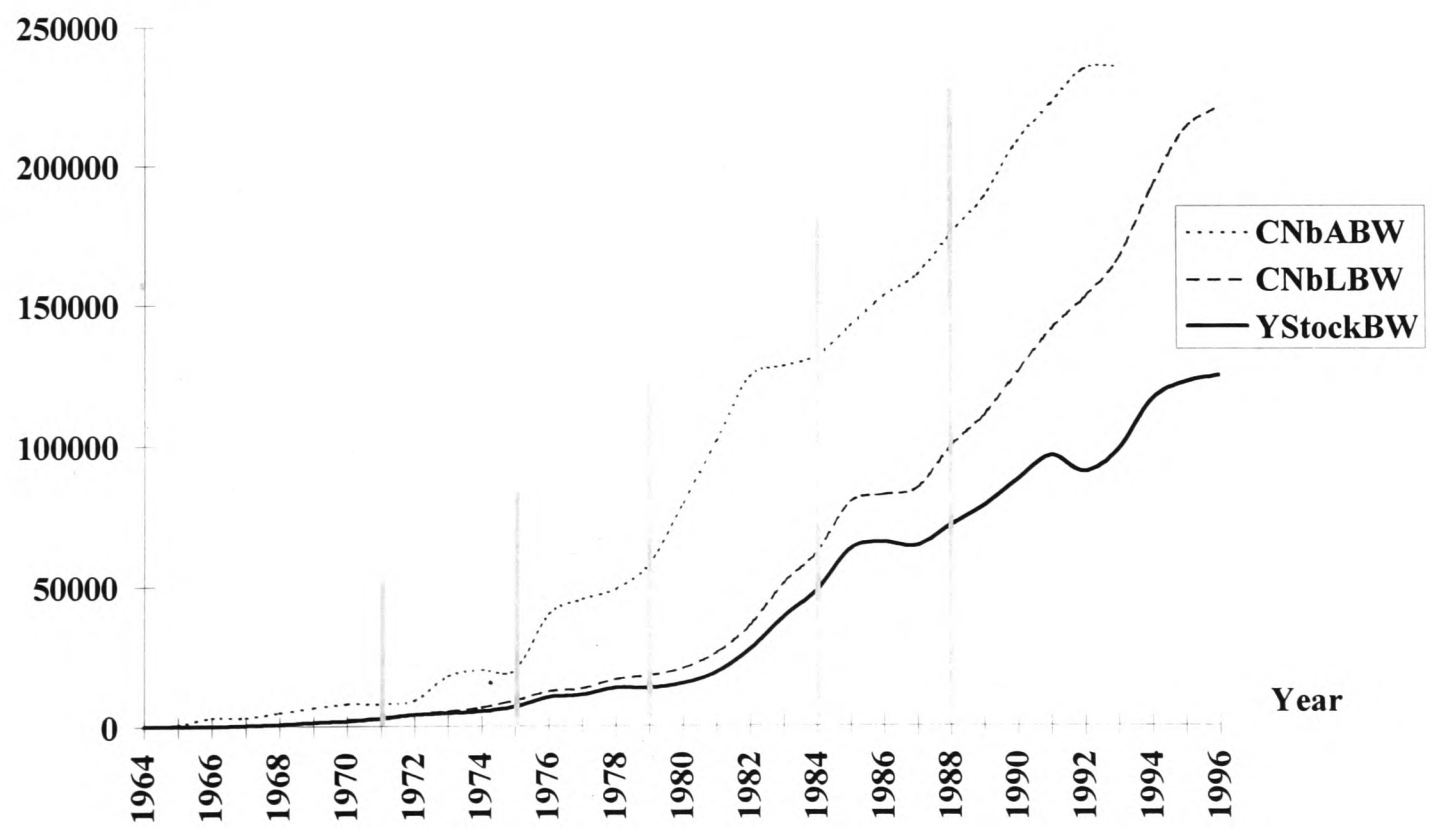


Figure 1.21: Stock of capacity (solid line) and cumulative quantity of ordered (dotted line) and of launched (dashed line) capacity; total bandwidth.

The measure of system capacity using bandwidth may become increasingly invalid as different compression and other frequency re-use techniques modify the 'effective' or usable satellite capacity. One thing is certain though, the cycles identified before are more apparent when bandwidth capacity measures are used.

1.4 Conclusion

In the first part of the chapter, three different players involved in the commercial communication satellite industry were distinguished: manufacturers, launchers and customers. The launch aspect of this industry was shown to be exogenous, mainly because launch prices are determined by 70 % of non-commercial activities. Over the years, not only did the number of firms involved on both supply or demand sides increase, but so did the degree of integration, both vertical and horizontal, of this civil telecommunication and broadcasting satellite industry. A parallel was drawn between the spacecraft and aircraft industries in terms of the reasons for this increased integration. Reducing the risks and fixed costs incurred in both industries were the major factors outlined. Subsequent to this description of the players, the transaction mechanism particular to this industry was explained: first-price sealed-bid auctions. Satellite production contracts are characterised by risk-sharing from both vendor and buyer; incentive contracts are employed to spread the risks involved in spacecraft operation. A second mechanism utilised by both satellite suppliers and purchasers to protect themselves from the uncertainties of satellite business, are insurance policies. Launch, initial operations and in-orbit insurance are the three main types of security provided to customers (who use all three) and manufacturers (who use the last two only). Furthermore, satellite builders must also ensure that their product is competitive compared with alternative technologies such as cables and fibre optics.

After this description of the interaction between spacecraft buyers and suppliers, the second part of the chapter examined the growth of various telecommunication and broadcasting indicators related to satellite services. It was discovered that some countries, mainly the western world, implemented a full scale telecommunication infrastructure earlier and have maintained a slower growth in main lines, for instance, than countries which adopted the technology at a later date. Moreover, some similarities between late adopters of satellite technology have been found with respect to their telecommunication infrastructure before they ordered their domestic satellites. This is the case for Korea and Malaysia, for instance. Further, the geographical structure of some countries, such as Canada and the US, have been put forward as the reason for the spread of cable television services provided by satellite feeds to regional networks, and the consequent slowness of these countries to adopt direct-to-home satellite television services, compared with the UK and Germany, which are more densely populated, and possess a greater proportion of households equipped with satellite dishes.

The third and final part of the chapter concentrated on the product, commercial communication satellites, and its temporal evolution of quantity purchased. The growth of satellite numbers was examined for the period 1964 to 1992, and six sub-periods were identified from the change in the flow of orders. Stagnation and decline in the number of orders were the two main identifiers of these cycle boundaries. A significant difference between the number of satellites ordered from North American and European manufacturers was noticed, the former having built around three quarters of the total number of spacecraft included in this study. Over time, however, North American satellite producers saw their market share decline mostly to the benefit of European builders. Following entry from various satellite vendors, concentration in the manufacturing sector of the space industry has diminished until recently, when restructuring and the tendency towards mergers and

acquisitions has increased the concentration ratio. From the point of view of customers and satellite operators, the US has suffered the most since the introduction of high capacity fibre optic networks. For all other regions of customers, Europe, international organisations and other countries, the number of satellites ordered has increased almost steadily. In the satellite operators industry, concentration has decreased everywhere, except in the US. Indeed, in the US, too many small satellite service providers entered the market but were then taken-over by more efficient companies.

This first chapter summarised the evolution of the market as far as satellite numbers are concerned. In a last section of the chapter, growth of alternative measures of capacity, number of transponders and total bandwidth, have been examined. It was discovered that such measures accentuate the separation into cycles noted earlier, but because of the change in technology, still do not present a complete picture of the evolution of the commercial communication satellite industry. These satellites have changed over time, like the production of automobiles at the time of Henry Ford to today. Before going further in our analysis of the communication satellite industry, we need to understand the satellite in itself, what are its functions and characteristics, and how it is built. The second chapter concentrates on the technical aspect of the commercial communication satellite industry, and provides insights on the change in communication satellite technology.

Annex 1.1 Concentration ratios

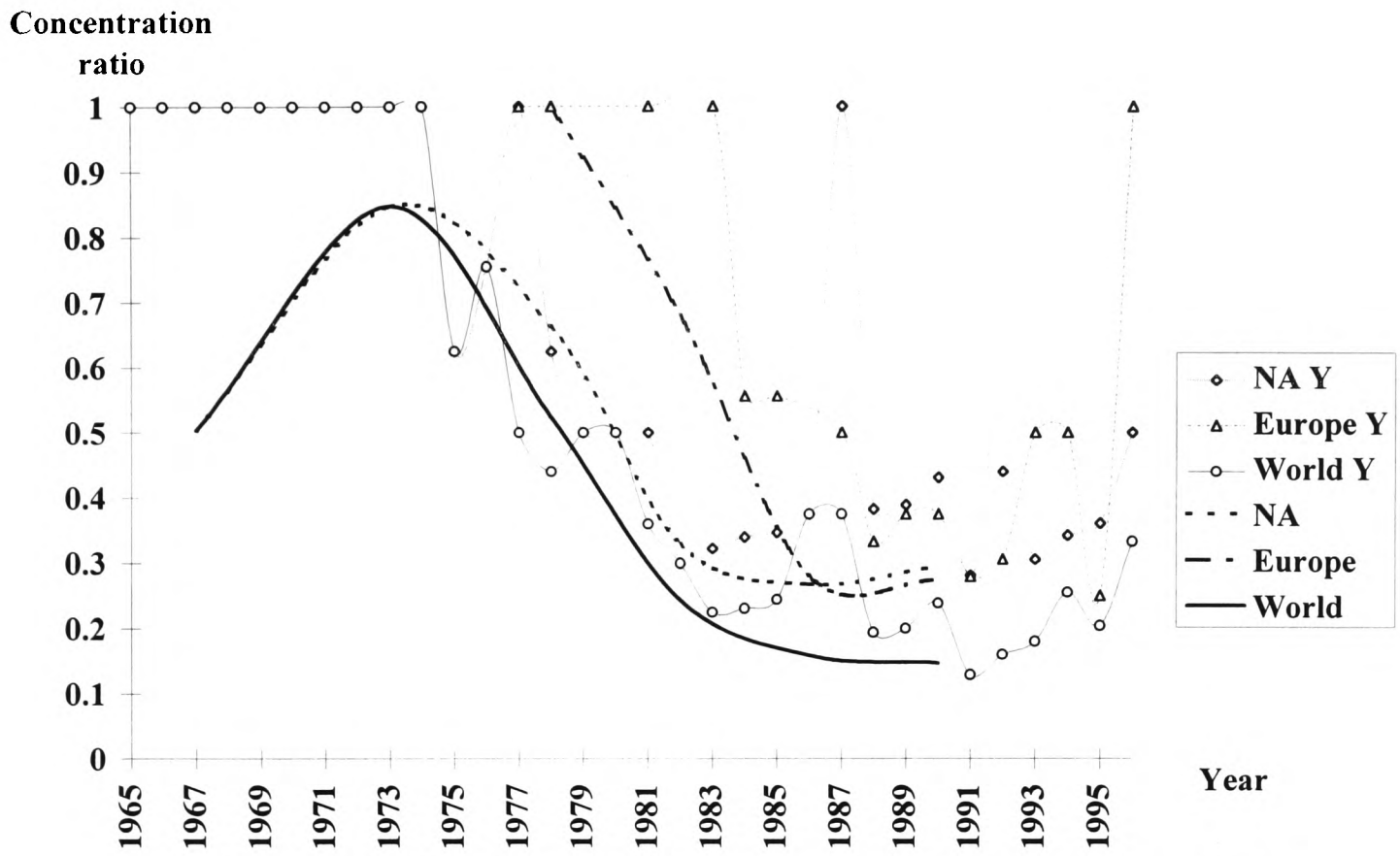


Figure 1.i: Evolution of the Herfindahl index, manufacturers; number of launched satellites.

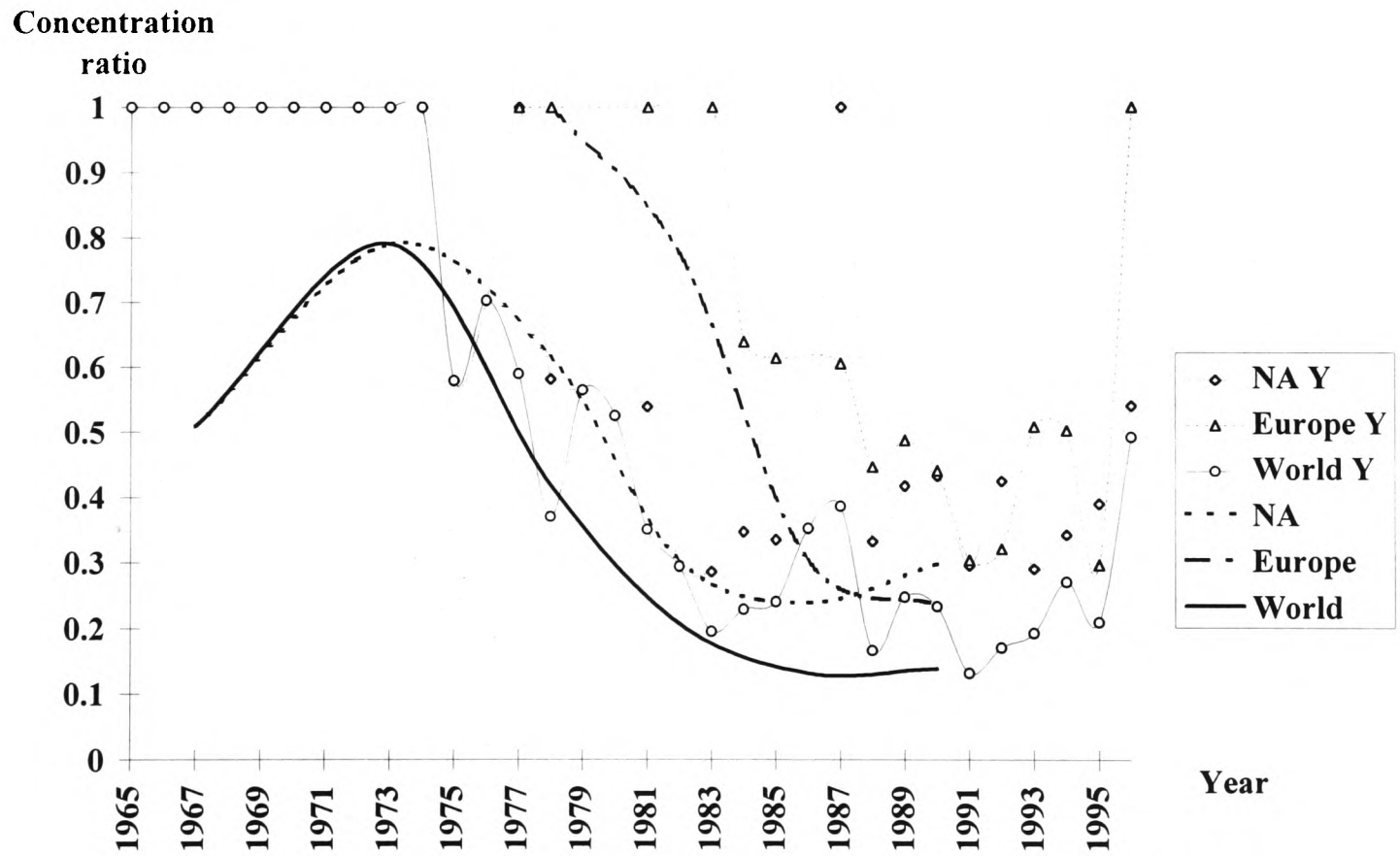


Figure 1.ii: Evolution of the Herfindahl index, manufacturers; value of launched satellites (constant US dollars, 1980 = 100).

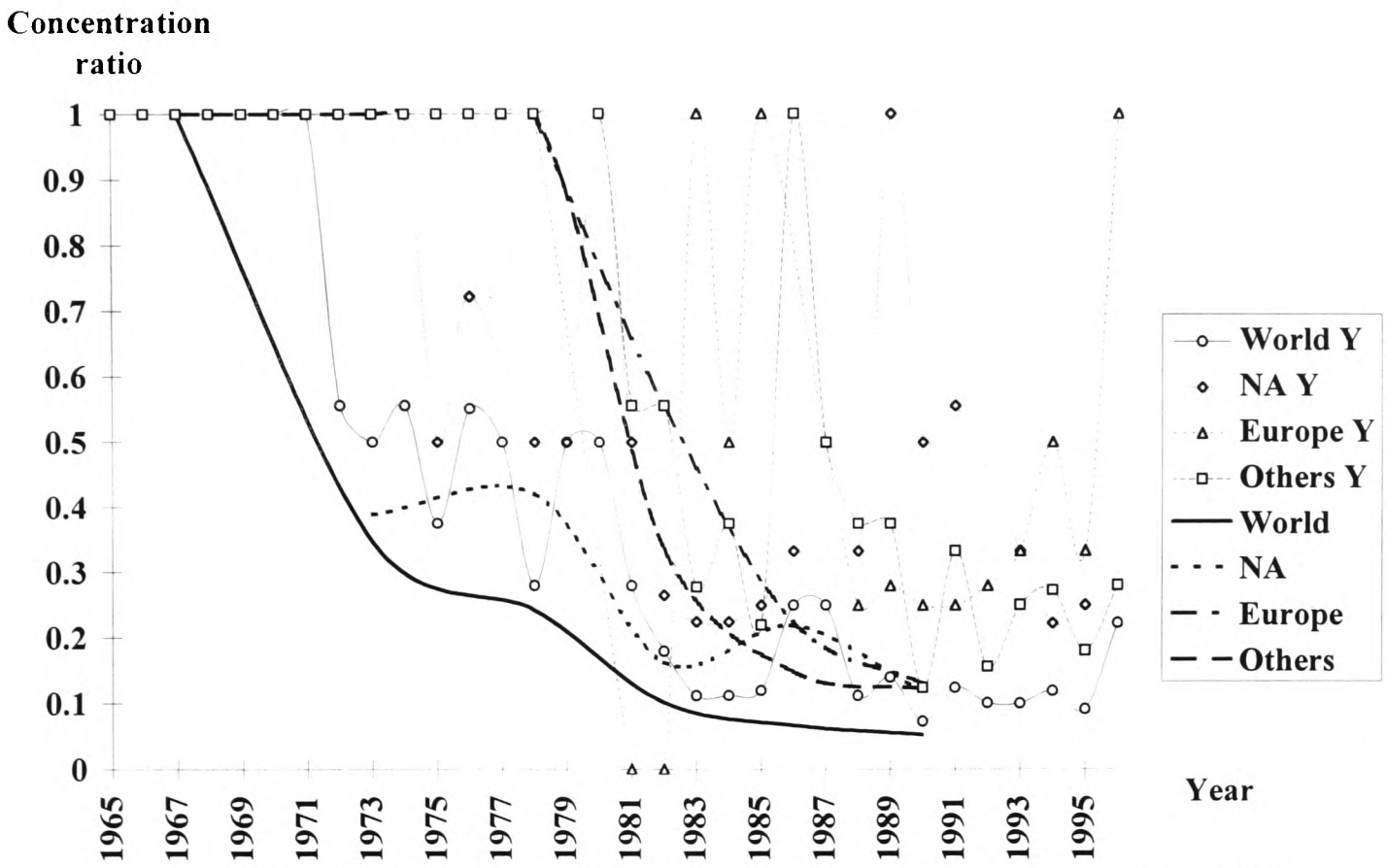


Figure 1.iii: Evolution of the Herfindahl index, customers; number of launched satellites.

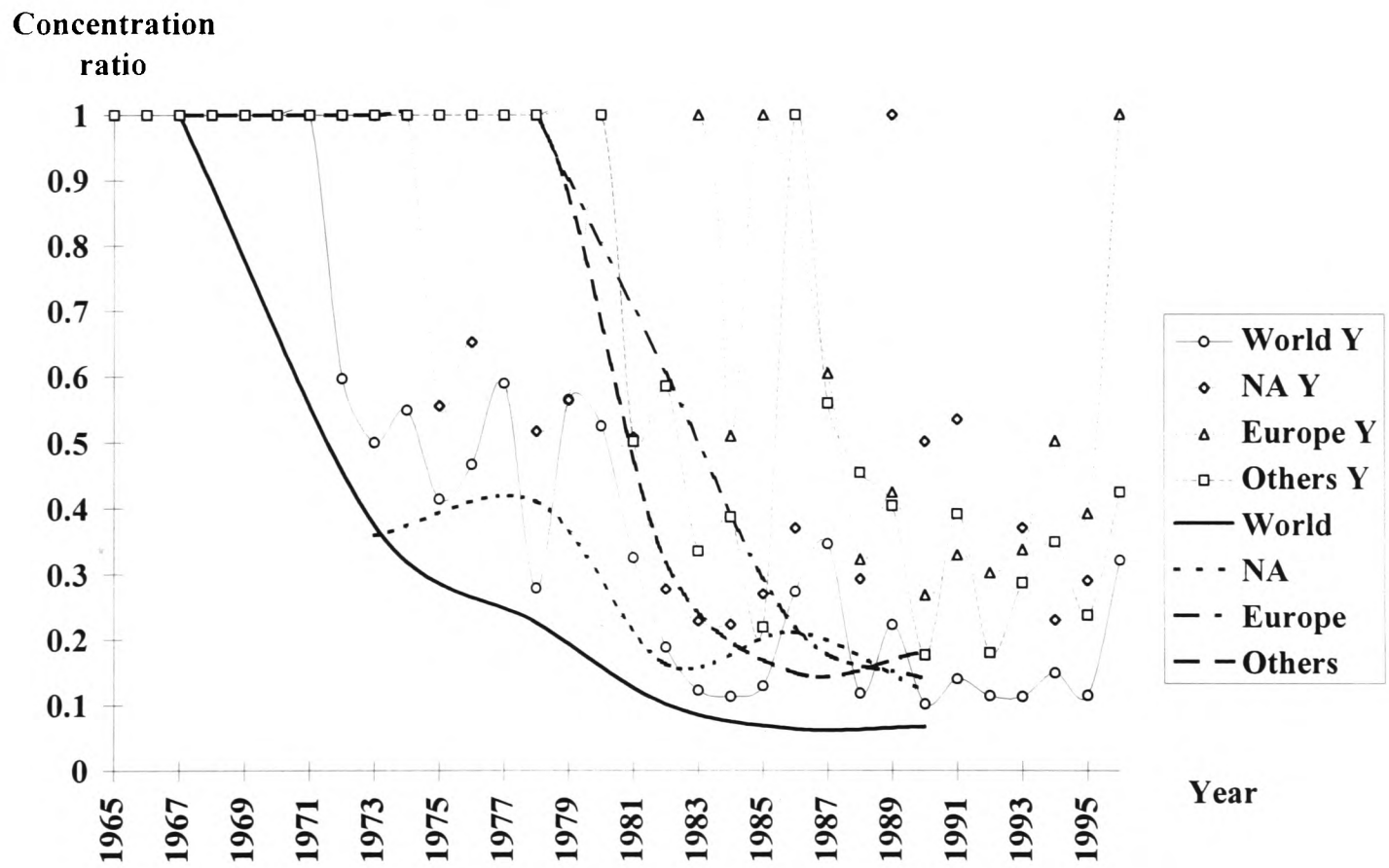


Figure 1.iv: Evolution of the Herfindahl index, customers; value of launched satellites (constant US dollars, 1980 = 100).

Chapter 2

Nature of the communication satellite technology

2.1 ARCHITECTURE OF A COMMUNICATION SATELLITE SYSTEM 62
2.1.1 Components of satellites 63
2.1.1.1 Organisation of the telecommunication payload 63
2.1.1.2 Organisation of the telecommunication platform 65
2.1.2 An elementary course in satellite design for economists 67
2.1.2.1 Exogenous characteristics 68
2.1.2.2 Design trade-offs 68
2.2 EVOLUTION OF TELECOMMUNICATION SATELLITES 70
2.2.1 The data 70
2.2.2 From characteristics to variables 71
2.2.3 Descriptive statistics 74
2.2.3.1 Basic statistics for the entire industry 74
2.2.3.2 Supply-side fragmentation of basic statistics 77
2.2.3.3 Demand-side disaggregation of basic statistics 79
2.2.4 Evolution of satellite characteristics 81
2.2.4.1 Evolution of frequency bands 82
2.2.4.2 Evolution of capacity 82
2.2.4.3 Evolution of power 84
2.2.4.4 Evolution of signal quality 87
2.3 THREE GENERATIONS OF COMMERCIAL COMMUNICATION SATELLITES 89
2.4 CONJECTURE ON THE ECONOMIC SIGNIFICANCE OF THE VARIABLES 91
2.5 CONCLUSION 92

2. Nature of the communication satellite technology

In the first chapter, the study of the temporal evolution of the number and capacity of commercial communication satellites led us to believe that the change in capacity over time was partly due to the evolution of demand for telecommunication and broadcasting services, but also attributable to the change in technology of the extremely complex good that the satellite is. While the change in demand will be examined in a fifth chapter, this second chapter attempts to give an explanation of the different satellite functions and components that affect the need for these satellites. Like most high technology fields, the number and high level of constraints that characterise space programs lead to specific technical solutions that are expensive. Furthermore, in the case of complex goods such as communication satellites, it is very difficult to understand the supply and demand of the product without prior knowledge of the nature of that product. From nature of the satellite, we imply its functions and the means to achieve them. Price or cost loading only become intelligible when the characteristics of technology are understood. This high technology environment justifies studying the evolution of the communication satellite technology. One of the main purposes of this chapter is concerned with transforming satellite technology into quantifiable characteristics. A secondary aspiration is to investigate a technological basis for the periodisation of the industry.

For the majority of people, the function of a communication satellite is a very vague concept. Moreover, the main constituents of a communication satellite and the way they achieve their functions are even more obscure. An essential part of the economic study of high technology products requires a basic understanding of the technology intrinsic to the good. Not only is the basic science involved important, but so are the production mechanisms of the various components and the role of this complex product in the communication network. Questions crucial to the present study are: are there exogenous specifications that engineers must absolutely respect in designing specific satellites, and if so, what are the characteristics that they can vary in order to achieve these levels of specification? Understanding the design compromises that engineers must achieve in order to respect the specifications given by customers is one of the keys to understand the evolution of communication satellite technology.

A quantitative description of satellite technology is more appropriate for empirical studies and economists will want to transform these characteristics into something a bit more palatable to the average computer. In the first chapter, differences in the production and operation of commercial communication satellite markets across various regions were discovered. Are these idiosyncrasies also noticeable in terms of the technology used in these regions? The chapter will show that satellites possess on average different characteristics according to the region of ownership and manufacturing. Furthermore, these characteristics have considerably evolved over time. One remaining question that economists may ask is whether the technology exhibits a continuous or vintage-type evolution. The temporal evolution of characteristics will justify the separation of these satellites into generations depending on their characteristics and production periods.

The chapter will proceed in the following manner. The chapter begins with a brief explanation of the role of the satellite within the communication network and a description of the two fundamental parts of a satellite, the payload and platform, as well as their respective functions. Then follows a short course in satellite design for economists which focuses on the design compromises that engineers encounter in the development of a spacecraft. The second part of the chapter concentrates on the quantifiable characteristics of these satellites and presents the variables that will be used in the analysis of commercial communication satellite prices (see chapter 3). Subsequently, an account of the technical characteristics corresponding to the main satellite subsystems is presented. A third part justifies the separation of these satellites into generations depending on their characteristics and production periods. And the final section postulates a conjecture on the economic significance of satellite characteristics.

2.1 Architecture of a communication satellite system

A communication satellite system is generally composed of a ground segment and a space segment. The ground segment consists of all the earth stations utilised for telecommunication. These earth stations are habitually connected to the end-user's equipment by a terrestrial network. But in the case of small stations, earth stations are directly connected to the end-user's equipment (e.g. direct broadcasting satellite services, DBS). Together with the necessary terrestrial facilities for its control and monitoring, the satellite composes the space segment. Territorial facilities include telemetry, tracking and command (TT&C)[1] stations as well as the satellite control centre, where all operations related with maintaining the appropriate orbit (station-keeping) and checking the vital functions of the satellite are performed. Figure 2.1 illustrates the various components of such a communication satellite system. The objective of this section is to explain briefly the technical information used in this thesis.

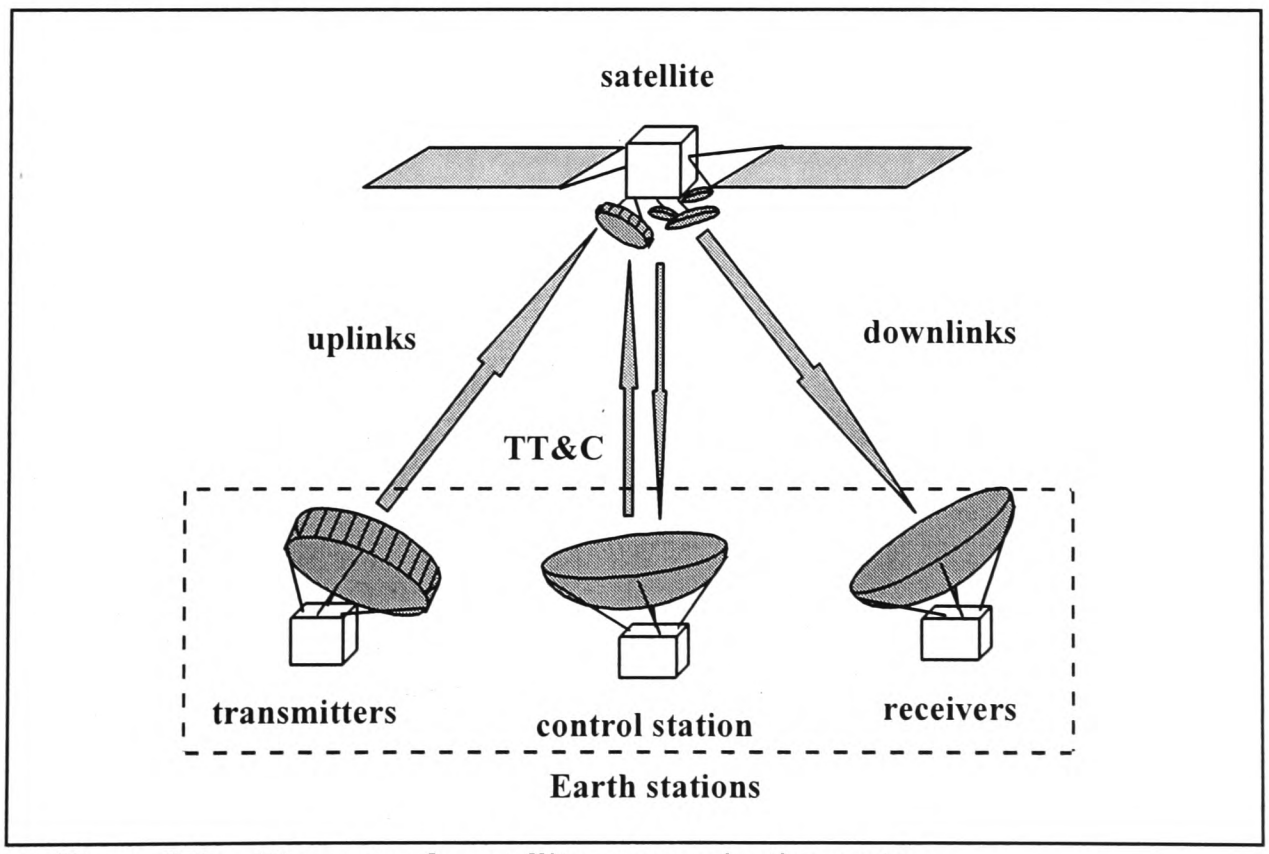


Figure 2.1: Elements of a satellite communication system.

[1] All subsystems will be described in section 2.1.1.

2.1.1 Components of satellites

A satellite consists of a payload and a platform. The payload is composed of the receiving and transmitting antennas, as well as all the electronic equipment which supports the transmission of signals, mainly the transponders. Also known as the spacecraft bus, the platform provides all necessary support for the operation of the payload: supports the payload mass; provides electrical power, commands and telemetry; puts and keeps the payload in its assigned orbit and points it correctly; and finally, maintains the payload at the right temperature. The principal subsystems of the platform are the following:

- structure;
- power supply;
- attitude determination and control;
- telemetry, tracking and command;
- propulsion;
- thermal control.

The next two sections will describe the main constituents of the payload and platform in details.

2.1.1.1 Organisation of the telecommunication payload

The payload of the satellite has two main functions: frequency conversion and amplification. To avoid interference from its transmitted signal, the satellite changes the frequency of the carrier (which carries the signal) received from earth.[2] Once the frequency has been converted, the transponder amplifies the received carriers for retransmission to earth. As mentioned above, the telecommunication payload is composed of the receiving antenna(s), the transponders, and the transmitting antenna(s). This is a relatively simplistic view of the payload as there are a greater number of transponders than antennas. The entire frequency band allocated to the telecommunication satellite system is divided into smaller bands, which are filtered and directed to their allocated amplifier to be amplified before being recombined, and finally retransmitted to earth. A repeater, or transponder, generally consists of three main elements: receiver, amplifier, and transmitter, as illustrated in figure 2.2.

High power amplification and transmission are often combined, but to avoid confusion, they will be presented separately. A transponder must provide frequency conversion, high amplification with low noise and high output power over a wide frequency band. The receiving part of the repeater generally filters the noise from the signal received, then converts the frequency of the carrier before it is amplified by the high power amplifier. In a transponder, input stages operate on the entire frequency band; Several carriers share this frequency band and will thus give rise to inter-modulation noise as they are amplified. Hence, the system's frequency band is divided into several sub-bands, or channels, which are amplified separately. With

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[2] As the signal is transmitted through the atmosphere, it is attenuated by gaseous components in water, the troposphere and ionosphere. Attenuation becomes more important as the frequency increases and the signal required must be more powerful to reach its destination. This is the reason the up-link frequency is higher than the down-link frequency.

channelisation, the power used per carrier is greater and thus the total power transmitted by the repeater is increased. Intelsat IV was the first satellite family to introduced channelised repeaters and to introduce the concept of transponder. After the amplifying stage, the channels are recombined in the transmitter part of the transponder, and the harmonics, created by non-linearity in the amplification, are filtered out to transmit the 'purest' signal back to earth. If this seems too complicated, the following paragraph makes an analogy with goods transported by train to France via the Eurotunnel.

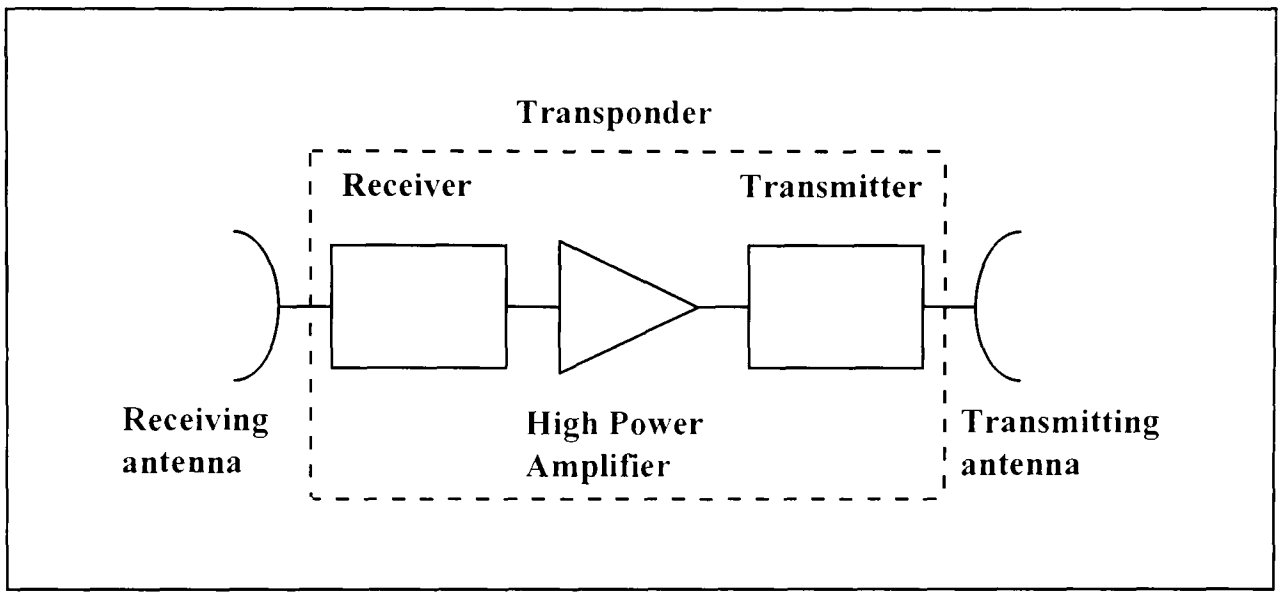


Figure 2.2: Components of the payload.

As an analogy to the signal travelling through space, imagine that the entire frequency band is a train divided into wagons (smaller frequency bands), and that each wagon acts as a carrier or a container filled with signals. Through a controller's actions, the train is directed to the entrance of the Eurotunnel, *i.e.* the receiving part of the payload, receiving antenna and receiver. Before entering the tunnel, the wagons must be separated and their containers put onto the shuttle; This is usually referred to as the channelisation of the signal. As the signals are amplified in the transponder, a custom tax is imposed on the products to be delivered in France. Once in France, assuming here that the British and French rail network are completely incompatible, the containers must be reloaded on different wagons (different frequencies), and the train reformed (the signals transmitted back to earth), which is the action of the transmission equipment, the transmitter and transmitting antenna.

Once the satellite has processed incoming signals, where they will be received back on earth is the next concern. The geographical coverage (see figure 2.3) of the satellite is determined by the satellite communication mission and is measured in terms of radio-frequency objectives such as the effective isotropic radiated power (EIRP). By definition, the EIRP is the measurement of the power that is radiated by the antenna and is the product of the power fed to the antenna (transmission power, P_T), roughly similar to that of the high power amplifier in most cases, and the transmission gain of the antenna (G_T):

$$EIRP = P_T G_T \tag{2.1}$$

As the transmission gain of an antenna is proportional to its aperture size: the larger the antenna, the larger the gain, the more focused it is (narrow beam width) and thus the larger is the EIRP. As a consequence, the footprint of the satellite, as illustrated in figure 2.3 is established by the minimum EIRP acceptable for a type of terrestrial receiver. Basically, the further away from the centre of the footprint the

ground station is, the smaller is the EIRP, and the larger must the terrestrial antenna needed be for accurate reception.

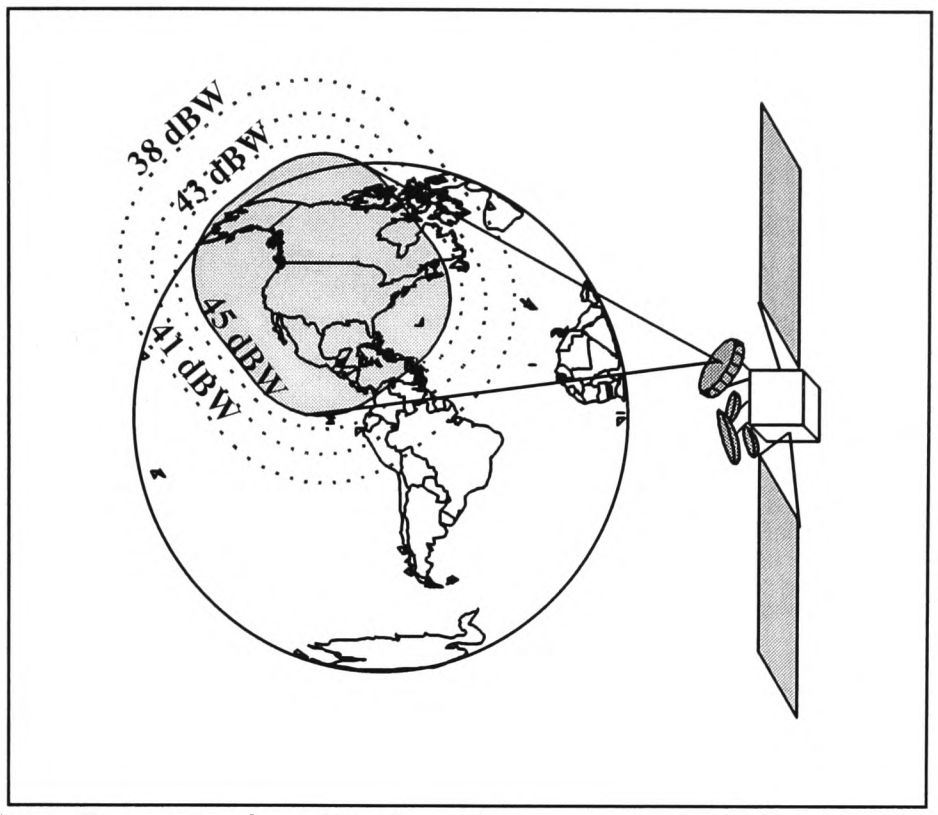


Figure 2.3: Example of satellite footprint.

2.1.1.2 Organisation of the telecommunication platform

Now that the main function of a satellite is understood, its platform, which provide support and shelter to the electronic equipment, will be examined. In this section, each of the numerous subsystems of the platform listed above will be described in details:

Not only does the *structure subsystem* support on-board equipment, but it also provides the means by which to deploy the equipment, such as antennas and solar panels, which were folded during the launch phase because of limited enclosed volume considerations. This subsystem also protects the spacecraft from minor collisions with space debris and harmful celestial radiation.

The *power subsystem* poses the most restrictions on satellite design because of mass and volume limitations imposed by launch vehicle providers. First, the electric power required by the satellite is directly related to the radio-frequency power of the amplifiers in the payload. In addition, the smaller the terrestrial receiving antenna, the higher the power required on-board the satellite to cover a designated footprint. As a consequence, mobile and direct broadcasting satellite systems, which both use small ground antennas, require more electrical power to perform their duties. Solar power is the primary source of energy for the satellite. Batteries of electrochemical accumulators, the secondary source of energy, take their energy from the solar generators when they are operational (during the solstice period) and return the stored energy to the satellite when the primary source ceases to operate (during the eclipse period). For a geostationary satellite, eclipses occur 90 days a year and can last for up to 70 minutes. Unfortunately, solar cells convert less and less solar energy as time goes by, and batteries decay is a consequence of the number of charge/discharge cycles.

As both the efficiency of solar cells and batteries declines over time, design specifications must ensure that there is enough energy at the end of the life of the

satellite[3]. Gravitational and other forces still affect satellites even at geostationary altitudes (35,000 to 38,000 km from the surface), and thus alter their position around the earth. The *attitude determination and control subsystem* (ADCS) consequently stabilises the spacecraft and orients it as to point its antennas towards the earth. The ADCS function is therefore closely related to that of the navigation and propulsion subsystems (see below). Using sensors, the satellite determines its position and controls its attitude by means of actuators. Stabilisation by rotation, for spin-stabilised satellites, was used on early communication satellites and is still used nowadays. Later introduced, but still the most common stabilisation method, is the 'three-axis' stabilisation. This stabilisation method allows the utilisation of larger antennas and makes better use of the enclosed space of the satellite, not needing to be cylindrical[4]. Moreover, it is simpler to install folding solar panels which follow the movement of the sun than cover an entire cylinder with solar cells in the case of a spin-stabilised satellite.

Monitoring the vital signs of satellites to ensure their optimum operation, is the main concern of the *telemetry, tracking and command subsystem* (TT&C). Telemetry refers to the transmission of measurements and information concerning the satellite operation to monitor the satellite from the ground. Tracking, also called navigation and guidance, is used for orbit determination, orbit control and station-keeping. Orbit determination and control maintains the distance from the satellite to the earth (on the operating orbit), while station-keeping maintains the satellite within a pre-assigned box to avoid interference with neighbouring satellites. Finally, the command part of this subsystem receives instructions from the ground station to initiate manoeuvres and to change the state or mode of operation of the satellite.

In addition to the navigation and guidance subsystem, the *propulsion subsystem* works closely with the attitude determination and control subsystem. The propulsion subsystem hence provides thrust in order to maintain the allocated orbit and the antenna pointing direction. Once all the fuel propelling the spacecraft has been consumed, the satellite slowly drifts out of orbit towards the atmosphere, were it may eventually be destroyed. Satellite lifetime is therefore determined by the amount of on-board propellant necessary for attitude and orbit control that can be stored within the mass restrictions. As a general convention, the planned end-of-life of the satellite is defined as the time when the designed lifetime elapses, while the actual death of the satellite occurs when it slowly goes out of its assigned orbit as it runs out of propellant (providing nothing more serious damages the spacecraft beforehand). Some satellites are equipped with apogee motors which initially propel the spacecraft onto its geosynchronous orbit. Consult appendix E for more details on the trajectory satellites must follow in order to reach their assigned orbit.

Finally, the main function of the *thermal subsystem* is to maintain the temperature of each satellite subsystem within its operational range. As the satellite goes in and out of eclipse, the ambient temperature can vary over a range of 300 °C.

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[3] The end of the life of a satellite is defined as the end of the planned number of service years that the satellite was designed to provide. This does not imply in any case the actual death of a satellite which occurs when no successful communications can be related via the satellite. There are many causes to the real death of satellite, magnetic storms disabling all electronic components and fuel depletion are some examples.

[4] Three-axis stabilised satellites are generally box-shaped, rendering the stacking of equipment and subsystems more efficient and compact within the spacecraft.

Moreover, different subsystems must operate within different ranges of temperature. For example, electronic equipment must operate within +10 to +45 °C whereas antennas can operate within a much wider range of temperatures, -150 to +80 °C.

Now that satellites no longer are mysterious boxes relaying signals via space, the compromises encountered in their design must be examined in order to understand the implications of the technology in the evolution of telecommunication and broadcasting via satellite.

2.1.2 An elementary course in satellite design for economists

As we have seen, the most important technical characteristics of a communication satellite are its power, communication capacity, launch mass, lifetime and operating frequency. The architecture of a telecommunication satellite is determined mainly by the communication mission, characteristics of the space environment and constraints imposed by launchers. First, the communication mission determines the requirements of the telecommunication payload. Then, platform requirements are defined by the payload needs in terms of electric power, antenna pointing accuracy, thermal power, space required for the equipment, number of TT&C channels, and so on. Orbit control, subsystems organisation and the choice of materials and components are affected by the nature and effects of the space environment. Furthermore, launchers have various performances and impose different constraints on satellite design; Their performance limits the mass that can be launched into orbit and therefore influences the specification of the propulsion subsystem. In addition, the limited enclosed volume available in the satellite bay requires solar panels and antennas to be folded during launch.

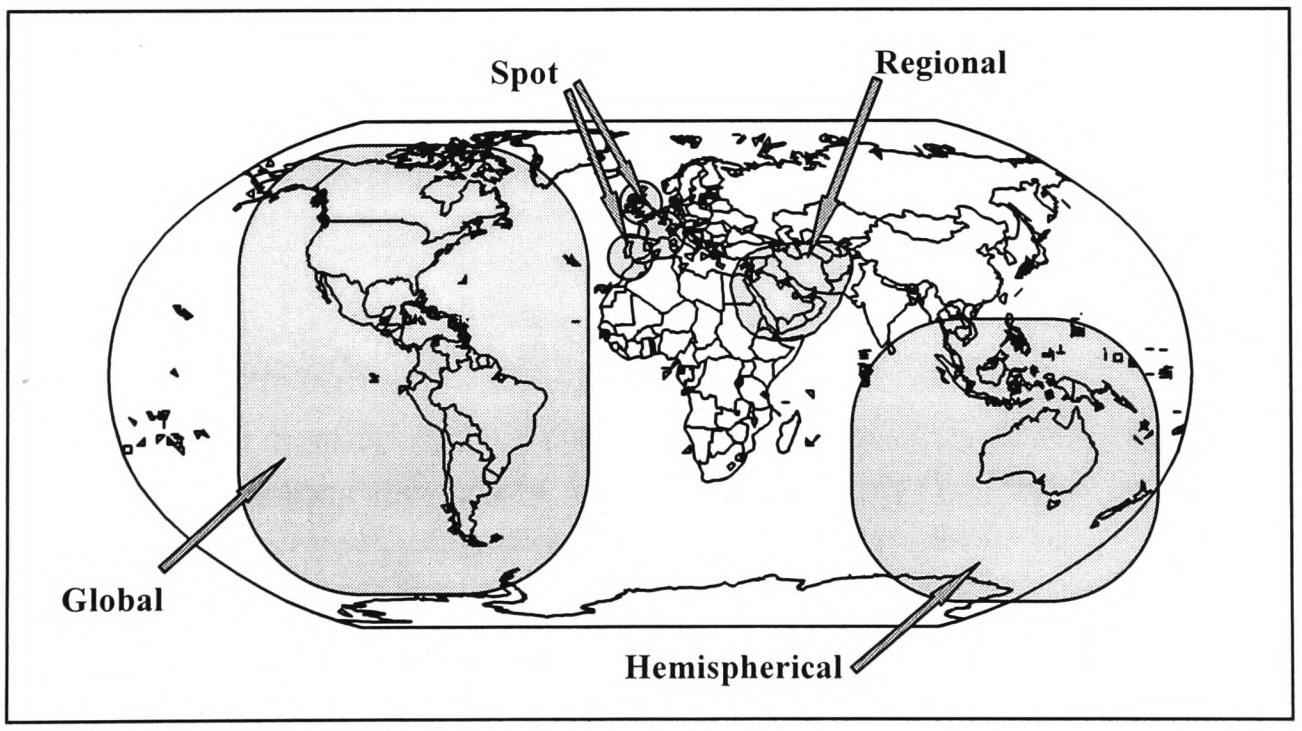


Figure 2.4: Types of antenna beams.

As described earlier, a telecommunication system is a chain of nodes in between which the signals travel. Link analysis at the design phase determines the necessary specifications of each node. In most cases, the satellite is the middle node of the telecommunication network, i.e. the link between two earth stations, one transmitting (up-link) and the other receiving (down-link). As a consequence, the characteristics of the two ground stations, transmitting and receiving, determine the satellite transmitter power and antenna aperture size required to fulfil the link analysis's findings. These parameters have the greatest impact on satellite mass, and

thus on the cost of the system. High gain antennas are required to support high data rates with low transmission power. But with a high gain antenna comes a narrow beam width which may not necessarily provide enough geographical coverage to establish links between several widely scattered ground stations. A small antenna gain yields a large footprint. Figure 2.4 illustrates the four main categories of geographical coverage, i.e. global, hemispherical, regional or zonal and spot beams which result from the different types of transmission systems.

2.1.2.1 Exogenous characteristics

In designing a satellite, certain characteristics are exogenous and some other must fall below a maximum, or lie above a minimum value. For example, in order to prevent interference between communication systems, the International Telecommunication Union (ITU) attributes allotments to satellite service providers. An allotment consists of an orbital position, a bandwidth in predetermined bands (to prevent interference, the up-link and down-link frequencies occupy two different frequency bands) and a service area. These characteristics are therefore exogenous to the design configuration. Moreover, numerous limitations are dictated by the ITU to prevent harmful interference, of which the most obvious are:

- limitation of the power flux generated by satellites on the earth surface;
- limitation of the EIRP generated by earth stations towards the orbit of geostationary satellites;
- specifications concerning the radiation patterns of all antennas, and so on.

All these restrictions impose constraints on the design configuration of the spacecraft. Volume and mass of a satellite are limited respectively by the enclosed space available in the launch vehicle and by its performance. Additionally, the size and gain of the antennas are influenced by the geographical coverage required, and the size of earth station antennas. For instance, in the case of mobile and direct broadcasting satellite services, a small aperture size for the ground receiving antenna is crucial.

2.1.2.2 Design trade-offs

One of the most critical characteristics in designing a satellite is its mass; the heavier the satellite, the more costly the system becomes, i.e. the more expensive is the launch. As a result, determining factors in the mass are the number of transponders and the power they require, the quantity of on-board propellant necessary to maintain the right orbit and attitude for the entire planned satellite lifetime. When the telecommunication mission necessitates a greater number of transponders, the satellite bus must provide more power. To achieve this greater power, engineers must increase the size of the solar power system, as well as the number, capacity and efficiency of the batteries. In addition, a greater number of transponders occupy a larger volume in the spacecraft. Nonetheless, with more transponders on the satellite, the quantity of transmission channels is increased and so is the communication capacity of the spacecraft.

Power efficiency and mass of transponders are often the key factors in sizing a satellite. Two types of amplifiers are used on satellites: travelling wave tube amplifiers (TWTA) and solid-state power amplifiers (SSPA). Travelling wave tubes

operate by interaction between an electron beam and a radio wave, while solid state amplifiers use field effect transistors (FET). For an equivalent output power, SSPAs are more reliable and have a lower mass than TWTAs, but require more input power for their operation. SSPAs also have a greater capacity because of their greater linearity in terms of input to output power ratio. TWTAs, however, have a greater efficiency, their power consumption and thermal dissipation being less than that of SSPAs. SSPAs can achieve very high power, up to 80 W, below 2 GHz, but were limited to around 10 W in C band (4/6 GHz) until recently. These transistor-based amplifiers are now appearing in Ku band (12/14 GHz) with powers around 30 W. The choice between the two types depends on the application; for direct broadcasting services, for instance, the powers required vary between 100 to 250 W, hence the necessity to use travelling wave tubes.

Furthermore, power and mass are affected by the designed lifetime of satellites. Increasing the lifetime of the spacecraft may prove to be more complicated because of the repercussion on all subsystems. A lengthier lifetime first impinges on the mass allocated to other components, by requiring additional propellant to maintain the spacecraft in its position. Furthermore, the satellite requires more battery and solar power to compensate for their further decay which may cause the satellite to be deficient in power before its end of life. The depth of discharge, which characterises the percentage of stored energy effectively utilised during the longest period of use without recharging (i.e. the longest eclipse period), is the only parameter defined by the user. For this reason, the lifetime of a battery is calculated in terms of number of charge/discharge cycles. By increasing the lifetime of the satellite, a greater number of cycles of charge/discharge of the batteries is required. Figure 2.5 shows that the depth of discharge diminishes with an increased lifetime, hence the need for a greater number of batteries to provide enough power to the satellite for this extended lifetime.

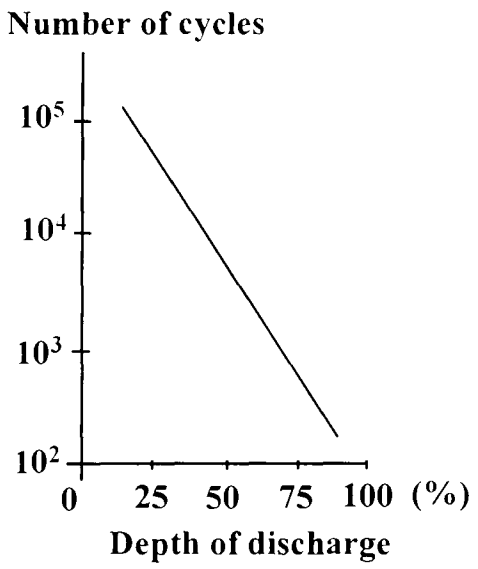


Figure 2.5: Lifetime of a battery (in number of cycles) in function the depth of discharge (Source: Maral and Bousquet, 1994).

The consequent increase in mass due to an increase in lifetime must be compensated in order to respect the mass constraint imposed by the launch vehicle. Somehow, the payload must be reduced; either by reducing the size and number of antennas, which would decrease their gain and the EIRP; or by diminishing the capacity of the satellite by decreasing its number of transponders. Ground stations must make up for this reduction in payload, by increasing the size of their antennas, power of their amplifiers and efficiency of their receiving equipment, or investing in more sophisticated signal compression methods.

However much effort engineers put in the design of satellites, their lifetime may still be shortened by space accidents such as magnetic storms or collisions with meteorites and space debris, or by malfunction caused by design errors or defective parts. Problems engendered by defective parts can usually be by-passed by employing sufficient redundancy[5] within the electronic systems. Satellite manufacturers must then compromise between redundant parts and the quantity of propellant on-board in order to respect the mass margins required by the launcher.[6]

The problems are not over yet, after a few years in the life of a satellite, its technology becomes outdated. Engineers must therefore be careful when designing a too long-lived spacecraft, as the investment may prove to be wasted in the later years, as other operators launch more sophisticated satellites capable of offering a wider variety of better, cheaper services, and steal market share as a consequence.

2.2 Evolution of telecommunication satellites

Now that the technological structure of communication satellites has been examined, these technical characteristics can be related to variables. This section will focus on the evolution of the variables representing the subsystems and characteristics of civilian telecommunication and broadcasting satellites.

2.2.1 The data

The data available for this study are both cross-sectional and time series, with repeated observations on some models when a series of satellites is ordered. Data sets collected for this study include price measures and technical attributes for most new civilian commercial communication satellites sold world-wide from 1964 to 1992. 1964 was chosen to begin the sample period, even if only one satellite was ordered that year, because it marks the beginning of commercial communications via satellite. Missing values and contradictions between databases were investigated on an individual basis, and in a few cases, approximated to the best of the author's knowledge of satellite systems. The primary source of price and technical characteristics data was collected by Roger Rusch (1992) in a database which is, for most figures, a collection of public information gathered from various journals about space.[7]

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[5] Most satellites incorporate up to twice the number of transponders required in the mission statement in order to alleviate the chances of a 'deaf-and-dumb' satellite in orbit.

[6] What precedes is a rather simplified explanation on the designing of satellites, but suffice for the purpose of this thesis. For further information on the subject, consult Maral and Bousquet (1994) or Wertz (1994) which are both very comprehensive.

[7] Secondary sources of data, used to complete and correct the main database, comprise the 1991 and 1992 European Space Directories, which provided general technical attributes data about satellites planned or in operation, at the beginning of the 1990s: number of satellites purchased, geostationary transfer orbit mass, geostationary orbit mass, number and frequency band of transponders, effective isotropic radiated power. The third edition of the Space Satellite Handbook (Curtis, 1994), was used to compare the planned and actual launch dates. The third edition (1995/96) of World Satellite Yearly (Baylin, 1994) as well as Matra Marconi 1993/94 and 1995/96 editions of the World Communication Satellite Directory provided invaluable information to complement and update the Rusch database. Euroconsult's 1993 edition of the World Space Markets Survey, Ten Year Outlook (Euroconsult, 1994) was a third source of technical data, providing numbers and frequency band of transponders as well as a great understanding of the satellite market.

To compensate for the small number of satellites ordered each year, observations were grouped by aggregates of three to five years, corresponding to the cycles described in section 1.3.1. Remember that each of the six sub-periods was chosen to start with the purchase of a greater number of satellites than the end of the previous sub-period. As a consequence, the end of each year group represents a slowdown in satellite purchases. Although it would probably be more accurate to choose sub-periods using a measure of satellite technical complexity, this method coincides with the satellite generations described at the end of this chapter.

2.2.2 From characteristics to variables

From all the characteristics available in various data sets, the most relevant were extracted, and the following variables will then be used to explain the price of satellite programs (the type of variable and the unit of measure utilised are shown in parentheses following the name of the variable):

- *number* (continuous, #): Quantity of satellites of a communication system purchased in a given contract. This variable can help measure the fixed costs of design set over an entire family of satellites, and infer on the state of economies of scale. Note that one system of satellite may be purchased in more than one order. For example, the Intelsat IV series of satellites was bought in two separate orders to the same manufacturer, the first in 1968 and the second in 1969. Satellites of the same family generally possess the same technical characteristics, sometimes with minor differences arising from the operation of the first spacecraft launched in the program. For simplification reasons, it will be assumed in this thesis, that all the satellites of a given order are identical.
- *rdev* (continuous, months): Development time; the time elapsed between contract signing and the real (as opposed to planned) launch date. This variable was modified from the data provided in the Rusch database, and replaced the real launch date by the first launch date included in the contract. The real launch date is preferred because it accounts for delays that may be encountered in spacecraft production and hence increase the necessary development time, giving the real development time.
- *gtomass* (continuous, kg): Geostationary Transfer Orbit mass, or launch mass[8] compiled from different sources (the arithmetic average was calculated when the values differed from one source to another). Geostationary Orbit mass (*geomass)* and end-of-life masses (*drymass*, with propellant depleted) were also available but for a lesser number of satellites, and were judged less important, because they do not account for the mass of the apogee motor propellant. Since the launch vehicle has to lift the satellite with all its fuel contents, the critical mass is *gtomass*, because launch providers price their services partly on the mass to inject into orbit. In addition, including any pair of mass variables would bias the analysis as they are obviously strongly correlated with one another.

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[8] Launch mass after perigee burn. The perigee burn is the thrust, usually given by the launch vehicle, that increases the velocity of the spacecraft and pushes the satellite into higher orbit (the geostationary transfer orbit in this case). Consult appendix E for a detailed explanation of the launch process.

- *eolpower* (continuous, W): End-Of-Life solar array capability at the summer solstice. In other words, end-of-life power is the minimum power delivered by the solar arrays (recall that solar arrays decay over time, so their capacity to convert solar power into electrical power decreases) required to operate the satellite on the last part of its planned lifetime. The Beginning-of-Life power (*bolpower*) was also available, but not being a critical value for the lifetime of the satellite, the end-of-life value was preferred. Indeed, just after a satellite becomes operational, its solar arrays are producing more power than the spacecraft actually requires. Over time, this power margin decreases until the satellite is crippled by the lack of sufficient power to operate (this represents the real death of the satellite and not its planned end of life).
- *lifetime* (continuous, years): Planned number of service years for which the satellite is designed. The *lifetime* of a satellite is proportional to the mass of on-board propellant. Remember that gravitational forces pull satellites out of their assigned boxes and orbits, consequently, thrusters have to burn propellant to reposition them. It is possible today to use satellites in inclined orbit in order to extend their lifetime, unfortunately, data on the effective lifetime of satellites was unavailable, and is rarely published.
- *sumtr* (continuous, #): Total number of transponders (recall that a transponder receives, modifies the frequency, amplifies, and finally transmits signals) on-board the spacecraft, regardless of their frequency bands. This excludes spare transponders included as a redundancy measure. It is possible that a better measure of satellite capacity would be the actual frequency bandwidth used by the satellite, combined with its particular use: voice, television, data, and so on. Unfortunately, detailed data on the exact use of each transponder was unavailable.[9]
- *mtrp* (continuous, %): Proportion of the transponders operating in any of the following bands: UHF (0.3-1 GHz), L (1-2 GHz) and S (2-4 GHz) frequency bands. These bands are generally used for mobile communications, and therefore represent a class of their own in satellite communication services.
- *ctrp* (continuous, %): Proportion of the transponders operating in the C band (4-8 GHz). Fixed satellite services such as telephony and television feed operate in this frequency band. These frequencies are utilised mainly by US and international organisations.
- *kutrp* (continuous, %): Proportion of the transponders operating in the Ku band (12.4-18 GHz). First introduced in Europe, the Ku band is utilised for fixed and broadcasting satellite services (FSS and BSS). Recall that BSS implies direct-to-home satellite services using individual satellite dishes.
- *otrp* (continuous, %): Proportion of the transponders operating in any of the three following frequency bands: X (8-12.4 GHz), Ka (26.5-40 GHz) and O (40-60 GHz) frequency bands. These frequency bands were grouped together because of their rarity in communication services. The main purpose of the X band is Governmental communications. Ka and O band transponders were introduced by Japanese companies in order to escape the increasingly

[9] In addition, because of the nature of signal transmission, transponder functions can vary according to the demand for various services. Moreover, improvements in compression techniques increased the capacity of these repeaters. Consequently, the type of service offered by certain transponders has been known to vary over the years.

crowded Ku frequency band. Although not used in main stream communication services, these frequencies are included because they represent the latest technology in terms of signal transmission.

- *totbw* (continuous, MHz): Potential capacity of a satellite in terms of bandwidth, excluding the capacity available from redundant transponders. Most satellites possess transponders of various bandwidths, and by calculating the total bandwidth available on a satellite, a better measure of the potential number of channels can be obtained.
- *eqvvoice* (continuous, voice channels): Expected number of voice channels that could be transmitted via the entire satellite bandwidth using the technology of the time. An index of current voice capacity technology was calculated using satellites for which data on the number of voice channels was available, and this includes all Intelsat satellites. Details of the calculation are reported in appendix G.
- *hmpower* (continuous, W): Weighted harmonic mean of the amplifier power required by each transponder of a spacecraft. With the advent of hybrid satellites, which are the norm nowadays, the amplifier power required by each frequency band or service differs. Possibly because of the non-linearity of power amplifiers[10], the weighted harmonic mean gave better regression results (see chapter 3) than the simple weighted arithmetic mean, and was consequently preferred.
- *gmeirp* (continuous, dB(W)): Weighted geometric mean of the Effective Isotropic Radiated Power, EIRP, which is a measure of the power of the signal emitted by the antennas. Because of the heterogeneity and multiplicity of transponders and antennas on each satellite, a weighted geometric mean of all EIRP measures per satellite was calculated. The measures of EIRP are generally given in their natural logarithm form (decibels or dB) and therefore, it was more appropriate to calculate a geometric mean. Once again, because of the variety of types of transponders on-board satellites, a weighted average is more accurate.
- *D3a* (categorical): Dummy variable taking the value 1 if the satellite structure is 3-axis stabilised, and 0 if it is a spinner satellite.
- *Dtwt* (categorical): Dummy variable taking the value 1 if all transponders use travelling wave tube amplifiers, and 0 if some transponders use SSPAs.
- *service* (categorical): Dummy variable representing the type of service offered by the satellite; for fixed satellite service (FSS), the variable takes the value 0; for FSS and broadcast satellite service (BSS), it takes the value 1; for FSS and mobile satellite services (MSS), it takes the value 2; for BSS only, it takes the value 3; and for MSS only, it takes the value 4.[11]

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[10] Input to output power ratio exhibits a non-linear behaviour; at low levels of power, most of the input power is transformed into output power; but as the level of power augments, this ratio (usually called efficiency) drops increasingly below 100 % to reach levels near 50 % for powers as high as 160 W.

[11] First, fixed satellite services are services that involve reception by 'important' earth stations as opposed to small portable units; of these services, telephony, television feeds are the most common. Second, portable units consisting of very small aperture terminals (VSAT) are used to receive mobile satellite services. Third, broadcasting satellite services are generally concerned with direct-to-home television services, which are received by small antennas (note that these antennas have shrunk considerably since they were first introduced) affixed to buildings.

2.2.3 Descriptive statistics

Characteristics of commercial communication satellites have evolved a great deal over the chosen sample period of 29 years. This section will examine the characteristics of communication satellites in more details, using basic statistics on the variables mentioned in the previous section. In the first chapter, significant differences in production and ownership patterns of commercial communication satellites were noticed across various regions of producers and customers, respectively. Following a description of the basic statistics of satellite characteristics from the whole sample, an account of the differences in these characteristics over divers manufacturers and various customers will be presented.

2.2.3.1 Basic statistics for the entire industry

For simplification purposes, relative rather than absolute evolution of commercial communication satellite characteristics will be analysed in this section. For the reader curious to examine absolute measures, Appendix F contains the descriptive statistics raw data for the variables discussed here. Figure 2.6 shows the relative evolution of the weighted means of the main characteristics other than the frequency band proportion and those features described by dummy variables. The number of satellites ordered in the series have been used to weight the characteristics. In addition, variables have been normalised with respect to the first period (1964-71). For example, this signifies that the end-of-life power of the satellite, *eolpower*, has increased almost fourteen-fold between the first and the last sub-periods.

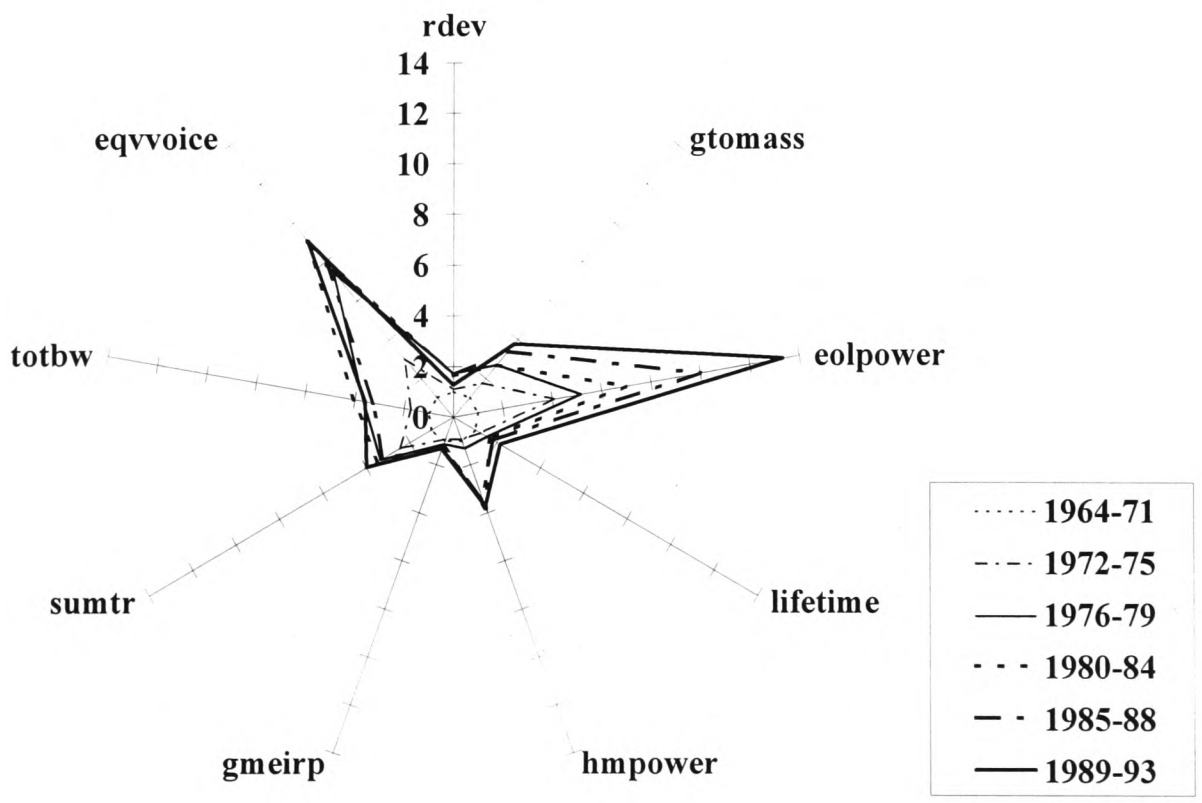


Figure 2.6: Evolution of the indexed weighted mean of each characteristic over the time periods chosen (the first period 1964-71 being normalised to one).

Furthermore, the equivalent number of voice channels has increased nine-fold between the first and last sub-period. Notice that the last four periods have very similar values and this is due to the advent of more sophisticated software compression techniques since the late 1970s. Recall that the measure of equivalent number of voice channels is given in appendix G and excludes methods such as

DCME[12] introduced during the 1980s, because of the lack of data available on the subject. In addition, the launch mass, lifetime and end-of-life power appear to have increased more gradually over the years than any other variable depicted in this graph. Eliminating the extreme values from the previous graph allows a closer examination of the rest of the variables in figure 2.7.

Apart from lifetime and launch mass, most variables stabilise quite rapidly from 1976 onwards. The development time increased sharply from the mid-1970s, stayed relatively long until the late 1980s and then diminished to approximately 40 months during the last period. This support the hypothesis of increasing demand from 1976 onwards; a greater number of satellites with increased capacity would necessitate a longer production time. Does this imply also an increase in the order books of manufacturers during these periods, and a congestion of output as a consequence? Chapter 5 will investigate this hypothesis in greater details.

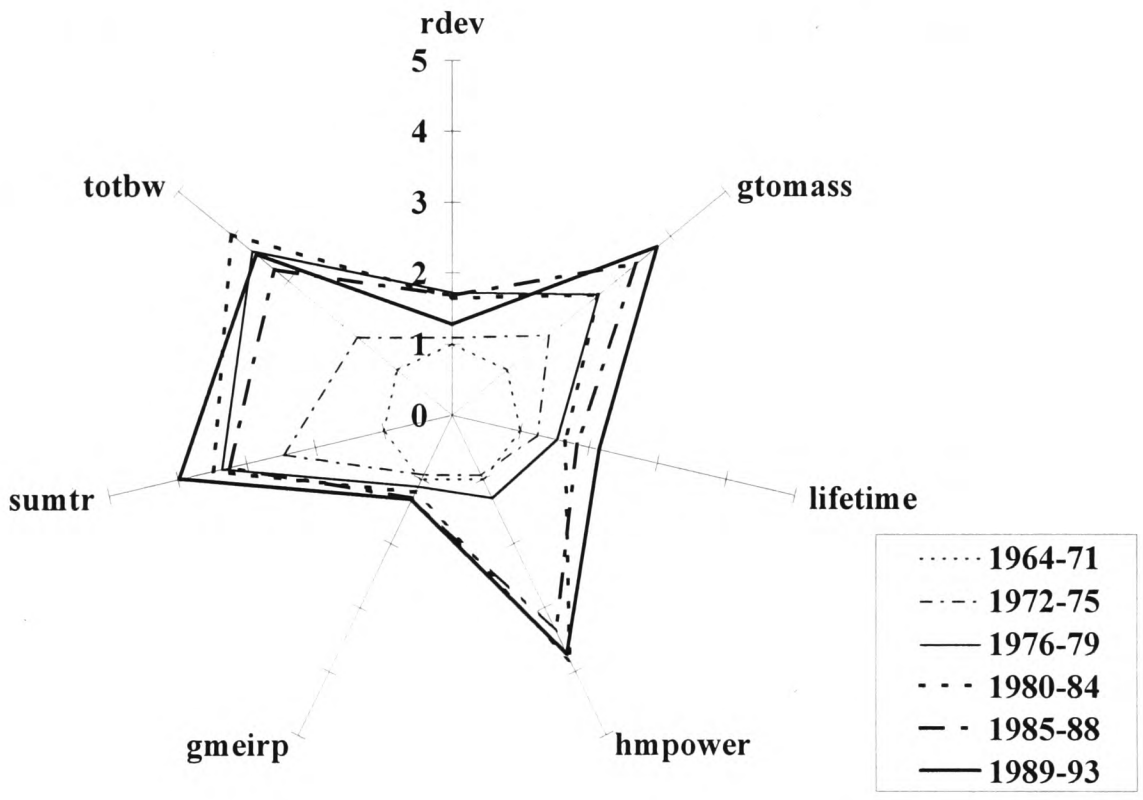


Figure 2.7: Evolution of the indexed weighted mean of each characteristic over the time periods chosen, with the exception of the variables *eqvvoice* and *eolpower* (the first period 1964-71 being normalised to one).

Moreover, communication satellites were increasingly heavy and high-powered, due to a steady augmentation in their lifetime and transmission quality. Bandwidth capacity seems to have reached a maximum in the mid-1980s, and has decreased since, which presuppose that sophisticated software compression techniques were expanding the physical bandwidth available, hence reducing the need for extra hardware on-board. Although bandwidth capacity has reached a maximum in the first half of the 1980s, the number of transponders has increased, which supports the hypothesis of software frequency compression rather than bandwidth increase; according to this graph, the bandwidth per transponder must have decreased since the mid-1980s. Amplifier power, *hmpower*, has increased sharply in the middle of the sample, subsequent to the introduction of high-powered direct broadcasting and

[12] Digital Circuit Multiplication Equipment.

mobile communication satellites, at the beginning of the 1980s. In addition, from the beginning to the end of the sample, satellite lifetime has more than doubled, from 6 to 12 years approximately, following a continuous increase in the process. In comparison, the effective isotropic radiated power does not appear to have varied a lot, but remember that EIRP is measured in logarithms, and therefore, has increased substantially in its non-logarithmic form, with antenna gain and transponder power improving over time.

Over the years, the mixture of transponders of different frequencies has varied with the introduction of new bands. Figure 2.8 shows the rest of the continuous characteristics and the evolution of the proportion of transponders of each frequency band. In the first sub-period, only C band was present. Then, in the second period, the number of C band transponders diminished with the introduction of mobile communication using L and S bands as well as experimental Ku band (mostly in Europe though). This new Ku band has proved successful because since the 1980s, it has represented about 40 to 50 % of all transponders on-board commercial communication satellites. The proportion of C band transponders has decreased as a consequence but not as fast as experts expected.

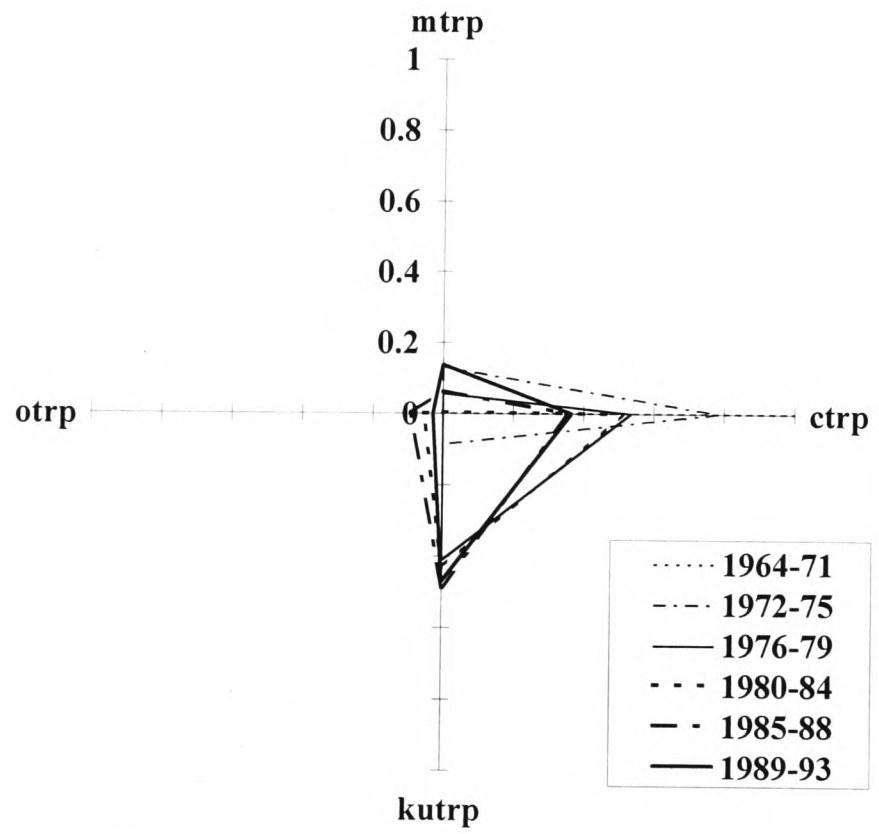


Figure 2.8: Evolution of the indexed weighted mean of the transponder frequency band proportion over the time periods chosen (the first period 1964-71 being normalised to one).

There has been an active resistance from North American and third world customers against investment in new expensive Ku band ground stations before the C band ones were out of order or rendered completely obsolete. Only recently has North America finally succeeded in upgrading to the Ku band. In the last period, mobile communications have regained the transponder proportion they had when Marecs and Marisat were first introduced. The category of other transponders mainly consists of Ka band transponders mostly on board of Japanese satellites. Note that these characteristics are measured in terms of average per contract year, they do not represent the in-orbit stock of satellites; this type of graph would be blurred if the stock of satellites was used rather than the flow.

2.2.3.2 Supply-side fragmentation of basic statistics

In this section, manufacturers have been disaggregated in the same as way as they were in the first chapter, i.e. the three most important US producers: HAC, MMAS and SS/L; the rest of the North American manufacturers; European builders; and the rest of the worlds manufacturers. Figure 2.9 shows the breakdown of relative satellite characteristics by manufacturing region. These graphs are scaled with respect to the mean value of satellites built in the first period by Hughes Aircraft. Again, characteristics mean values in absolute terms are presented in appendix C.

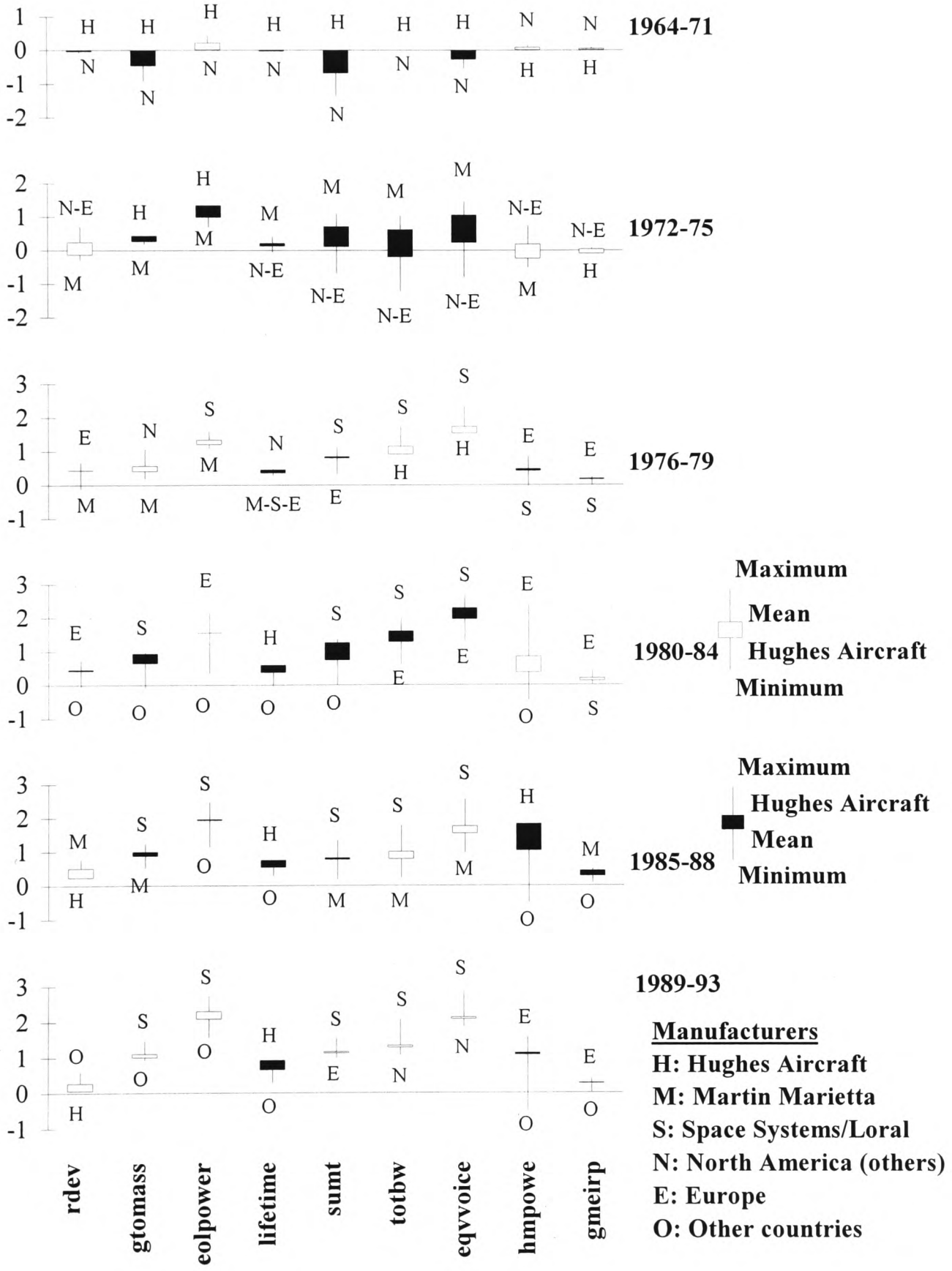


Figure 2.9: Comparative evolution of the characteristics of communication satellites by region of manufacturer; natural logarithm of the normalised indicated variable relative to the mean value of the satellites contracted to Hughes Aircraft during the period 1964-71.

For the last three sub-periods, Space Systems/Loral (formerly Ford Aerospace Corporation) built the most heavy and powerful satellites with the most capacity on average. Their mass though was not the consequence of an exceptionally long life, because Hughes Aircraft built the most long-lived satellites for most of the sub-periods, but rather of their capacity, which was the highest. Moreover, Martin Marietta Astro Space produced satellites with the highest effective isotropic radiated power, which is a measure of the quality of the signal received on the ground. Apart from the period 1985-88, US manufacturers produced the heaviest satellites on average with the highest bandwidth capacity. In addition, US satellite builders consistently produced the most long-lived satellites. In the 1980-84 period, European and smaller North American manufacturers built spacecraft with the highest transponder power ever produced. These satellites were intended for direct-to-home broadcasting services and required extremely high power to considerably reduce the size of the ground antennas from the previous generation of C band DBS systems. Since then, the transponder power required by HP-DBS systems has been compensated by more efficient antennas with higher gain. Figure 2.10 illustrates the change in the proportion of transponders of each frequency band across the six sub-periods chosen.

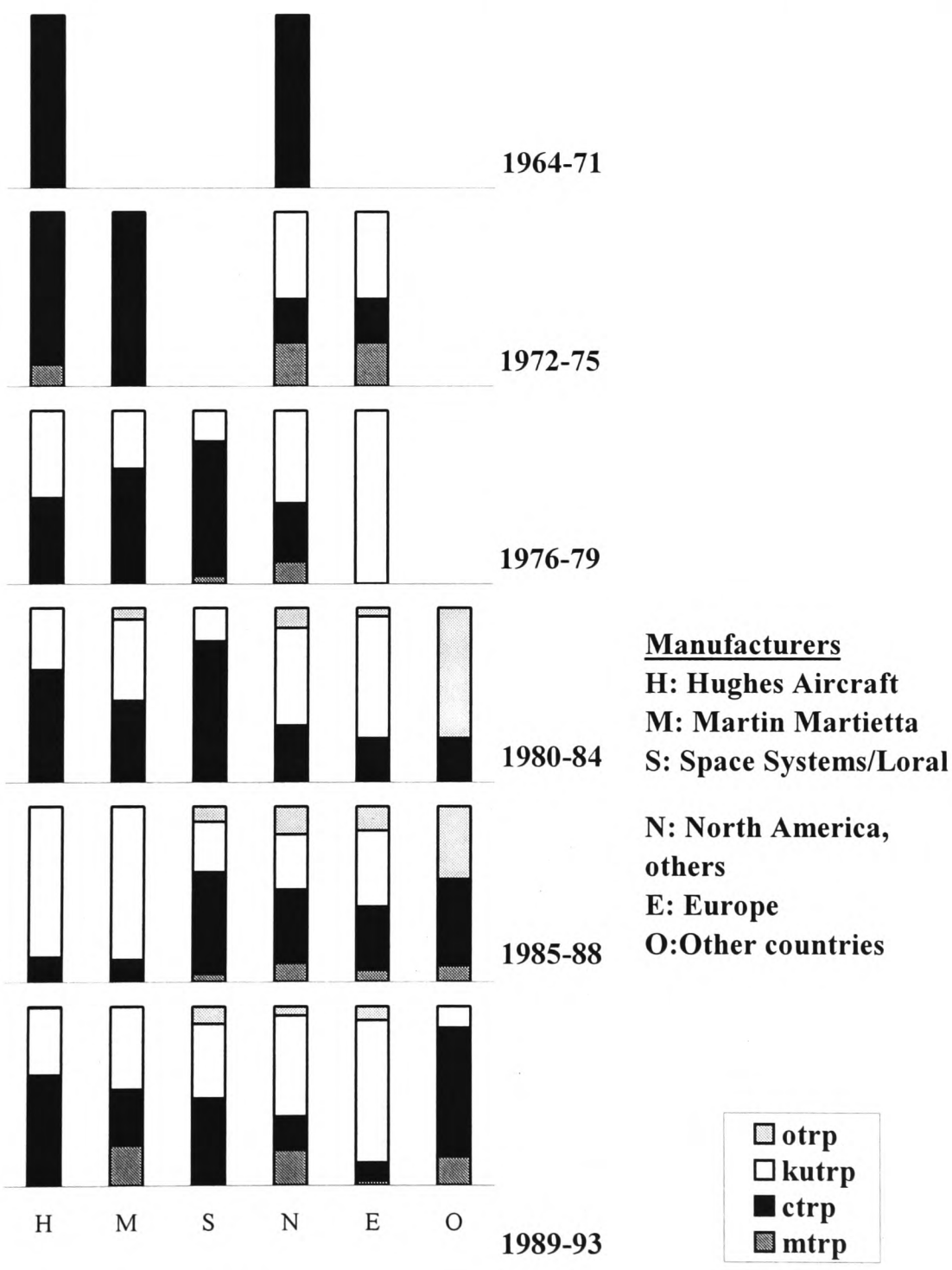


Figure 2.10: Evolution of the proportion of transponders of each frequency band by region of manufacturer.

As noted before, the proportion of C band transponders decreases over time as the capacity is replaced by Ku band transponders. European produced satellites with the highest proportion of Ku band transponders apart from the years 1985-88 where it was Hughes Aircraft and Martin Marietta. US manufacturers generally produced satellites with a higher proportion of C band transponders, while European manufacturers built satellites with a higher percentage of Ku band transponders. However, the situation changed in the second but last sub-period, where Hughes Aircraft and Martin Marietta built satellites with a higher percentage of Ku band than C band transponders. At the same time the percentage of Ku band transponders in European built satellites dropped below 50 %. We postulate that this change in pattern may be attributable to the fact that US customers purchased Ku band-heavy satellites built by US manufacturers and Europe built satellites for the export market requiring C band transponders, having proved it could build satellites for its own domestic market in previous periods.

2.2.3.3 Demand-side disaggregation of basic statistics

In this section, operators of satellite services have been separated into the following types and regions: domestic systems for the US, Europe and the rest of the world, as well as satellite programs from international organisations (mainly Intelsat and Inmarsat). Figure 2.11 shows the main characteristics of communication satellites by region of customers/operators.

During the course of the entire period, international and US domestic satellite systems have alternated turns in owning the heaviest satellites. The heavy weight of these satellites can only partially be explained by a greater number of transponders in the case of international programs. In the case of US domestic satellites, an increased lifetime, and consequently a greater quantity of on-board propellant, seem to be the cause of this greater mass. In addition, international satellites had the highest capacity for only three of the sub-periods. For the first period, the higher capacity of other countries satellites over Intelsat is due to the Canadian spacecraft Anik A. An interesting point of this graph is the consistent higher amplifier power of European satellites, particularly during the period 1980-84, where it is twelve times the value of Intelsat satellites in the first period. This last period saw the emergence of high power direct-to-home broadcasting satellite services, which have mushroomed in Europe during the mid-1980s. Europe however, has had on average the smallest number of transponders per satellite throughout the entire sample, as well as the highest amplifier power. This is probably due to the fact that the majority of satellites, in this region, are launched to fulfil broadcasting services. And that this type of satellites has a smaller number of transponders in order to accommodate more powerful amplifiers on-board. Indeed, the main difference between European and international satellite programs is the type of services they offered; international organisations have concentrated their services on telecommunication, whereas European satellites focused on broadcasting by introducing the Ku band at the beginning of their operations.

Figure 2.12 shows the transponder frequency band breakdown of these satellite providers. European satellite operators provided communication services almost entirely using Ku band transponders. After uniquely utilising transponders in C band, at the end of the 1970s, US domestic firms started offering services in the Ku band, but only recently has the number of C band transponders been overtaken by the

number of Ku band ones. International organisations and US domestic firms have been reluctant to switch to Ku band transponders because it would have rendered obsolete the recently implemented C band infrastructure. Furthermore, a number of the members of Intelsat are third world countries which cannot afford to completely replace their C band ground stations by more expensive Ku band terrestrial stations.

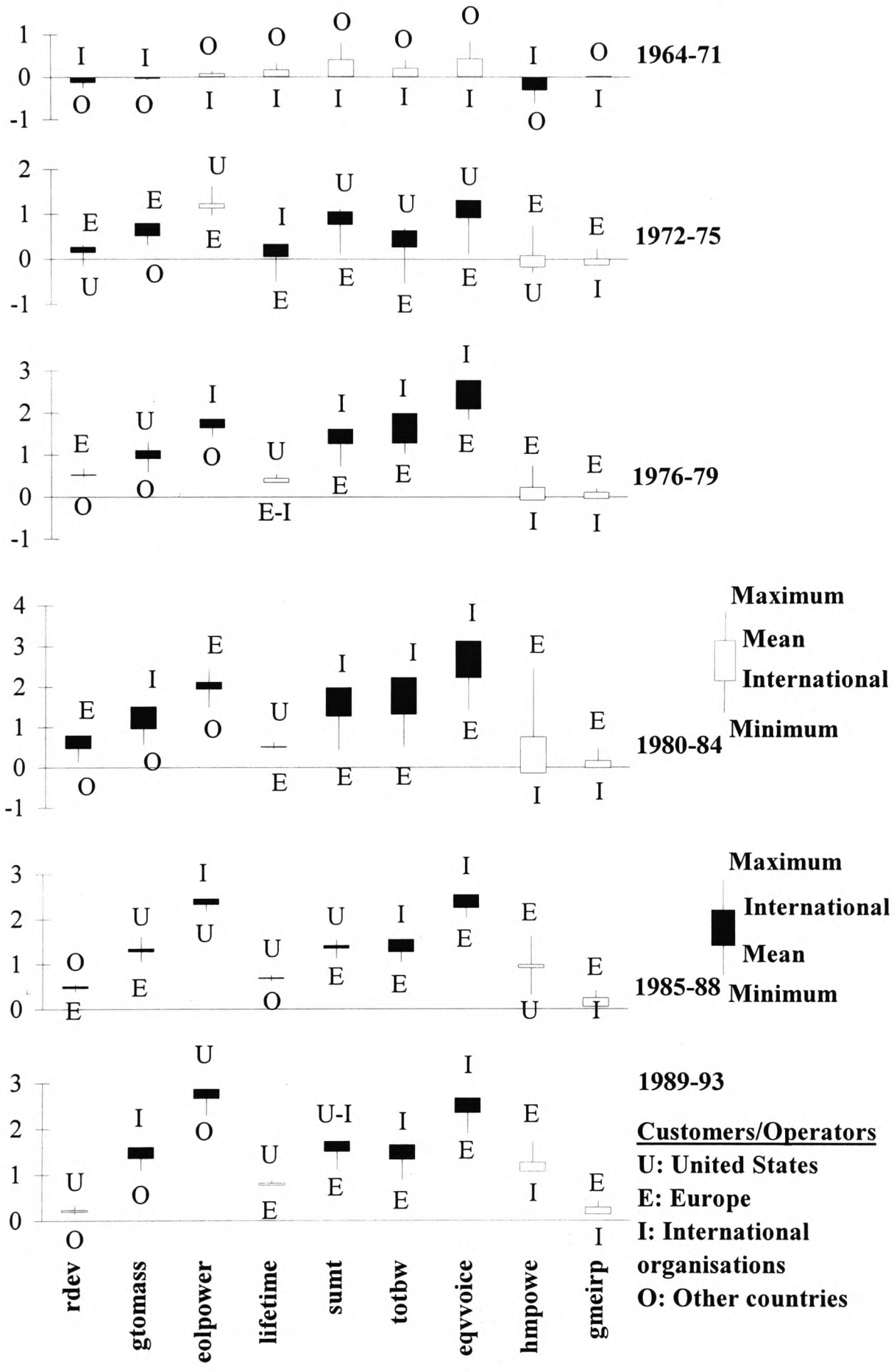


Figure 2.11: Comparative evolution of the characteristics of communication satellites by region of customer/operator; natural logarithm of the normalised indicated variable relative to the mean value of the satellites contracted by international satellites during the period 1964-71.

Regarding other frequency bands, in the last sub-period, the observed high percentage of transponders for mobile telecommunication is due to the purchase of the

Inmarsat III satellite family. Earlier, in the 1980s, Japan and some European countries introduced communication experiments using the Ka band, because of the prospect that the Ku bandwidth may become overcrowded in the future, and higher frequency band may be needed. Sophisticated modulation and compression techniques to increase frequency reuse may have partially solved the overcrowding of the Ku band problem, and may account for the decline in the use of Ka band in the last sub-period.

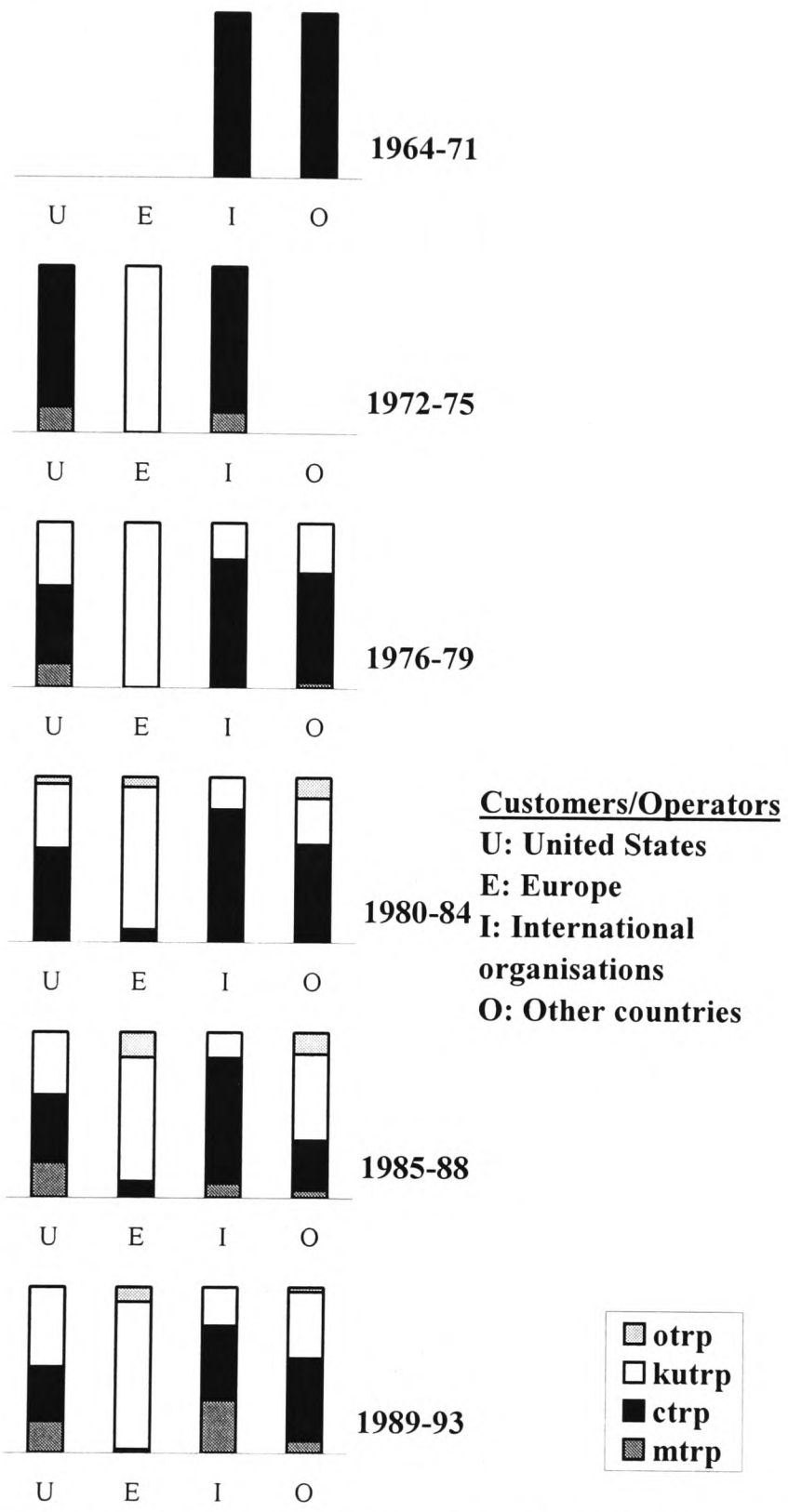


Figure 2.12: Evolution of the proportion of transponders of each frequency band by region of customer/operator.

2.2.4 Evolution of satellite characteristics

Instead of presenting a time series for each satellite characteristic, we have chosen, in this section, to illustrate technological evolution from a relative point of view. The first paragraph excepted, all the subsections of this part will examine a time series of the progress of comparative characteristics. Comparisons deriving from critical design compromises, such as lifetime versus total power, will be studied.

2.2.4.1 *Evolution of frequency bands*

As seen in figures 2.10 and 2.12, civilian fixed space communication systems currently occupy three frequency bands: C, Ku and Ka[13]. Although most analysts predicted the end of the C band with the advent of the Ku band, nothing of the sort occurred. In Europe, with the late implementation of space communications, Ku band transponders were used from the start without the drag caused by a heavy C band infrastructure. C band, however, still dominates the market for international systems because of the third world constraint mentioned above. As a consequence, this reticence from customers to convert completely to one frequency band has led to the development of hybrid satellites operating in multiple frequency bands. Europe has specialised from the beginning in Ku band payloads and has supplied around 15 % of the world production of Ku band satellites during the 1980s (Euroconsult, 1991). Nevertheless, Europe is still virtually absent from the C band production market, a serious disadvantage on the export market which is still dominated by this frequency band. US manufacturers, on the contrary, benefit from significant economies of scale in building TWTAs in the C band, but Japanese producers hold the lead for low to medium output power SSPAs in this low frequency.

2.2.4.2 *Evolution of capacity*

In the early days of satellite communications, the number of transponders represented a direct measure of the capacity available on board the satellite. This was true until the well-known C band dual polarisation experiments on two Intelsat IVA satellites introduced the first frequency re-use techniques (Intelsat, 1990). However primitive this may sound today, the technique consists of transmitting twice the number of signals using orthogonal polarisation; half the signals in vertical linear polarisation and the other half, in horizontal linear polarisation.[14] Following the success of this experiment, the Intelsat V family provided four-time frequency re-use at C band and spatial re-use at Ku band, and the Intelsat VI family, six-times frequency re-use. Since then, sophisticated compression techniques have been introduced and allow a further multiplication of the physical capacity of satellites. The evolution of the potential capacity, represented here by the number of transponders, is compared to the mass in figure 2.13.

Transponder to mass ratio decreased for the first three Intelsat series, showing that the mass was increasing a faster rate than the number of transponders. This is probably due to a combination of factors; first, the lifetime is increasing with each new series, thus requiring greater quantities of station-keeping propellant; and second, the power required by each new family of satellites is increasing, therefore requiring bigger solar panels and a greater numbers of batteries to store the solar energy during eclipse periods. From Intelsat IV onwards, the average of the transponder to mass ratio varied substantially until the early 1980s due to a greater diversification in the functions of the satellites launched. With the introduction of the

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[13] Recall that communication satellites first used the C band, then followed the Ku band in the late 1970s. The Ka band was introduced in Japan at the beginning of the 1980s and followed in Europe at the end of the decade.

[14] The signal transmitted between the earth and satellites is similar to the waves created by disturbing a water surface; these waves are propagated vertically. Imagine that the water surface is rotated by 90 °, the waves would then be propagated horizontally compared to the original framework. This is a rather simplistic representation but this is the general principle of signal transmission.

first domestic satellite, Anik A, and its followers, the number of transponders per unit of mass increased dramatically. These first domestic satellites had a greater capacity than their Intelsat predecessors and in these early days, capacity increase was a consequence of hardware improvement, i.e. a greater number of transponders on-board, hence heavier satellites.

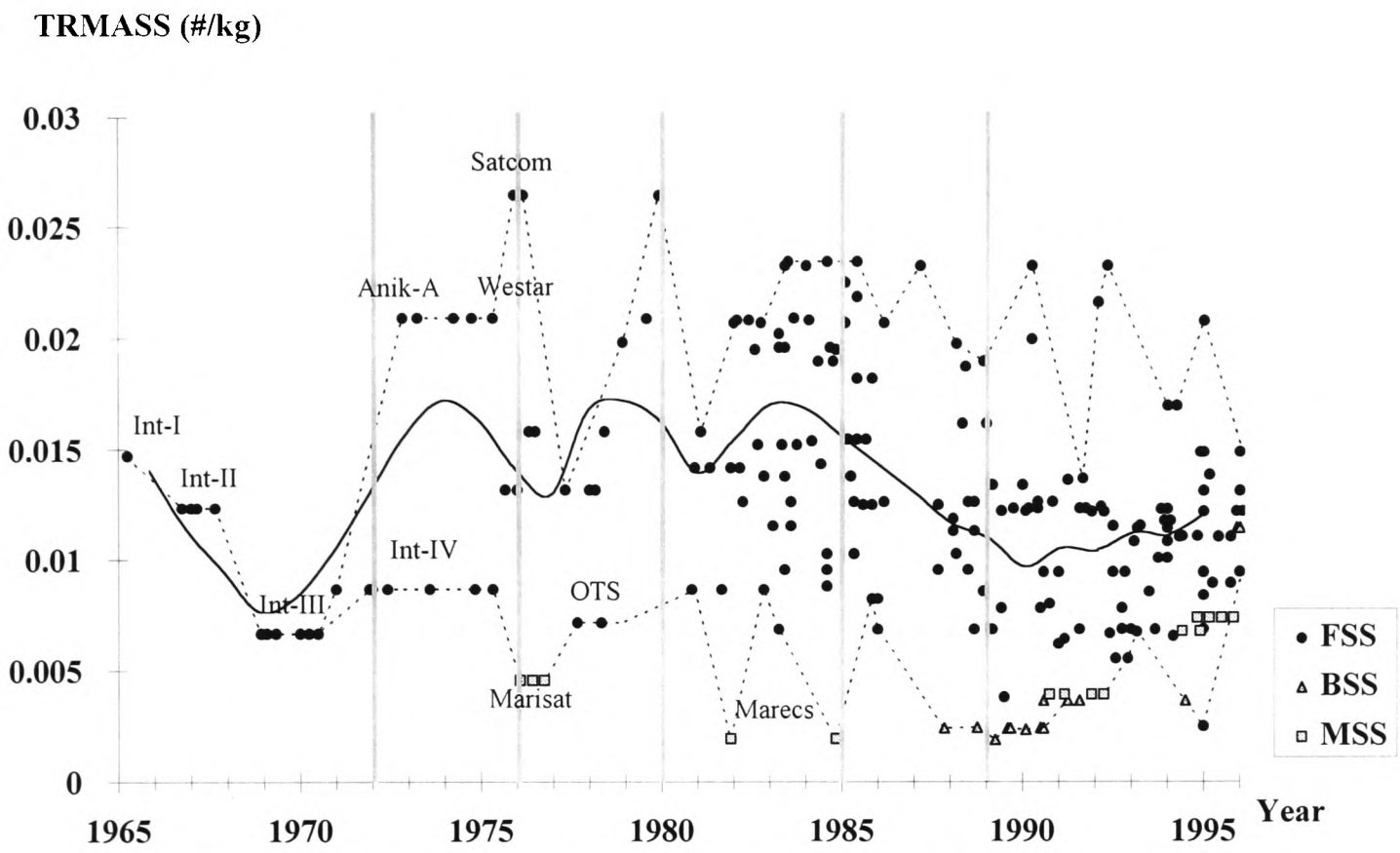


Figure 2.13: Number of launched transponders per unit of mass for the sample period (1965-96). The continuous line represents the yearly moving average (smoothed), and the dotted lines, the envelope of the sample.

From early 1980s, sophisticated software compression techniques started to appear, and by the middle of the decade, the number of transponders required to provide the same service considerably diminished, hence the decline in the number of transponders compared to the mass. But the end of the 1980s did not completely eliminate satellites with high transponder to mass ratio, as Asiasat 1, PAS 1, Palapa B4 and Pacstar, all satellites of earlier technology purchased later, were launched during the 1990s. Westar 6S, in particular, a second generation satellite, was refurbished to be launched as Asiasat 1[15].

The first satellites were characterised by increasing capacity, lifetime and power, all of which were improved by more and better hardware. Augmentation in total power relative to the number of transponders during the first decade of commercial communication satellites is illustrated in figure 2.14. The first part of the graph represents the hardware improvements that resulted in higher capacity. In the late 1970s, the diminution noticed is due to the launch of mobile communication satellites with fewer transponders than fixed communication satellites. Economies made on transponders resulting from the use of software signal compression follows the tendency towards software improvement that characterised so many domains during the 1980s. Apart from the drop in 1981, this ratio shows a steady decline from 1978, corresponding to the stagnation in the number of transponders due to software

[15] Refer to the first chapter for details on this second-hand satellite.

improvements, but an augmentation of the total satellite power which, if you recall, helps to reduce the size of the ground infrastructure.

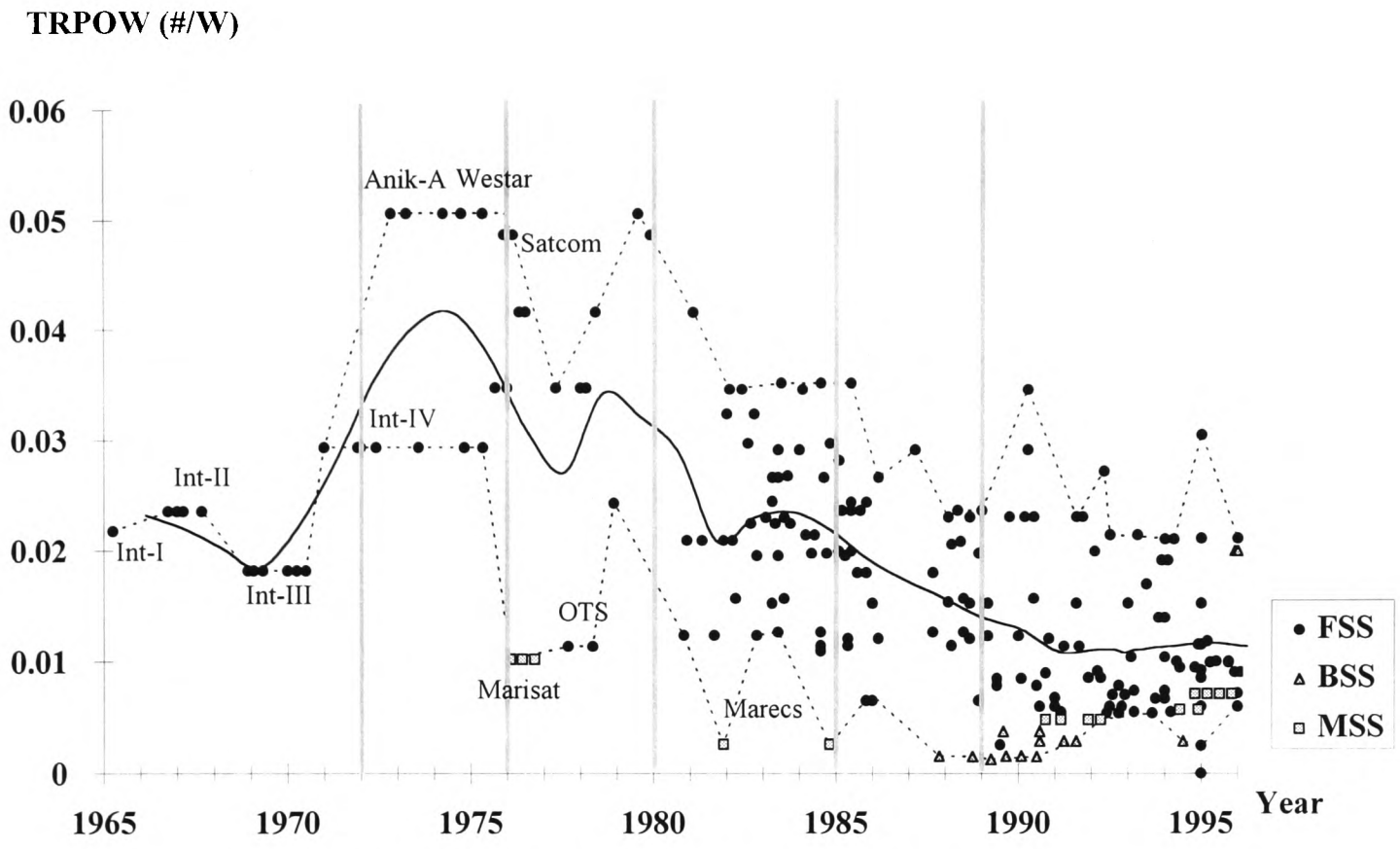


Figure 2.14: Number of launched transponders per unit of total power for the sample period (1965-96). The continuous line represents the yearly moving average (smoothed), and the dotted lines, the envelope of the sample.

2.2.4.3 Evolution of power

The evolution of the relationship between the end-of-life total power and the mass of the satellite at launch. Over the years, engineers have succeeded in providing increasingly powerful satellites without impeding too much on the mass margin. During the late 1960s, diminishing power to mass ratio (see figure 2.15) was a direct result of the increase in capacity and quality of the satellites, i.e. a greater number of transponders and a higher EIRP, needing a greater antenna gain and therefore a bigger transmitting antenna. From 1972, the total satellite power augmented steadily faster than the mass, fulfilling the requirements of increasingly intelligent satellites. Miniaturisation of electronic components allowed this increased power with no real impact on the mass. In the 1980s, the gradual increase in power to mass ratio was probably due to the introduction of nickel-hydrogen batteries to replace the nickel-cadmium ones. Nickel-hydrogen batteries have a longer life-cycle, greater depth of discharge and greater energy storage density, hence a smaller number of batteries is needed for an equivalent power supply. Intelsat built and tested the first nickel-hydrogen battery cells in 1971 and modified the Intelsat V prime-contract with Ford Aerospace to replace the originally planned nickel-cadmium batteries by nickel-hydrogen ones (Owens, 1990). This increase in power supply broke the barrier imposed by mass restrictions and allowed greater power budgets for on-board data management[16].

[16] Maral & Bousquet (1994) describe increased on-board management used for the telemetry, tracking and command subsystem. Wertz (1994) mentions advanced on-board computers for autonomous navigation, i.e. determining the orbit on board the satellite in real time by accessing the Global Positioning System (GPS).

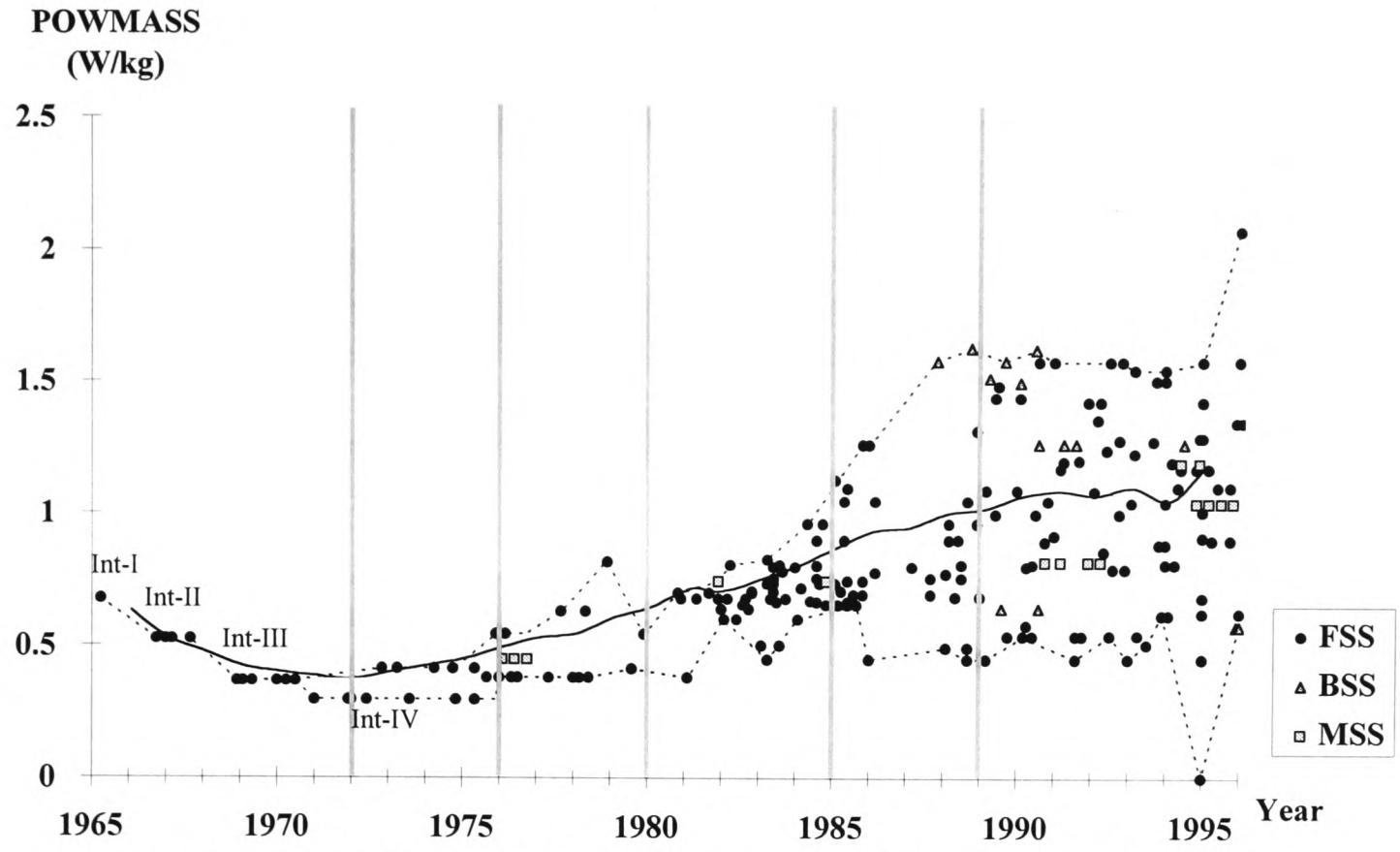


Figure 2.15: Total end-of-life power per unit of mass at launch for the sample period (1965-96). The continuous line represents the yearly moving average (smoothed), and the dotted lines, the envelope of the sample.

Constant augmentation in total power characterises satellites can be attributed to different subsystems depending upon the decades they lie in. In the early days of commercial communication satellites, the proportion of total power fuelling transponders has decreased dramatically as shown by figure 2.16.

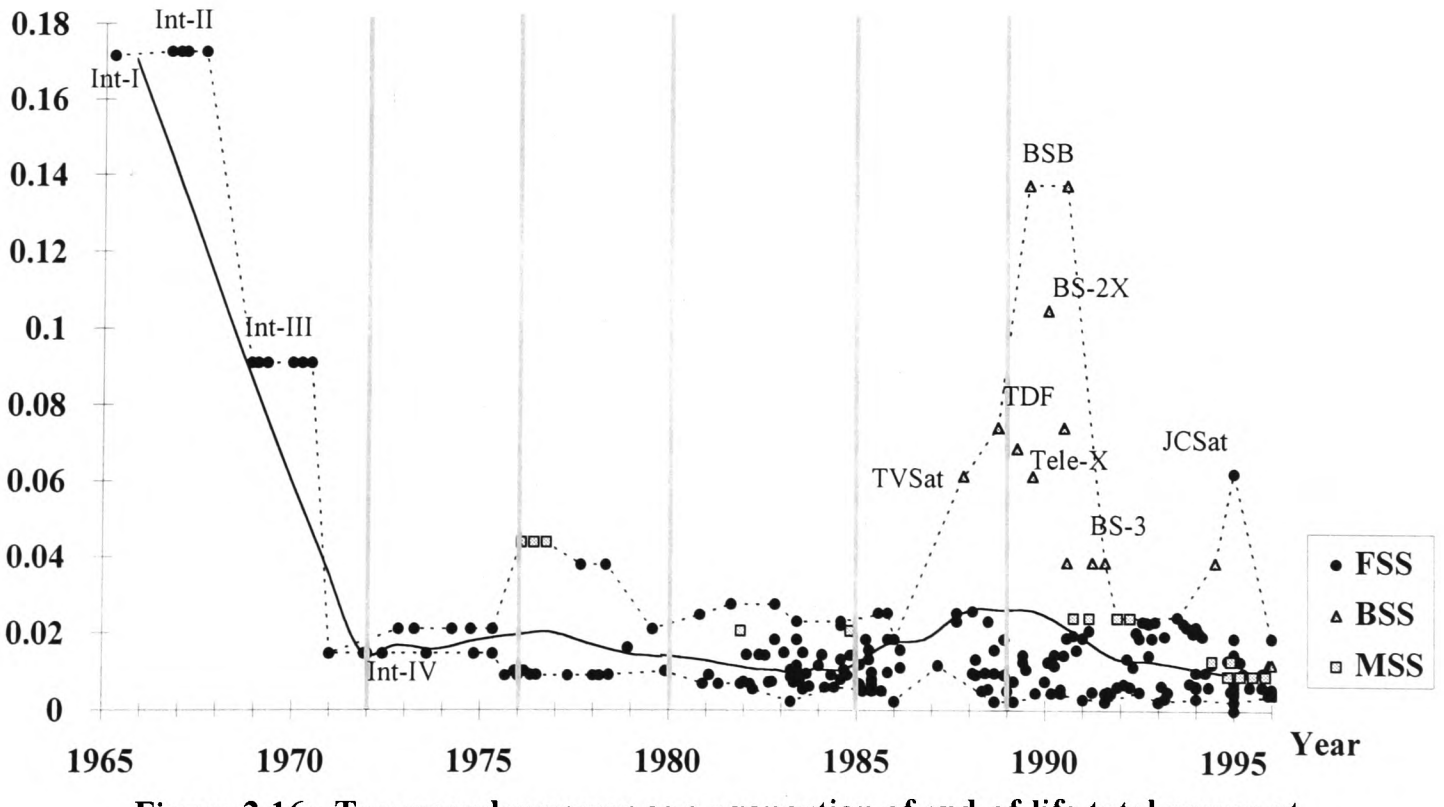


Figure 2.16: Transponder power as a proportion of end-of-life total power at launch for the sample period (1965-96). The continuous line represents the yearly moving average (smoothed), and the dotted lines, the envelope of the sample.

This fast diminution is essentially due to improvements in the efficiency of power amplifiers, i.e. the input power they require in order to provide a certain output power. During the late 1960s, this efficiency increased steadily but has since then more or less reached a plateau. For very high power, the amplifier efficiency level generally drops to around 50 %. As a consequence, to provide an output power of 160 to 200 W, almost 400 W of input power is required. After the initial decrease and until the beginning of the 1980s, the proportion of transponder power to total power was relatively stable. Satellites then became more complex and offered more services. As expected, high-power direct-broadcasting-satellites (HP-DBS) which require enormous amounts of power to allow for small aperture ground antennas, form a separate cluster; these are TDF, TVSat, Tele-X, BSB and BS.

Satellites have so far been a more or less passive link in the telecommunication system, hence their qualification of 'transparent' satellites. Transparent satellites only use a simple converter to change the frequency of the carrier, Maral & Bousquet (1994). The tendency is towards regenerative satellites that demodulate the signal and remodulate it with a different carrier. As a result, the proportion of transponder power to total power is expected to increase from the mid-1990s as more on-board processing becomes the norm in commercial communication satellites.

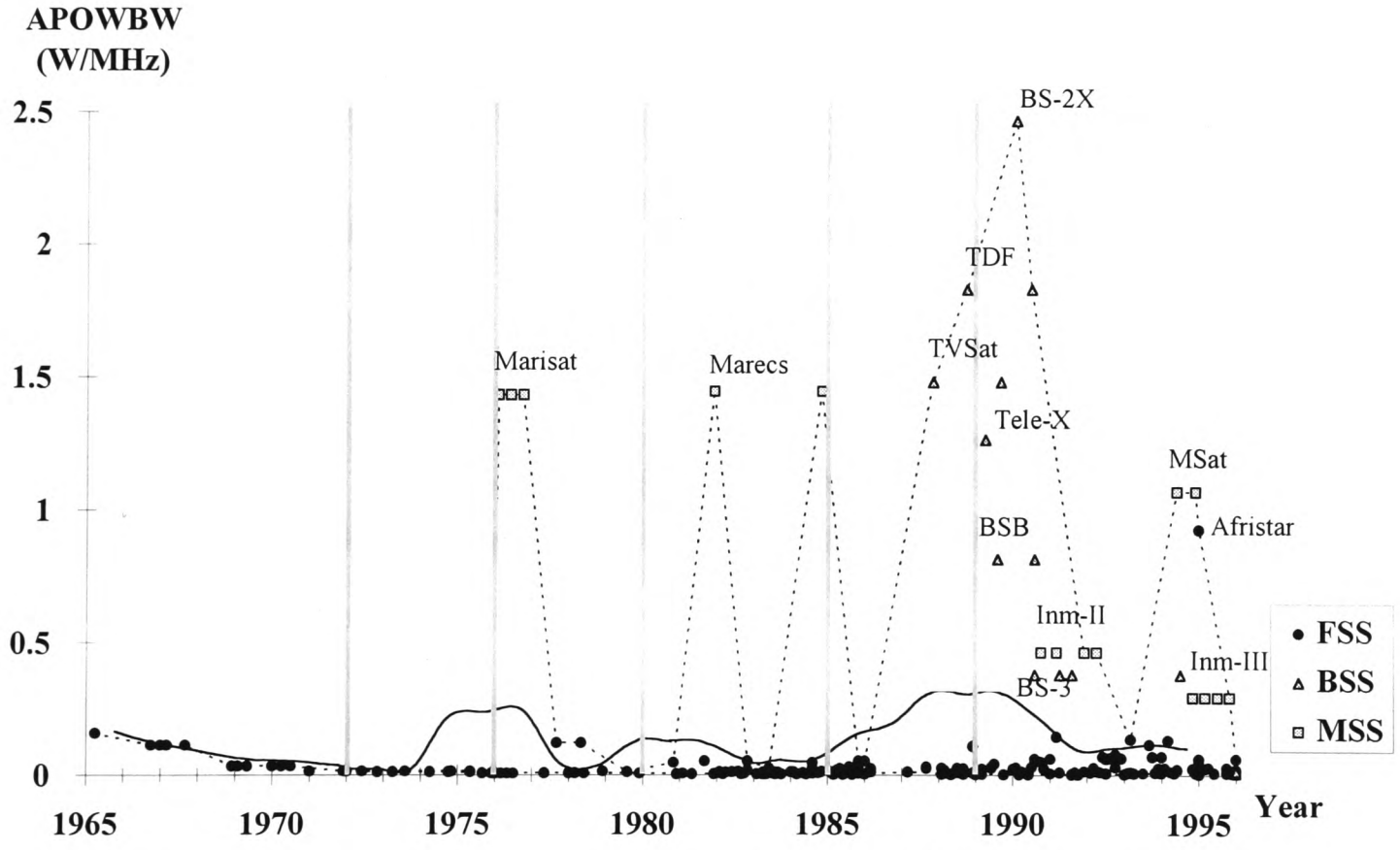


Figure 2.17: Transponder power per unit of bandwidth at launch for the sample period (1965-96). The continuous line represents the yearly moving average (smoothed), and the dotted lines, the envelope of the sample.

A surprising fact is the absence of a cluster of mobile communication satellites in figure 2.16. Indeed, it would be expected that because of the very high power required from satellites to provide mobile telecommunications powerful enough to be picked up on small transportable antennas, or VSATs (Very Small Aperture Terminal), transponder power to total power ratio would need to be higher than that of HP-DBS. There are two reasons for this discrepancy. First, mobile communication satellites have a very small capacity, or bandwidth, compared with the

power they require, as is illustrated in figure 2.17. Second, only a proportion of transponders transmit to mobile terminals. In fact, in most mobile communication satellites, a greater number of channels are dedicated to the mobile terminal to fixed ground station link (L to C bands)[17].

There has been a great improvement in orbit maintenance in the early days of geostationary communication satellites. Improvements in antenna design and ground tracking technology have allowed satellites to manoeuvre within a larger box, hence needing less station-keeping thrusts and using less precious on-board propellant. In addition, engineers soon realised they could save almost twice the fuel by replacing satellites that fall below their orbit line, slightly above it, therefore retarding the next station-keeping thrust. Figure 2.18 demonstrates clearly the trade-off between power and lifetime that was occurring at the beginning of the space era.

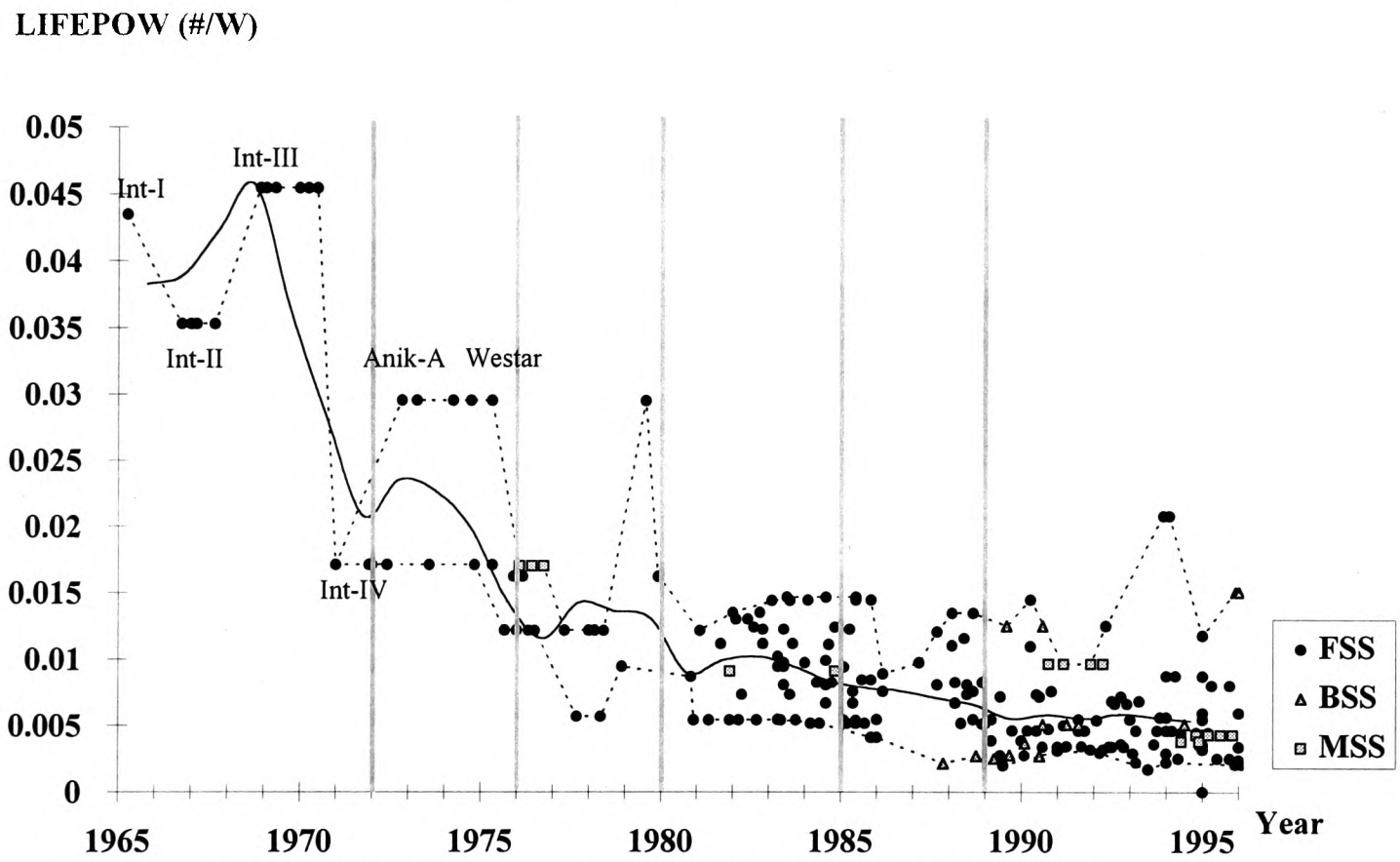


Figure 2.18: Lifetime per unit of total power at launch for the sample period (1965-96). The continuous line represents the yearly moving average (smoothed), and the dotted lines, the envelope of the sample.

During the pre-76 period, the decrease in lifetime to power ratio can be qualified as the 'learning-to-fly' period in the satellite communication history. This sharp diminution at the beginning of the advent of a new technology is characteristic to learning-by-doing. The gradual diminution since the 1980s is related to the improvements in energy storage (in batteries) and solar power conversion into electrical power mentioned above.

2.2.4.4 Evolution of signal quality

During the late 1970s and early 1980s, the first mobile telecommunication satellites, Marisat and Marecs, were launched with high quality signals (corresponding to high EIRP) but very small capacity (relatively low bandwidth). Also, from the

[17] Because lower frequency signals are less attenuated, satellites communicate with mobile terminals via the L band and use the C band to communicate with fixed ground stations equipped with higher gain antennas.

beginning of the 1980s, high-power direct-broadcasting-satellites (HP-DBS), to be launched from the mid to late 1980s, started to appear, and the power they required was considerable compared to other types of satellites, hence their high EIRP values. Note that TDF, TVSat and Tele-X are all based on the same design produced by the Eurosatellite consortium. Figure 2.19 illustrates a typical example of this change in the demand structure.

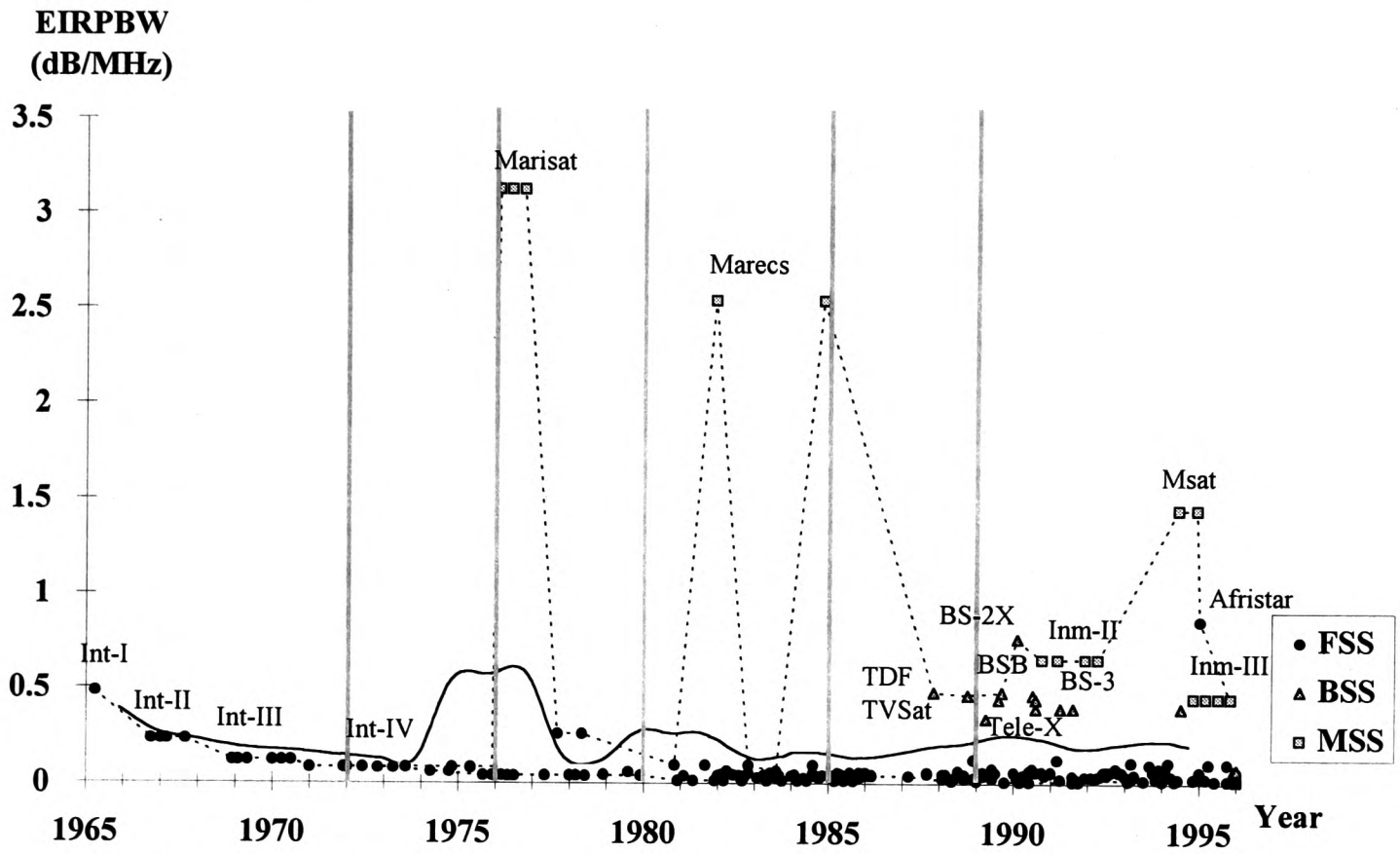


Figure 2.19: Effective Isotropic Radiated Power (EIRP) per unit of bandwidth at launch for the sample period (1965-96). The continuous line represents the yearly moving average (smoothed), and the dotted lines, the envelope of the sample.

The BS satellite series are Japanese direct broadcasting satellites, and if data on BSE, the direct broadcasting Japanese experimental satellite was available, it could be singled out on the graph as well. BSB represents the British Satellite Broadcasting Marcopolo series that was later sold to Norway and Sweden when British Satellite Broadcasting merged with Sky Television to form British Sky Broadcasting (BSkyB). The second generation of mobile communication satellites, Inmarsat II and MSat, were launched in the early 1990s with a greater capacity than their predecessors. Because mobile satellites still require less bandwidth than broadcasting ones to provide their services, the former have slightly higher EIRP to bandwidth ratio than the latter.

Figure 2.20 shows the evolution of spacecraft capacity by illustrating the transponder to bandwidth ratio. Because mobile telecommunication satellites have a much greater transponder to bandwidth ratio than other spacecraft, they have been excluded from this graph. As illustrated on this graph, after the third series of Intelsat, the bandwidth per transponder was relatively stable to 36 MHz per transponder. From the beginning of the 1980s, Ku band transponders with 54 MHz bandwidth made their apparition. In general, more varied applications requiring different bandwidth were introduced during the course of this decade. It is interesting to note that European direct broadcasting satellites possess a slightly greater transponder to bandwidth ratio than other satellites.

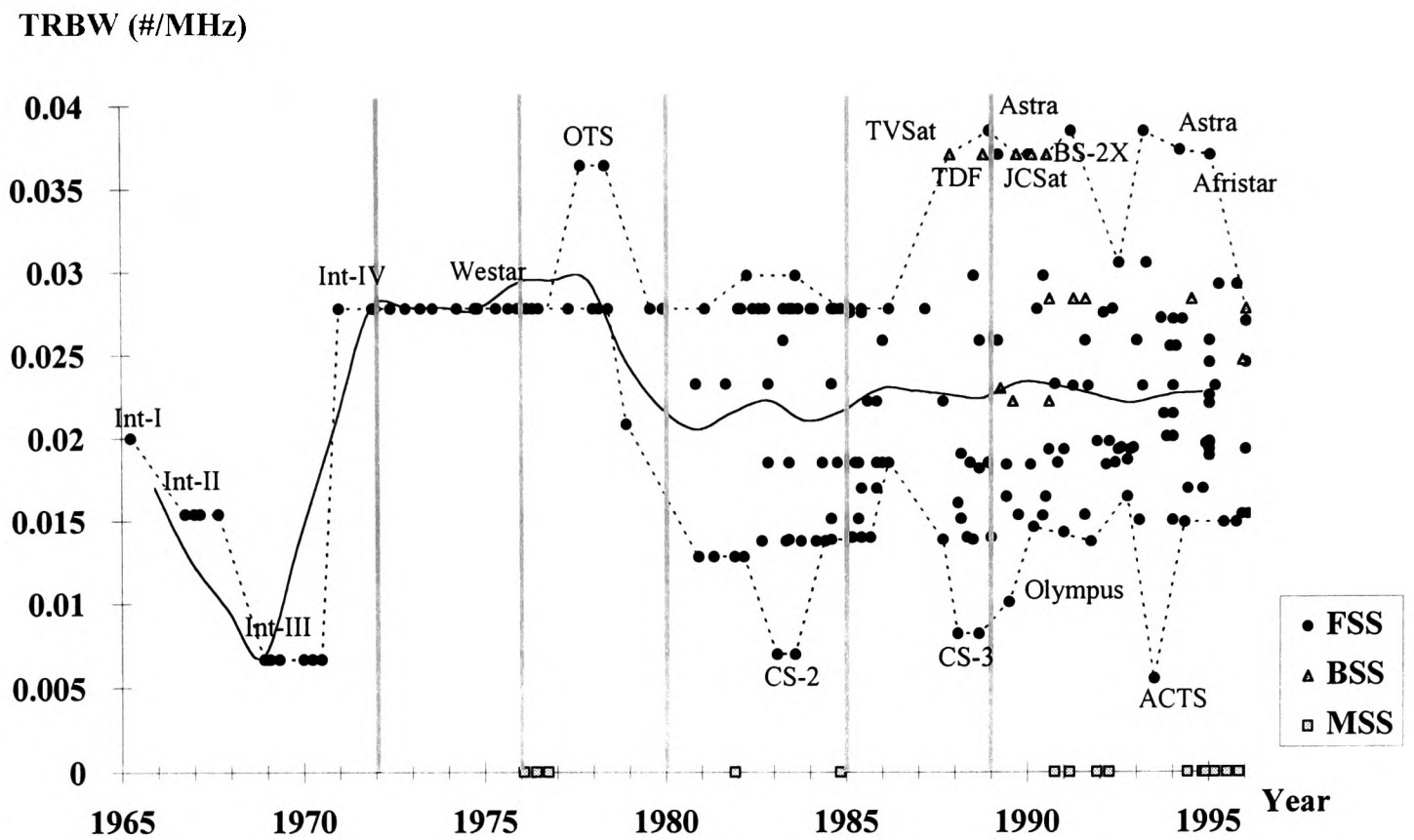


Figure 2.20: Number of transponders per unit of bandwidth excluding the mobile communication satellites at launch for the sample period (1965-96). The continuous line represents the yearly moving average (smoothed), and the dotted lines, the envelope of the sample.

From the analysis of the characteristics of the satellites included in this study, we can now examine briefly the case of product differentiation. In the commercial communication satellite industry, both horizontal and vertical differentiation are present. Horizontal differentiation appeared with the launch of direct broadcasting satellites and mobile satellite services. As was noted earlier, both BSS and MSS require higher amplifier power than fixed satellite services. Furthermore, very different customers generally provide these types of services. Apart from the high power, these satellites are relatively similar to FSS spacecraft. Vertical product differentiation, however, dominates as the main driver behind the evolution of commercial communication satellites. All customers generally agree that more bandwidth, higher power, longer lifetime and greater ground coverage constitute the most desired bundle of satellite characteristics.

2.3 Three generations of commercial communication satellites

Although Euroconsult (1994) classifies satellites by their launch date for simplification reasons, this makes little sense for the research presented in this thesis because satellites are usually contracted for in groups of satellites belonging to the same system. In this thesis, satellites will thus be classified by their award date, i.e., the date on which the contract was allocated to the prime-contractor. So to date, three generations of communication satellites can be distinguished from the graphs presented in the first two chapters, each of them consisting roughly of two of the cycles identified in the first chapter; a first generation from 1964-1975, corresponding to the period before the second stagnation in orders; a second generation of satellites from 1976-1984, corresponding to the period between the last two halts in purchases; and a third generation from 1985, corresponding to the period after the last stagnation

in orders. It is common practice in the communication satellite literature (Euroconsult, 1994) to exclude the first three Intelsat families, Intelsat I, II and III, from this first generation of commercial telecommunication satellites as their characteristics differ completely from that of the 1970s satellites because the technology was still in its infant stage during the 1960s. These early designs will however be included here because they represent the fast technical development typical of a new industry.

The main distinctions among these three generations, apart from the decades in which they lie, are the power, the lifetime and therefore the mass of the satellites to be launched. The link between these three characteristics follows from the fact that increased lifetime or power both result in higher launch mass as more on-board propellant reserves are required. The first generation was characterised by satellites of less than 800 kg and an average lifetime of 6 to 8 years, although the first satellites to be launched were much smaller, lighter and less long-lived. Even though the first generation is said to have been completely launched by the late 1970s, in reality, these types of satellites totally disappeared only in the late 1980s. In other words, even when the second generation of civil telecommunication satellites were being launched, some customers did not need or trust the new technology employed by the new generation, and so preferred smaller satellites. Additionally, the second generation of commercial communication satellites was dominated during the 1980s by satellites of longer lifetime (around 8-10 years) weighting 800-1500 kg. Surprisingly the second generation of satellites, the medium-sized spacecraft, employed in the 1980s, are still being used to replace some second-generation systems as well as to satisfy the emerging domestic needs of developing countries like Turkey and Thailand. Although these types of satellites accounted for half of the launches from 1992 to 1996, there exists a third generation of commercial communication satellites which weight approximately more than 2500 kg and should operate for 10-12 years. For example, the last generations of Intelsat satellites are designed to have launch masses ranging from 3500 to 4600 kg. Furthermore, some satellites still at the design stage will probably have a lifetime of 15-20 years, which is close to that of transoceanic cables. However, unless the payloads can be reconfigured partially during the lifetime, obsolescence might become a limiting factor for expanding lifetime of any type of satellite. Thus, it may not be in the interest of customers to order such long-lived satellites. Because the technology will become obsolete by the end of the satellites life, they may become less profitable than a newly designed satellite.

Ignoring the first three Intelsat satellite families, the separation between the first and second generations is clearly illustrated by figure 2.20. Indeed, towards the end of the 1970s, which corresponds to satellites ordered before 1976, the number of transponders decreased with respect to the total satellite bandwidth. Two relatively stable levels are thus obtained before and after this period. The second transition, between the second and third generations, is less obvious on these comparative graphs, but is, nevertheless, notable on the number of transponders to mass (figure 2.13) and to total power (figure 2.14) ratios. After a steady decline of these ratios during the course of the second generation, around 1990, an increase is noted in the former, while the latter stabilises. These three 'vintages' will play a greater role in the next chapter where hedonic regressions will be separated into three time periods.

2.4 Conjecture on the economic significance of the variables

In section 2.2.2, basic characteristics of communication satellites were transformed into quantitative variables. Pre-empting the ensuing chapter on hedonic regressions, a conjecture on the evolution of the effect of these variables on the contract price of satellite series will be examined here.

As the chosen sample period includes the first commercial applications of satellite communication, we would expect the coefficient of *rdev*, the real development time, to be positive at the beginning of the period, because the process was still experimental, and contracts were more flexible to cost overruns. This variable should lose its significance, or its coefficient even become negative as the bidding process brings conformity among manufacturers (slow producers consistently loosing the bid to faster ones).

Regarding *gtomass*, we would anticipate a strong positive influence on the price at the beginning of the era, but decreasing with time as miniaturisation and signal compression render the mass more a design consequence than a constraint. Possible attenuating factors to this trend are the introduction of larger, more powerful launchers which reduce spacecraft mass and volume restrictions, increasing lifetime of spacecraft requiring greater quantities of propellant, as well as the advent of more intelligent satellites with greater on-board processing. Amongst engineers, the mass is commonly used as a rule of thumb to approximate the price of satellites, so its significance should not be negligible. Similarly to the mass, *eolpower* has increased steadily over the years, but slightly faster (refer to figure 2.15). In contrast to the mass, however, no software enhancement exists in the case of total satellite power. Because of the introduction of new types of batteries in the second generation, we foresee an increase in the importance of *eolpower* in the price at that time, followed by a decline in significance, as more manufacturers incorporate this new technology in their design. Moreover, as observed in figure 2.18, *lifetime* was an important characteristic compared to the total spacecraft power before the 1980s. During those years, launch mass was the critical constraint, and extra operating years implied as much as doubling the quantity of positioning fuel. Therefore, as satellites increase in complexity over the years, the influence of the quantity of propellant on the price should decrease to the benefit of other more sophisticated parts. We postulate that increasing on-board fuel is a compromise to the detriment of the satellite complexity, and as a consequence, lifetime should have a negative impact on the price after 1980.

Note here that the number of transponders is not the sole measure of satellite complexity. As a result, *sumtr* will not necessarily reflect the mirror image of *lifetime* in terms of coefficient importance. Indeed, software compression techniques will certainly have an influence in this matter. This variable should, however, have a positive effect on the price of the first generation of commercial communication satellites. Additionally, in the first period, *ctrp* should not be significant because the majority of satellites employed this frequency band. With the introduction of the Ku band (represented by *kutrp*), this should however change. It is difficult to make any prognosis as for the percentage of low frequency band transponders (*mtrp*), because of their specific, and rather rare, use outside non-mobile communication satellites (*otrp* will be omitted to avoid multicollinearity). Postulating that hybrid satellites are more expensive then less complex spacecraft, a higher percentage of a given frequency band should therefore have a negative effect on the price. Also related to the total number

of operating transponders, is the total satellite bandwidth, *totbw*. Bandwidth was not an issue in the first few years, but became increasingly important as television networks and telecommunication systems relied even more on satellites for some of their long-distance services. Consequently, before the advent of software compression techniques enhancing the physical satellite bandwidth, this variable should have a positive effect on the price. Afterwards, the significance of total bandwidth is ambiguous.

During the first decade of the sample, amplifier power, *hmpower*, represented a greater proportion of the total satellite power than it does nowadays. As a consequence, we postulate that the coefficient of this variable will have a strong positive effect on the price at that time. As improvements in antenna gain increase the effective isotropic radiated power, *gmeirp*, the positive effect (on amplifier power) should be transferred to this latter variable. In other words, these two variables should move in opposite directions, increasingly positive and negative for the coefficients of *gmeirp* and *hmpower*, respectively. A mitigating factor in the case of amplifier power resides in the introduction of HP-DBS requesting more than 150 W in power. This effect should, however, be noticed in the dummy variable *service*. In the early period of satellite services, only fixed satellite services existed, for this reason, we expect the coefficient of this variable not to be significant before the mid-1980s, and have a positive influence from then on, as mobile and broadcasting satellite services develop.

Three-axis stabilisation, represented by the dummy variable *D3a*, was first introduced in the 1970s. As for most new technology, customers had to pay a premium for it, and we postulate that within the first decade of its introduction, this dummy variable will have a positive effect on the price. As the old technology is slowly abandoned (although not entirely), the significance of this variable should diminish, indeed even disappear. Another dummy variable representing a new technological advance is represented by the type of power amplifier utilised in transponders. As mentioned in section 2.1.2.2, solid-state power amplifiers are the most recent amplifying technology employed in communication satellites. Consequently, the coefficient on the dummy variable representing the type of amplifier, *Dtwt* (taking the value 1 if only travelling wave tube amplifiers are utilised), should be non-significant before the introduction of the first SSPAs, and negative afterwards, as this old technology is cheaper.

With this brief overview in mind, the next chapter will study in more details the effects of satellite characteristics on their price.

2.5 Conclusion

In the case of complex goods involving high technology, it is very difficult to understand supply and demand without prior knowledge of the nature of that product. Therefore, the ultimate goal of this chapter was to introduce the technology intrinsic to satellite communications, and particularly, to the satellite itself. In a first part, the basic architecture of a satellite system was described as a ground and a space segments. Only the space segment is of importance in this thesis and thus followed an account its components. In a satellite, the platform supports, protects and provides energy to the payload, which receives, processes and transmits the signal to earth. Each of these two main constituents of a spacecraft are also composed of various subsystems which must be assembled in such a way as to occupy the smallest possible

volume (to fit into the allocated launch bay), and weigh less than the mass permitted by the launch vehicle (recall that the price of launch services is roughly proportional to the launch mass of the satellite). Various compromises are necessary in order to respect such constraints. For example, the spacecraft lifetime is limited by mass restrictions because of the weight budget allocated to on-board propellant. Furthermore, satellite capacity is affected first by volume constraints, but also by the amount of power requested by these transponders, which in turn has an effect on the mass by requiring a greater number of batteries and more substantial solar arrays, and so on.

Once all this engineering jargon had been assimilated, satellite characteristics were converted into quantifiable variables. 17 variables were identified, and the evolution of their basic statistics was then examined. To be consistent with the previous chapter, the same 6 sub-periods were used to compare the variables across time. Some variables evolved quite rapidly to stabilise in later periods, such as the total satellite bandwidth and amplifier power; others increased steadily, like the mass and total power; some even decreased after an initial augmentation, this is the case for the real development time. It was then discovered that these characteristics not only vary across time, they also differ across satellite producers and purchasers. After this initial study of the characteristics, they were analysed from a comparative point of view. Variables related by design compromises were divided by one another, and the ratio obtained was plotted against time. The ratio of the number of transponders to the mass did not vary as much as expected, but when compared with the total power, the transponder to power ratio decreased from the mid-1970s. An interesting breakdown of the demand pattern was noticed in the comparison of amplifier power to total power and to total bandwidth. Indeed, direct broadcasting and mobile satellite series formed clusters separated from the fixed satellite service group. Three generations, by groups of two sub-periods each, where then identified from all this technology analysis. Finally, the variables studied in this second part of the chapter where then examined in order to evaluate their effect on the price of satellite programs. This last section constitutes a prognostic on the hedonic regression results that will be presented in the next chapter.

Chapter 3

Hedonic price regressions

3.1 EVOLUTION OF COMMUNICATION SATELLITE PRICES 95
3.2 THEORY AND DATA 98
3.2.1 Literature review 99
3.2.1.1 Hedonic regression methods 99
3.2.1.2 Alternative methods 101
3.2.2 Model 102
3.2.2.1 Assumptions 103
3.2.2.2 Specification issues and concept of complexity 104
3.2.3 Data 106
3.3 HEDONIC REGRESSION RESULTS 107
3.3.1 Pooled regressions 107
3.3.2 Different manufacturers 118
3.3.3 Different customers 124
3.4 PRICE INDICES 131
3.4.1 General price indices 132
3.4.2 Different manufacturers 136
3.4.3 Different customers 137
3.5 CONCLUSION 139

3. Hedonic price regressions

While the previous chapter focused on the technical characteristics of commercial communication satellites, this chapter will concentrate on satellite prices over the years, and particularly try to explain how the evolution of spacecraft characteristics affected their price. The relationship between commodities, commercial communication satellites in our case, is determined by the vector of characteristics described in the previous chapter. We know the price of each of these spacecraft, that is the unit cost to the customers. The general question that this chapter will answer is what is the willingness of the customer to pay for these characteristics? This is a two-fold question about how does the willingness to pay change over time and across customers. The theory of a simple industry for the hedonic regressions implies a homogenous group of customers as well as a homogenous group of suppliers. The first source of change is the technical characteristics, i.e. the demand for services; with partitioning of the sample over the three distinct technological eras described in the first chapter, do we get a willingness to pay that shifts over time? The second source of change refers to the segmentation of the market as we do not have a homogenous industry. The US and European markets are segmented as they only order from particular manufacturers. This raises the possibility of a monopoly situation with cartel pricing within the sub-markets. It is also possible that each sub-market has a different pricing formula. An indication of this from the hedonic regressions would be a relation between characteristics and the price which is not invariant by location. Either customers' tastes are different and can be paired with manufacturers nationally, or regionally for Europe, or different conventions in pricing among manufacturers apply in different parts of the world. This second question will be briefly addressed in this chapter, but will constitute the focus of the fourth chapter. This justifies the separation into three generations, to investigate whether within each time period, the different buyers and sellers have an influence on the market.

The chapter is divided as follows. In the first part, the evolution of commercial communication satellites and its crude relationship with some characteristics will be examined in the form of price/performance ratios. Then an account of the theory underlying the model will be presented, hedonic regressions as well as alternative methods will be compared so as to choose the best functional form in our case. Subsequently, our model will be developed alongside the necessary assumptions. Next, the statistical analysis of these models will be presented in three parts: first, the regressions for the entire sample as well as some subdivisions over time will be explored; then, the sample will be divided according to the region of production; and finally, an account of the different taste for characteristics across various regions of ownership will be presented. In the end, hedonic price indices will be constructed using the results from the regressions mentioned above.

3.1 Evolution of communication satellite prices

This chapter is concerned with the price of commercial communication satellites and its relation with these technical characteristics. Examining figure 3.1, it can be noticed that the 6 sub-periods mentioned in the first chapter are clearly identified by the temporal evolution of the average price of satellites: the stagnation in orders of 1971 and 1979 are marked by local minima, while the slow down in orders of 1975 and 1984 represent a change in the price trend, from increasing to decreasing

with time. In the latter part of the sample, sub-periods are not as clearly marked, but the 1988 sub-period marker still illustrates a change in the trend, from slow decrease to sharp decrease. But prices on their own in the context of a high technology good do not necessarily make sense. As a convention for the next four graphs, the dotted line represents the yearly average, and the solid line, its moving average.

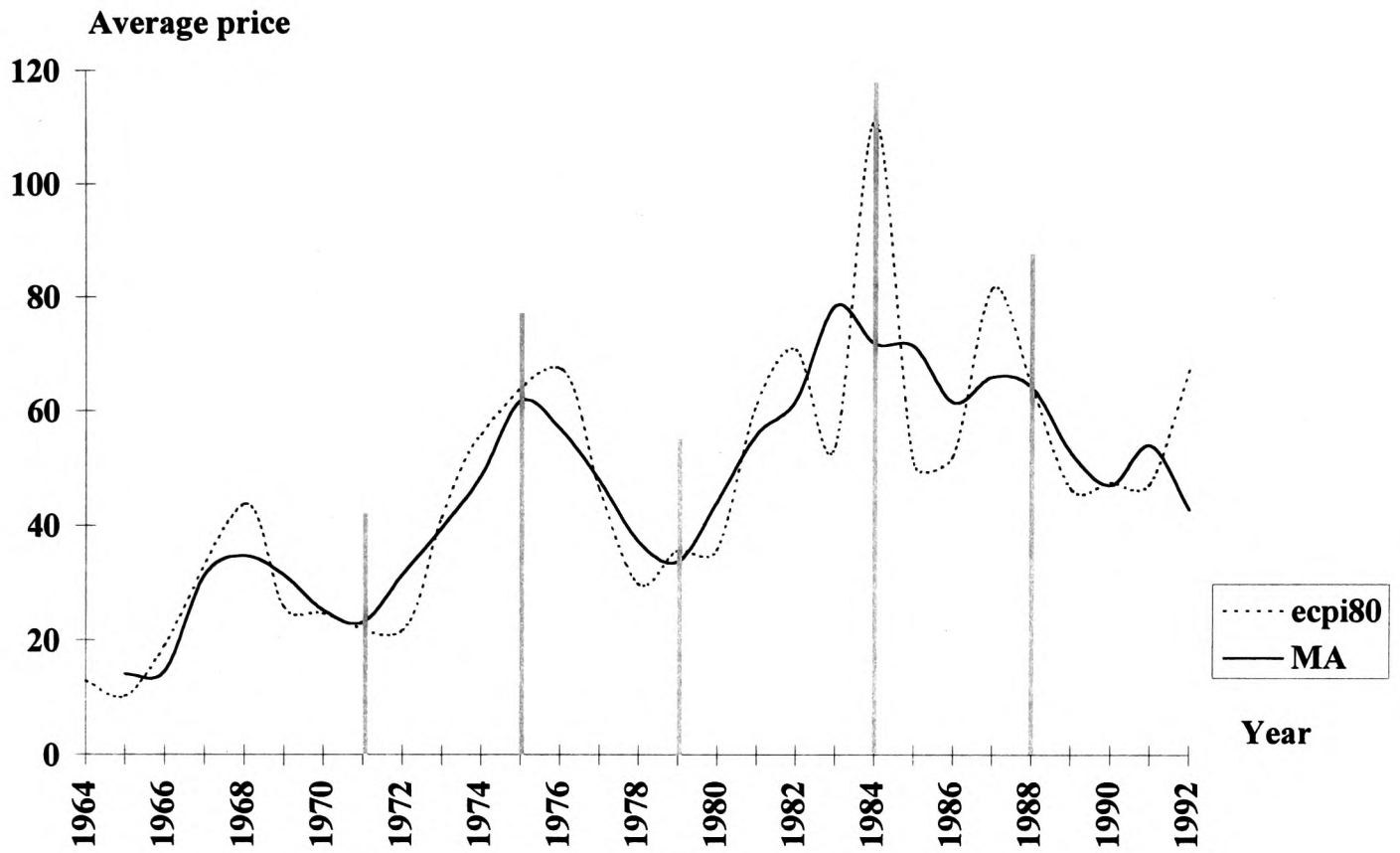


Figure 3.1: Evolution of average price (deflated by the CPI, 1980 = 100).

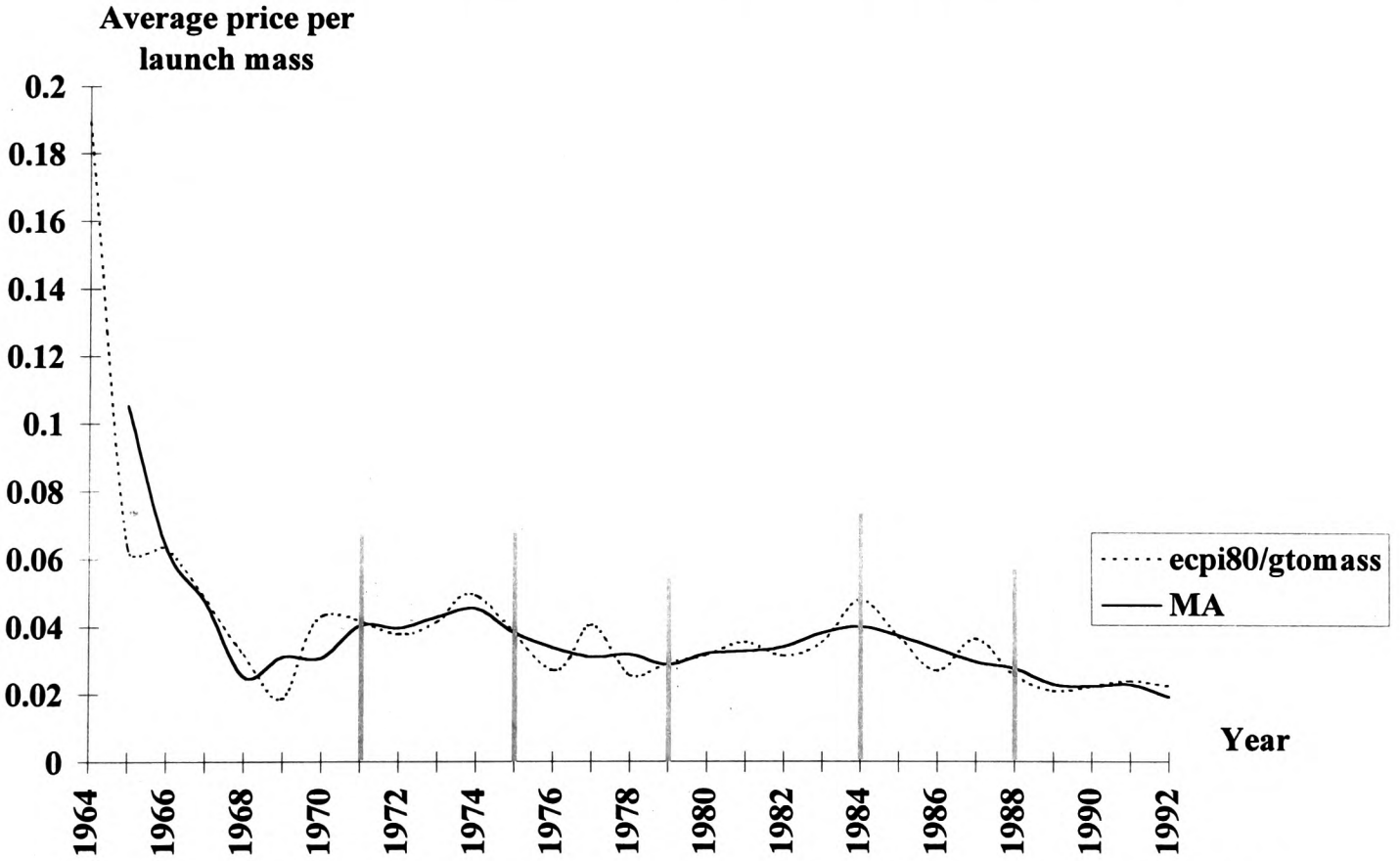


Figure 3.2: Evolution of average price (deflated by the CPI, 1980 = 100) with respect to launch mass.

A common practice amongst engineers in the industry is to compare the price of satellites with their mass. This method is based on a 'rule of thumb' which consists of estimating satellite prices by a factor multiplying their weight. Figure 3.2 illustrates this 'rule of thumb' and shows that the price to mass ratio is relatively stable from the

early 1970s, but is slowly decreasing by about half its value from then on. Note that this price performance ratio appears more stable than the price of satellites alone because of the fast increase in launch mass during the first sub-period of the sample.

Other variables were compared with the price with less success that the mass. On the one hand, figure 3.3 shows the ratio of the price with respect to the number of transponders, which, is a measure of capacity; Recall that in the first chapter, the number of transponders was used as a measure of stock capacity launched. On the other hand, figure 3.4 presents the price per signal 'performance', which is generally measured by the EIRP.

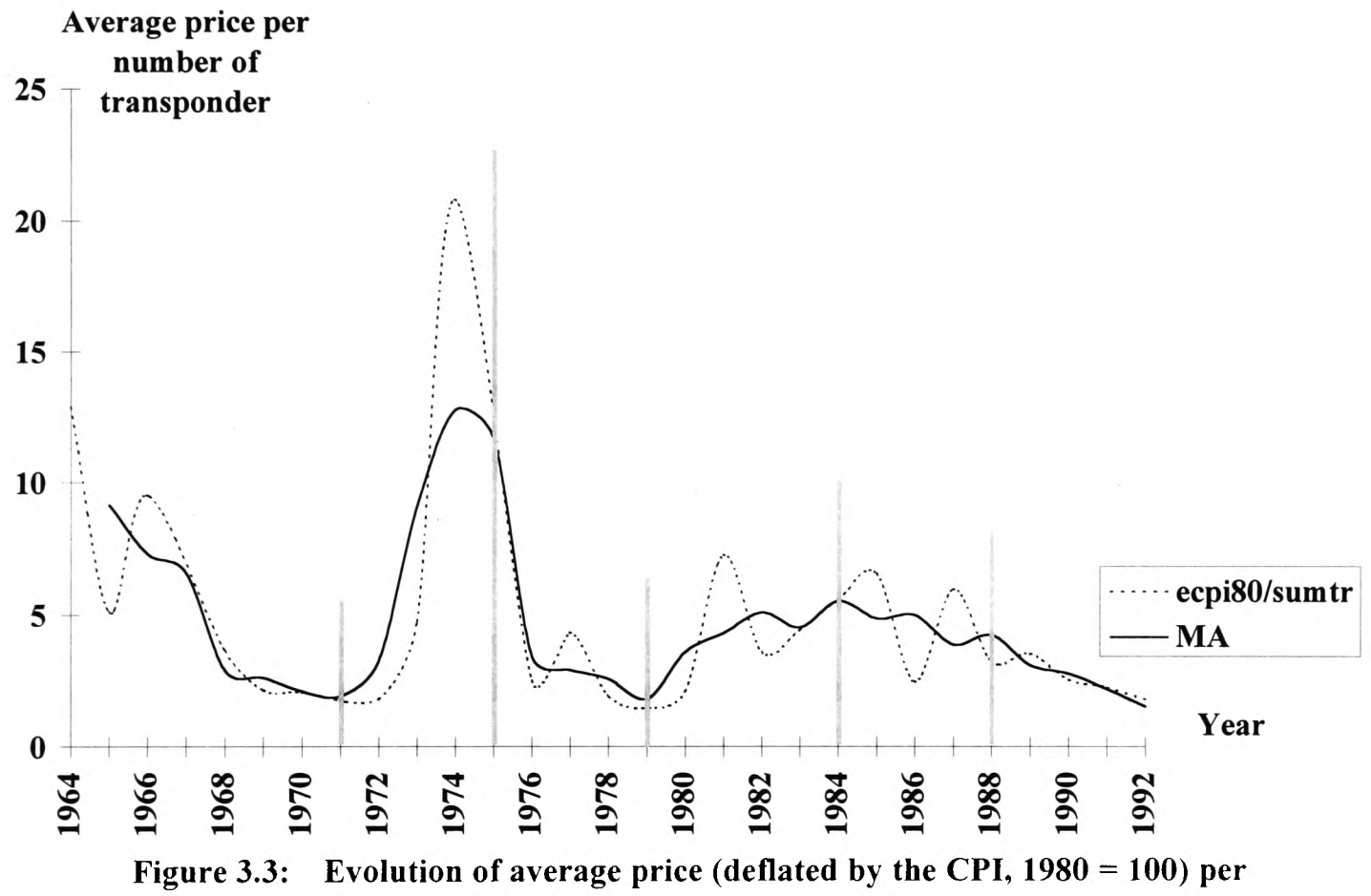


Figure 3.3: Evolution of average price (deflated by the CPI, 1980 = 100) per signal capacity (number of transponders).

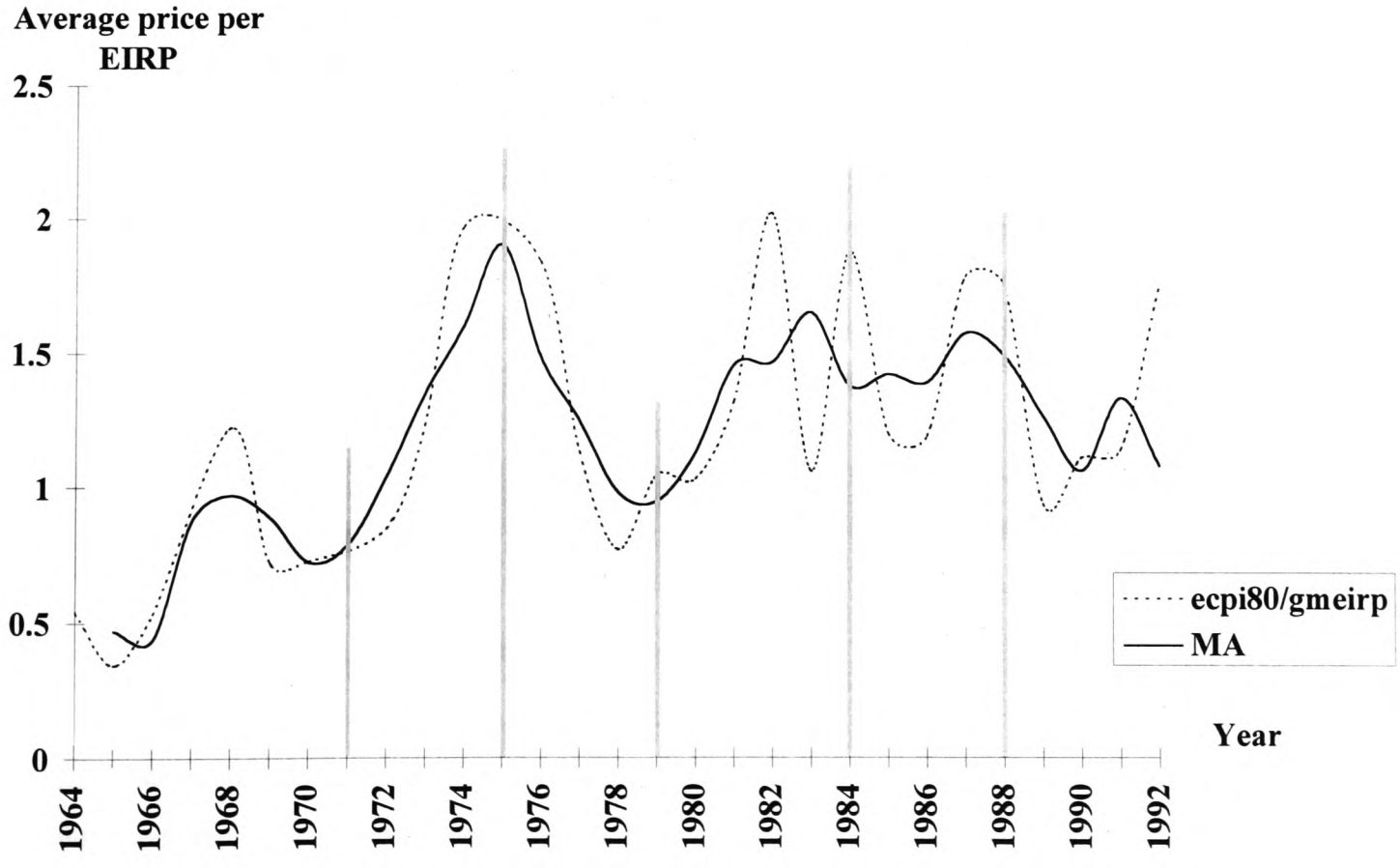


Figure 3.4: Evolution of average price (deflated by the CPI, 1980 = 100) per average EIRP.

The Effective Isotropic Radiated Power basically measures the power of the signal transmitted to different points on the surface of the planet. It gives indications on the size of antennas and capacity of receivers necessary to properly process the transmitted signal, so in a sense, it is a measure of performance. Unfortunately, neither capacity nor performance measures provide a near-linear relationship with the price as the launch mass does. It is often believed, in the space industry, that the mass is a consequence of satellite characteristics rather than an intrinsic 'component'. Following this line of idea, the price is then a consequence of the mass which in turn depends on the satellite characteristics. We believe that this may be the case on average (in the long run), but that this engineering rule of thumb is not precise enough in the short run, and a combination of characteristics would probably better explain the price. This is where hedonic price regressions prove useful.

3.2 Theory and data

Satellite manufacturers and customers estimate costs using two types of methods: analytical and technical approaches. The analytical method divides the manufacture of satellites into well-known simple tasks for which the cost is known. As a consequence, this method is perfectly adapted to the structure of each firm. The case of new technology can be easily estimated by analogy with similar products. The technical approach is simpler in order to be more portable and adaptable to different problems. This method divides the technical characteristics of satellites into smaller quantities and then calculates the cost using a complicated cost equation. The number of transistors of each type is an example of the smaller quantities entered in the cost estimation. Within the technical approach, two types of analysis can be distinguished: analogic and parametric methods. The former estimates the cost of a product by direct comparison with the past production of a similar product. Experts judge whether to increase or decrease the cost of some elements depending on the compared complexity between the old and new products. The cost of each sub-system depends on different cost drivers. Whereas the analogic methods are particular to each firm, the parametric methods are generally commercial software packages such as ECOS[1], FAST[2] and PRICE[3], that use the same aggregation of detailed characteristics in their evaluation.

The capacity and quality of civilian commercial communication satellites have improved dramatically since Intelsat I. Moreover, few satellites are produced every year, and the capacity increases for each satellite produced. As a consequence, quality change in this industry presents serious problems for economic analysis. In some ways, the hedonic approach shows great similarities to the parametric methods used by engineers in assessing the cost breakdown of their product. The hedonic method also uses technical characteristics of products, though not in such extensive details[4] as engineers would, as a measure of its cost. Indeed, the hedonic regression approach also disaggregates the transaction price of a product into a bundle of

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[1] Software developed by the European Space Agency.

[2] Software developed by Freiman Parametric Systems Inc.

[3] Software developed by RCA now Martin Marietta.

[4] The method employed by engineers accounts for every single electronic component included in the design, and that includes engineering models, flight models as well as the actual spacecraft. Engineering and flight models are preliminary prototypes of the spacecraft developed to test its specifications.

characteristics. Under the hedonic hypothesis, the price of the product is represented by an aggregation of the implicit price and quantity of the characteristics. In this case, hedonic regressions will be employed to evaluate how the willingness to pay for satellite characteristics has evolved over time.

3.2.1 Literature review

Although an extensive review of engineering cost estimation methods would be very enlightening, this is not the main purpose of this thesis as the required extremely precise data is not available. As a consequence, because engineering cost estimation methods will not be employed, the following paragraphs will present a brief review of the relevant hedonic price indices' literature.

3.2.1.1 Hedonic regression methods

Mentions of hedonic functions first appeared in the literature with Court (1939), Waugh (1928). Lancaster (1966), Griliches (1971) and Rosen (1974) are more contemporary and have re-launched the hedonic method as a technique to measure technical evolution. The basic hedonic function is represented by $P = h(c)$, where the price, P, is a function, h, of characteristics, c. Hedonic price indices are generally calculated by adding time dummies to the hedonic function (Triplett, 1987). But time dummies are by no means the only way to calculate a price index, a more general characteristics price index of the subsequent form can also be calculated:

$$P = p\left(h(\cdot), q^*\right) = \min_c \left[h(c) : q(c) = q^*\right] \tag{3.1}$$

$$index = \frac{\left[p\left(h(\cdot)_1, q^*\right)\right]}{\left[p\left(h(\cdot)_0, q^*\right)\right]} \tag{3.2}$$

where q is the utility function.

An advantage of such an index is that it allows substitution between characteristics as their cost changes from period to period. The hedonic price index calculated from time dummies fixes the shadow values of the characteristics for all the time periods included in the regression. It is however possible to partially circumvent this problem by splitting the entire sample into smaller sub-periods, evaluating a hedonic price index for each sub-period and constructing a chained index afterwards. Unfortunately, the number of observations being extremely limited in the case of commercial communication satellites, a characteristics price index is impractical[5], and the time dummies version will be used.

Using data collected from various other studies, Gordon (1989) calculates the evolution of post-war computer prices. As well as calculating price indices using the dummy variable method (the price index is calculated by taking the anti-log of the time dummy coefficients), he also uses the imputation method (Triplett, 1989). This third method consists of calculating the predicted value of each observation with the time dummy of the year associated with this observation replaced by the coefficient of the base year, called imputed price. This last method has the advantage of allowing comparison between models of the same year. For example, if the actual to imputed

[5] Indeed, this would require the calculation of a price functional $p = p(h(.), q^*) = min(h(c) : q(c) = q^*)$ for each sub-period or year, and in most cases, there are not enough data in the actual database.

price ratio of a certain model is much higher than the average of all other models of that year, that model is overpriced. In his conclusion, Gordon warns the reader against direct comparison of computer price indices calculated with data including new-models only versus all-models. The former price index reflects the rate of technology change while the latter reflects the influence of old models still in production. Because communication satellites, are generally custom-made, including all satellites in the study may not have the same effect. Moreover, it is relatively difficult to declare satellites as 'identical' since they all differ even within a family of spacecraft.

Dulberger (1989) includes in her study of computer price indices what she refers to as 'technologically induced disequilibrium'. In the market for computers, existing models are sold at higher prices than models incorporating new technology. This occurs because market adjustment is not immediate. To remedy the problem, she adds a technology dummy that groups computer models by technology class. The closest we get to technology class in the case of commercial communication satellites is the three generations defined in the second chapter. And even so, the technology has evolved continuously over the years.

Berndt and Griliches (1993) concentrate on the study of surviving vintages of computers. They evaluate whether they are priced at a premium and how their price varies as new more technologically advanced computers are introduced on the market. Their method consists of using the identity $T \equiv V + A$, where T is the year in which the model is observed, V is the vintage year and A is the age of the model. They suggest that *"a necessary condition for a hedonic price equation to be satisfactory is that the portion of quality change not captured by the characteristic variables should be unrelated to vintages"*. Therefore, hedonic regressions including time, age and vintage dummy variables should be considered for specification testing. All these elaborate calculations are unfortunately irrelevant in the present case as vintages are more or less non-existent and models do not enter/exit the market.

The satellite market is similar to that of hydroelectric dams in the sense that each purchase of a series of satellites is made to measure the needs of each customer. As a consequence, each satellite series, and to some extent each satellite, is unique. Moreover, satellite buyers are not regular customers; for instance, a satellite operator may purchase 3 satellites at one point in time, and another 2 a decade later. The closest the commercial communication satellite industry comes towards vintages is via the three generations of satellites identified at the end of the first chapter. Even so, one cannot say that in between these generations, the technology stayed the same; different sub-systems of satellites evolved at different times within and across each 'vintage' period. Satellite builders improved the quality and capacity of their product to suit their customers' increasing needs for cheaper and better communications.

Other studies examined the software side of the computer industry. Gandal (1994) estimated hedonic price regressions for computer spreadsheet software and found that the quality-adjusted price of these software decreased by approximately 15 % per year from 1986 to 1991. One important feature of this article is the empirical test for network externalities. Because the variables representing compatibility with the Lotus software and with external databases are highly significant, the industry exhibits network externalities. Moreover, consumers value more basic than sophisticated characteristics because the latter are not significant in the regression including all variables. He constructs most of the price indexes with the

method utilised by Berndt and Griliches (1993) to account for interactive dummy variables. A way to measure network externalities in the case of commercial communication satellites would be to incorporate a variable representing the link with terrestrial communication infrastructure[6] associated with each satellite. Unfortunately, such as variable was not available for this study.

Hedonic price indices have been used extensively to account for the quality change in the computer industry. Unfortunately, the commercial communication satellite industry has not been studied in such details and the literature concerning its economic characteristics is extremely sparse. To our knowledge, there has not been any work on constructing hedonic price indexes for entire commercial communication satellites. Naffrichoux (1993) estimated hedonic regressions for satellite sub-systems manufactured by one firm in order to evaluate the cost of this type of equipment.

3.2.1.2 Alternative methods

Gordon's (1990) analysis of the airline industry uses non-proportional quality change method. By non-proportional, Gordon implies the difference in net-revenue from the operation of the capital good and the actual improvement in selling price of that capital good. This kind of study is again impractical in the case of communication satellites, because no data on the operation revenue from these satellites was available for the entire fleet. In his study of commercial aircraft, he uses the price of purchasing aircraft as a durable good, but also performance characteristics and operating efficiency data to calculate a price index. Gordon argues that the conventional specification and the hedonic regression techniques are identical in principle but that their advantages are complementary: the hedonic method provides shadow values for the characteristics included in the study, but does not yield good results if there is a change in the relationship between an included and an omitted variable.[7] Moreover, Gordon declares that the hedonic technique is ill-suited on complex goods when vague characteristics such as comfort are ignored in this analysis. In contrast, the hedonic approach is better suited to goods whose output is homogeneous and easily measured. In the case of communication satellites, it can be argued that measured output is homogeneous: it transmits a certain number electromagnetic signals of certain frequencies; but the opposite, heterogeneity, is also true: signals of even similar frequencies are used for different services: television, telephone, or data transmission. Thus, the case of communication satellites does not strictly abide by these rules as output can only be approximated using the bandwidth capacity of the transponders. Furthermore, since the usage of the capacity changes over time, satellites are rarely fully utilised. Unfortunately, no data was available on the capacity usage of all commercial communication satellites[8].

Cropper *et al.* (1993) compare the hedonic and discrete choice (see McFadden, 1973) approach on data from bidding for a set of houses. They find little

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[6] This could be represented by the number of channels utilised to replace failing ground infrastructure. For instance, Intelsat restored over 4300 telephone circuits linking Europe and the US via the Intelsat-V-F2 satellite when the services on the TAT-3 and TAT-7 transatlantic communications cables were disrupted (April 1986).

[7] Some variables are omitted to prevent multicollinearity or bias caused by quality changes that affect most observations in a given period.

[8] Intelsat annual reports include an aggregated yearly capacity usage of the transponders of their fleet. This is however not available in a disaggregated format (for each particular satellite).

difference between the two models when estimating marginal value of attributes as well as when variables were omitted (specification error), but the multinomial logit model clearly outperforms the hedonic model when valuing non-marginal attribute changes. The fundamental difference between these two approaches is that in the former, customers equate the marginal utility of each characteristic of the good to its marginal price in order to choose their most preferred good, while in the latter, the customer chooses the good that gives the highest utility out of all the goods on offer. Their simulation of the housing market includes information on income from each household, personal characteristics and other goods as well as housing attributes. In the case of commercial communication satellites, such a study would be feasible if specific data was available on each spacecraft customer at the time of purchase and launch. Because of the small number of such type of spacecraft, all customers would have to be included in the study to maintain the sample size to a reasonable level. With a little more time to research the demand-side of the industry, such a study would be possible. Moreover, to implement the methodology of Cropper *et al.*, information about other goods purchased by the satellite operator would be necessary, such goods could be the length of cable to dispatch the signals received from the satellite, number and characteristics of ground stations, number of electronic switches, and so on. This represents a considerable data collection task and was unfortunately impossible within the time available. Further, the feasibility of such a study depends on the openness of the companies involved, which varies between firms and countries. In addition, because of the nature of the technology involved and the increasing tendency towards hybrid[9] satellites, purchasing commercial communication satellites is rather more like buying an office block, where floors and various rooms are leased or rented out to other organisations. Generally, an office block is therefore contracted to be built on the basis of the financial commitment from most of its future occupants. This analogy complicates matters slightly, in the case of communication satellites.

Trajtenberg (1990), used a combination of the discrete choice and hedonic approach to analyse the temporal evolution of CT scanners. He built a two-stage model where the residual prices calculated from hedonic regressions are implemented into a multinomial logit model (MNL). He then analysed a nested multinomial logit model with two branches: one for body scanner and the other for head scanners. This comes from the fact that the decision process involves two sequential decisions: first, deciding whether to buy a head or a body scanner, then which manufacturer to buy it from. These questions also apply to the satellite industry as telecommunication and broadcasting service providers must choose whether to invest in terrestrial (cable, fibre optics, cellular antennas) or space (mainly satellites and ground stations) infrastructure to provide their customers with the 'best' service. Such a study goes beyond the scope of this thesis, as no data was available on the proportion of investment of each category from each communication system operator.

3.2.2 Model

Before developing the functional forms underlying the hedonic price regression model, we will present the assumptions necessary to the application of hedonic functions to commercial communication satellites.

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[9] Satellites are considered hybrid when they incorporate different frequency bands to provide different types of services.

3.2.2.1 Assumptions

Demand for communication satellites is very complex in the sense that satellites have the possibility to offer a wide variety of services. Furthermore, satellite services is not a large number industry. As a consequence, we have to make certain assumptions to render hedonic price indices meaningful. One such assumption is to assume that buyers are price takers (large number assumption).

In the first chapter of this thesis, and in greater detail in Beaudry (1994), the tendering process between satellite operators and manufacturers has been examined. Recall that customers send a request for proposal to potential satellite producers specifying the characteristics[10] of the satellite to be produced. Manufacturers then submit a multiple bid including a price, delivery time and technical characteristics. Then customers analyse these bids and choose one of the bidders. Because of the expensive nature of the bidding process from the producers' part, customers rarely re-issue a second request for proposal. Customers can therefore be treated as price takers because they must choose among these three to five satellite builders. Because of these market imperfections, buyers need not be cost minimisers or competitors, buyers need to have stable profit functions.

Despite the fact that there are so few players in the industry, it will be assumed that the satellite buyers' industry is competitive, and that satellite operators are price takers in their purchasing transactions with satellite manufacturers. The competitive side of the market is the buyers' side if there are enough customers. The presence of Intelsat is not enough to push the market in one direction and destroy competition because they represent less than 25% of the market. Intelsat is just an aggregator of preferences because they vote on everything. They do not have stable transiting ordering preferences, no stable coherence of preferences when they buy a block of satellites. Therefore, it is more appropriate to treat Intelsat as a separate entity each time they order a new family of satellites. The case of Intelsat neither applies to the theory of the firm, which has to be a dictatorship. Furthermore, we will assume that there is no strategic interdependence between buyers that could compromise the assumption of a competitive demand side. Moreover, since the massive trend for liberalisation of telecommunication systems started, the competitive entry condition on the supply side has been validated.

Since in the first chapter it was discovered that the supply industry is not perfectly competitive, interpretation of the price reflects the maximum willingness to pay. For a bundle of characteristics, the price reflects either the minimum cost to the builder or his expectation of what other producers will bid. The data included in this study unfortunately divulge only the winning bid, no other data are available on the other bids.[11]

A problematic characteristic of the producing industry is the lack of perfect competition. The satellite vendors' market is oligopolistic rather than competitive.

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[10] The level of details of the request for proposal depends on the customer sophistication. For instance, Intelsat has its own research and development engineering team which determines the technical specificity of the satellites needed by the organisation.

[11] Empirical analysis of the bidding process was envisaged for the study in Beaudry (1994), unfortunately, such research had to be abandoned because of the secrecy of the satellite producing industry. Understandably, an empirical study of the spacecraft manufacturers bidding behaviour would reveal bidding strategies that the industry is not willing to divulge.

Although, perfect competition is out of the question, neutrality can be assumed without too many compromises so long as we do not have different suppliers who have different technologies. We will assume that all manufacturers are the same (pervasive technology), therefore, customers' behaviour does not affect the price, i.e. buyers cannot use their market power to signal that they will not pay for transponders. This aspect of the industry will be examined further in the next chapter.

In the first two chapters of this thesis, differences between manufacturers as well as between customers from various regions were observed. It is therefore possible that these differences trigger price discrimination. The main problem that price discrimination causes in the interpretation of hedonic price indices is that if there are two groups of customers with differing tastes, for example, and two price indices are obtained, the choice of an index representing the true fall in quality-adjusted prices is difficult. What kind of weighted index should be constructed in order to account for price discrimination? Fortunately, and despite the differences mentioned earlier, there is no strong evidence of monopolistic price discrimination between types or regions of customers in this industry. Intertemporal price discrimination, however, exists in that similar satellites ordered at a later date were found to be cheaper than the satellites of earlier design upon which they were based. The fact that these satellites were bought by non-European countries other than the US does not really affect hedonic price indices because the time delay in orders accounts for the difference in price. In fact, this type of intertemporal price discrimination reveals elements of fixed costs and does not cause the same problems to hedonic price indices that monopolistic price discrimination engenders. The former relates to a learning phenomenon rather than a difference in consumer tastes.

3.2.2.2 Specification issues and concept of complexity

In the commercial communication satellite producing industry, engineers consider the product as an aggregation of components, they have a measure of complexity that differs from the characteristics that customers value. Are there truly two functional forms, one from the engineering view point comprising of the cost of components plus a mark-up; and the other from the customer view point consisting of the price of characteristics? The potential difference in complexity for manufacturers and customers resides in the fact that characteristics of components (transistors, solar panels, etc.) differ from characteristics of output to the customer (number of transponders, EIRP, etc.). For engineers, cost = Σcomponents, while for customers, price = Σcharacteristics. As mentioned above, this industry utilises a software method based upon a $mass^{complexity}$ functional form, cost is non-linear and there does not appear to be any fixed costs in the calculation. The price is therefore proportional to the mass. If the industry exhibits diminishing returns to the complexity, the cost increases by something more than the mass. To all intents and purposes, this ideology considers the mass as a consequence of the characteristics.

The set of variables corresponding to the intrinsic characteristics of the satellite will be grouped in a 'complexity'[12] measure for the hedonic regressions. The number of satellites purchased in each contract should not contribute to this complexity dimension and will be treated as a separate variable in the analysis.

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[12] The concept of complexity will be used extensively in the fourth chapter, and a more complete definition will be provided then.

Whether the satellite mass should be included in the complexity variable is more ambiguous. On the one hand, the mass can be interpreted as a consequence of the complex and necessary technology intrinsic to the spacecraft, in which case it should not be part of the complexity measure. On the other hand, the extent to which space engineers will go to reduce the mass by even a few grams, favours the incorporation of this characteristic. The number of months of development, *rdev*, will be included in the complexity as a measure of innovation. All other variables representing characteristics will be incorporated in the complexity measure.

Because of the small annual production of satellites, and given the increase in their capacity, the basic hedonic equations will be extended to incorporate pooled time series and cross-sections. This will be accounted for, as it is usually done, by including time dummy variable, D_t, for each sub-period but one. These dummy variables will permit the estimation of the parallel shifts in the hedonic surface resulting from the inclusion of time series in the model. We will examine the following functional forms:

$$\textbf{M1: } \ln(p_i) = a + b\ln(nb_i) + c\ln(m_i) + \ln(Complexity_{1i}) + \sum^{t-1} \delta_t D_t + \varepsilon_i \qquad \textbf{(3.3)}$$

$$\text{where } \ln(Complexity_{1i}) = \sum_j \alpha_j \ln(X_{ji}) + \sum_k \beta_k Dx_{ki} \qquad \textbf{(3.4)}$$

$$\textbf{M2: } \ln(p_i) = a + b\ln(nb_i) + c\ln(m_i) + \ln(Complexity_{2i}) + \sum^{t-1} \delta_t D_t + \varepsilon_i \qquad \textbf{(3.5)}$$

$$\text{where } \ln(Complexity_{2i}) = \sum_j \alpha_j X_{ji} + \sum_k \beta_k Dx_{ki} \qquad \textbf{(3.6)}$$

$$\textbf{M3: } \ln(p_i) = a + b\ln(nb_i) + Complexity_{3i} \cdot \ln(m_i) + \sum^{t-1} \delta_t D_t + \varepsilon_i \qquad \textbf{(3.7)}$$

$$\text{where } Complexity_{3i} = \sum_j \alpha_j X_{ji} + \sum_k \beta_k Dx_{ki} \qquad \textbf{(3.8)}$$

$$\textbf{M4: } \ln(p_i) = a + b\ln(nb_i) + \ln(Complexity_{4i}) + \sum^{t-1} \delta_t D_t + \varepsilon_i \qquad \textbf{(3.9)}$$

$$\text{where } \ln(Complexity_{4i}) = \lambda_i m_i + \sum_j \alpha_j X_{ji} + \sum_k \beta_k Dx_{ki} \qquad \textbf{(3.10)}$$

and where in general,

p_i = price of each of the satellites of the i^{th} series,
nb_i = number of satellites included in the order of the i^{th} satellite series,
m_i = launch mass of a satellite of the i^{th} series,
X_{ji} = measure of the j^{th} characteristic of the i^{th} satellite series,
Dx_{ki} = dummy variable for the k^{th} characteristic of the i^{th} satellite series,
D_t = dummy variable for the t^{th} time period,
ε_i = error term associated with the i^{th} satellite series.

We will generally omit the first period time dummy because this period contains a fewer number of observations than the last period, even though we get a

noisier constant term. Moreover, omitting any other period time dummy would make the comparison of the shift of the hedonic surface through time slightly obscure. Hence, *a* represents the intercept for the reference period.

The first three models examined exclude the launch mass of the satellite from the complexity group while the fourth model will treat the mass as part of this complexity. Different functional forms of the complexity will be examined: the first model is multiplicative for the main characteristic variables and additive for the characteristic dummy variables; and the last three models are additive for all the characteristic variables. The third model is based on the engineering cost estimation software employed by the space industry (Naffrichoux, 1993), and is by definition closer to the engineers' calculation of the cost of satellites.

3.2.3 Data

In the second chapter, and particularly in sections 2.2.2 and 2.2.3, technical characteristic variables of the satellites under scrutiny were described and their evolution analysed. In this section, two more variables need to be mentioned: first, the dependent variable, the price of commercial communication satellites; and second, the number of spacecraft ordered in a given contract. Satellite prices were examined earlier and found to vary over time and characteristics. The number of satellites ordered in a given contract has decreased steadily over the years (see table 3.1).

Table 3.1: Evolution of the average number of satellites ordered per contract.

Sub-period	mean	period	mean
1964-71	4.333		
1972-75	2.875	**1964-79**	3.320
1976-79	3.091	**1976-84**	2.474
1980-84	2.222	**1982-93**	1.855
1985-88	1.913		
1989-93	1.677		

Note that the data in its original format listed the total price of the satellite series contracted, but we divided it by the number of satellites ordered to render the price comparable across contracts, i.e. a price per unit. The variable that we will therefore try to explain is the purchasing price of each satellite illustrated by the variable *ecpi80*, expressed in constant dollars[13] (1980s prices). The variable *each* represents the purchase price of each individual satellite in current dollars, and *deach*, its constant dollars value (base year = 1980). The price of each satellite, *each*, is obtained by dividing the price of the satellite series by the number of satellites ordered in the series, and its deflated version *ecpi80*, obtained by dividing the current value by the CPI.

Time dummy variables are added to the model in order to calculate price indices from the hedonic regressions. Yearly regressions are out of the question in the case of commercial communication satellites because of the few number of spacecraft purchased and launched in each year. The time dummy variables are pooled by groups of two to four years corresponding to the 6 sub-periods delineated in the first chapter: *D72-75, D76-79, D80-81, D82-84, D85-86, D87-88, D89-90, D91-93*. The reference

[13] Deflated by the US consumer price index.

period dummy variable *D64-71* is omitted. The three last time periods, 1980-84, 1985-88 and 1980-93, have been subdivided into six sub-periods in order to obtain a more precise price index.

3.3 Hedonic regression results

Using the four functional forms defined above, hedonic regressions will be first performed for the pooled sample. Then, the sample will be split by time period, regions of manufacturing and ownership.

3.3.1 Pooled regressions

Tables 3.2 to 3.5 present the regression results for models 1 to 4, corresponding to equations 3.3 to 3.10. For each model, the first two columns are pooled regressions of the full sample. The last six columns are the split regressions for three overlapping time periods: 1964-79, 1976-84 and 1982-93. All regressions qualified as 'best' in this thesis are obtained when all the variables left in the models, have coefficients significant at the 30 % level. All other variables not respecting this constraint have been eliminated judging their impact on the price negligible. Below the coefficient, in a smaller font, is the t-value with its level of significance represented as stars: three stars for significance at the 1 % level, two stars for significance at the 5 % level, and one star for significance at the 10 % level.

Table 3.2: Regression results, model 1, equations (3.3) and (3.4); dependent variable: ln(*ecpi80*).

Variables	pooled all	1964-93 best	split all	1964-79 best	split all	1976-84 best	split all	1982-93 best
Intercept	-0.9334	-1.49973	1.384755	1.505324	-8.01063	-8.31086	2.856389	2.862343
	-0.614	-1.139	0.445	2.808**	-2.161**	-3.043***	-1.355	3.856***
ln(number)	-0.12528	-0.12383	0.034115		0.055076		-0.04216	
	-1.531	-1.596	0.237		0.344		-0.44	
ln(gtomass)	0.38193	0.415914	0.28439	0.424351	-0.09275		-0.15379	
	2.076**	2.618**	1.083	3.331***	-0.153		-0.646	
ln(rdev)	0.080066		0.483238	0.446026	-0.02329		-0.10639	
	0.74		2.339**	2.804**	-0.097		-0.92	
ln(eolpower)	0.365129	0.38591	0.314271		1.333195	1.215012	0.651854	0.562544
	2.644***	2.923***	0.799		2.639**	5.552***	2.963***	5.225***
ln(lifetime)	-0.22658	-0.22765	0.664357	0.302604	-0.36777	-0.45762	-0.38697	-0.28985
	-1.236	-1.341	1.241	1.183	-0.805	-1.809*	-1.717*	-1.677
ln(sumtr)	-0.23869	-0.326	-0.12371		-1.03796	-1.01969	0.014476	
	-1.629	-3.139***	-0.342		-2.566**	-3.265***	0.085	
ln(totbw)	-0.05076		-0.64655	-0.53818	0.420046	0.412623	-0.06591	-0.1146
	-0.418		-2.473**	-3.689***	1.104	1.983*	-0.484	-1.305
ln(hmpower)	-0.2032	-0.20942	0.13824		-0.44364	-0.53763	-0.21835	-0.1763
	-2.133**	-2.301**	0.469		-1.134	-3.252***	-2.148**	-2.305**
ln(gmeirp)	0.567506	0.662938	-0.34049		1.6181	1.783152	0.222323	
	1.423	1.737*	-0.419		1.63	3.019***	0.484	
D3a	0.118856	0.106145	0.716762	0.599859	-0.40611	-0.41981	-0.03019	
	1.13	1.065	3.965***	5.133***	-1.724	-2.483**	-0.212	
Dtwt	-0.32216	-0.34482			-0.4435	-0.44274	-0.27437	-0.22243
	-2.88***	-3.188***			-1.278	-1.587	-2.345**	-2.197**
service	0.013043		-0.80061	-0.52738	-0.08283		0.077986	0.052944
	0.227		-2.359**	-3.464***	-0.509		1.279	1.088
ln(mtrp)	-1.71702	-1.41379			0.17786		-1.69732	-2.04659
	-2.862***	-3.346***			0.055		-2.86***	-4.388***
ln(ctrp)	-0.76907	-0.66576	0.445993		0.395536	0.671004	-1.01629	-1.18112
	-1.987*	-1.817*	0.194		0.292	1.856*	-2.613**	-4.064***
ln(kutrp)	-0.94168	-0.86704	-0.32485	-0.4793	-0.37874		-1.026	-1.2419
	-2.407**	-2.312**	-0.144	-1.93*	-0.335		-2.284**	-3.289***
D7275	0.128614	0.170869	0.308451	0.342648				
	0.56	0.781	1.199	2.202**				
D7679	0.033631	0.057624	0.071174	0.282879				
	0.14	0.255	0.184	1.54				
D8081	-0.12262	-0.09479			-0.09701	-0.11356		
	-0.49	-0.416			-0.473	-0.857		
D8284	0.018422	0.029452			-0.13558	-0.10141		
	0.069	0.119			-0.575	-0.568		
D8586	-0.38701	-0.36141					-0.40333	-0.38469
	-1.441	-1.433					-2.905***	-3.127***
D8788	-0.03993	-0.06164					0.021701	0.037651
	-0.141	-0.236					0.132	0.258
D8990	-0.35827	-0.3817					-0.36884	-0.31418
	-1.243	-1.394					-2.556**	-2.493**
D9193	-0.19284	-0.21503					-0.3166	-0.24229
	-0.642	-0.795					-1.898*	-1.683*
n	104	104	25	25	38	38	60	60
R^2	0.6754	0.6711	0.9307	0.9192	0.7895	0.7852	0.7197	0.7067
Adj R^2	0.5821	0.5918	0.8152	0.8708	0.6106	0.6944	0.5866	0.6239
F	7.237	8.467	8.056	18.968	4.413	8.641	5.407	8.527

***: significance at the 1 % level

**: significance at the 5 % level

*: significance at the 10 % level

Table 3.3: Regression results, model 2, equations (3.5) and (3.6); dependent variable: ln(*ecpi80*).

Variables	pooled 1964-93 all	pooled 1964-93 best	split 1964-79 all	split 1964-79 best	split 1976-84 all	split 1976-84 best	split 1982-93 all	split 1982-93 best
Intercept	1.374263	1.724554	1.411579	0.994227	-0.23994	-0.87829	3.58825	4.506071
	1.576	2.574**	0.736	1.532	-0.051	-0.337	2.103**	9.084***
ln(number)	-0.12691	-0.12628	-0.0253		0.021034		-0.07454	
	-1.601	-1.68*	-0.161		0.158		-0.763	
ln(gtomass)	0.445212	0.456641	0.266541	0.248954	0.759764	0.812503	0.171287	
	3.329***	3.855***	1.484	1.992*	0.918	1.888*	0.706	
rdev	0.003635	0.004356	0.01142	0.009453	0.005754	0.005915	-0.00096	
	1.599	2.096**	1.994*	2.727**	1.315	1.804*	-0.349	
eolpower	0.000136	0.000122	0.000223		0.000635	0.0006	9.33E-07	
	2.23**	2.436**	0.559		2.302**	3.568***	0.012	
lifetime	-0.05439	-0.04744	0.037381		-0.03018		-0.05583	-0.0473
	-2.224**	-2.067**	0.409		-0.649		-2.043**	-2.208**
sumtr	-0.00096		0.029749	0.028681	-0.03537	-0.0572	0.02602	0.030405
	-0.086		0.749	1.547	-1.198	-4.07***	1.983*	3.758***
totbw	-0.00022	-0.00024	-0.00057	-0.00042	-0.0002		-0.00027	-0.00027
	-1.789*	-3.204***	-1.405	-2.042*	-0.58		-2.124**	-2.286**
hmpower	-0.00155		0.048378	0.019563	-0.00667	-0.00682	0.000581	
	-0.981		1.484	1.209	-2.436**	-4.273***	0.308	
gmeirp	0.010866		-0.02585		0.001293		0.013334	0.016038
	1.14		-0.774		0.064		1.17	1.664
D3a	0.13403	0.146793	0.631265	0.536685	-0.13717	-0.15442	0.210756	0.256526
	1.378	1.585	2.584**	4.279***	-0.771	-1.233	1.561	2.466**
Dtwt	-0.34234	-0.33527			-0.47876	-0.51837	-0.36553	-0.33726
	-2.852***	-2.901***			-1.548	-1.951*	-2.881***	-3.02***
service	-0.02483		-0.19269		-0.01995		0.044835	0.055471
	0.541		-0.762		-0.141		0.905	1.303
mtrp	-1.27752	-1.28599			-1.82444	-1.31917	-1.42057	-1.48355
	-3.516***	-4.138***			-0.691	-1.22	-4.106***	-4.571***
ctrp	-0.63817	-0.77892	-0.1528		-0.45778		-0.87734	-0.96021
	-2.059**	-3.497***	-0.087		-0.517		-2.577**	-3.549***
kutrp	-0.781	-0.82386	-0.3165		-1.07288	-0.78775	-0.90411	-0.96584
	-2.92***	-3.303***	-0.177		-1.445	-4.2***	-3.062***	-3.941***
D7275	0.284469	0.242256	-0.05394	0.051231				
	1.264	1.18	-0.131	0.285				
D7679	0.189823	0.155795	-0.4635	-0.24877				
	0.826	0.729	-0.974	-1.048				
D8081	0.067917	0.038126			-0.11974	-0.12785		
	0.294	0.182			-0.71	-1.031		
D8284	0.257436	0.245614			-0.01311	-0.01145		
	1.005	1.019			-0.064	-0.072		
D8586	-0.21789	-0.22759					-0.42176	-0.42349
	-0.867	-0.989					-2.796***	-3.064***
D8788	0.161605	0.16888					-0.09299	0.062007
	0.593	0.652					-0.536	-0.396
D8990	-0.17915	-0.18267					-0.39513	-0.35547
	-0.669	-0.719					-2.557**	-2.548**
D9193	0.010379	0.025754					-0.29044	-0.2799
	0.038	0.1					-1.698	-1.823*
n	103	103	25	25	38	38	60	60
R^2	0.6802	0.6734	0.8948	0.8746	0.8406	0.8311	0.6944	0.6793
Adj R^2	0.5883	0.5995	0.7195	0.8119	0.7052	0.7596	0.5492	0.5796
F	7.399	9.115	5.105	13.95	6.205	11.631	4.784	6.81

***: significance at the 1 % level

**: significance at the 5 % level

*: significance at the 10 % level

Table 3.4: Regression results, model 3, equations (3.7) and (3.8); dependent variable: ln(*ecpi80*).

Variables	pooled all	1964-93 best	split all	1964-79 best	split all	1976-84 best	split all	1982-93 best
Intercept	3.040419	3.008563	1.633382	1.89536	3.867589	3.776204	4.561109	4.361509
	7.484***	8.757***	2.659**	5.809**	4.872***	7.488***	9.33***	9.912***
ln(number)	-0.09834	-0.08648	-0.04622		0.079911		-0.06861	
	-1.153	-1.056	-0.337		0.693		-0.693	
mrdev	0.00088	0.00096	0.001644	0.00157	0.000755	0.000848	1.63E-05	
	2.855***	3.383***	2.463**	4.299***	1.31	1.799*	0.047	
meolpower	2.13E-05	2.19E-05	5.9E-05	1.91E-05	0.000112	0.000106	6.93E-07	
	2.45**	2.945***	1.471	1.337	5.319***	6.304***	0.07	
mlifetime	-0.00349		0.009068		-0.00457	-0.00541	-0.0055	-0.00579
	-1.04		0.779		-0.733	-1.332	-1.68	-2.03**
msumtr	0.000823		0.004117	0.00613	-0.00393	-0.00361	0.004308	0.004042
	0.533		0.78	2.959***	-1.067	-2.674**	2.8**	3.609***
mtotbw	-1.9E-05	-1.2E-05	-9.2E-05	-7.4E-05	2.53E-06		-3.4E-05	-3.3E-05
	-1.103	-1.137	-1.654	-2.805**	0.07		-2.009*	-2.133**
mhmpower	-0.00026	-0.0002	0.008149	0.007275	-0.00076	-0.00095	0.000158	
	-1.163	-1.1	1.877*	2.702**	-2.22**	-4.347***	0.632	
mgmeirp	0.003265	0.002882	-0.00319		0.001298	0.001728	0.001639	0.002299
	2.577**	2.623**	-0.69		0.586	1.037	1.085	1.808*
mD3a	0.022741	0.023413	0.101405	0.080913	-0.02437	-0.02282	0.032386	0.034345
	1.585	1.716*	3.462***	4.668***	-1.056	-1.289	1.832*	2.451**
mDtwt	-0.0349	-0.03158			-0.05507	-0.05943	-0.04555	-0.045
	-2.041**	-1.995**			-1.345	-1.672	-2.766***	-3.001***
mservice	0.003187		-0.01437		-0.012		0.007633	0.007942
	0.464		-0.457		-0.725		1.148	1.314
mmtrp	-0.14397	-0.14142			0.0405		-0.1927	-0.19392
	-2.691***	-3.232***			0.208		-4.068***	-4.297***
mctrp	-0.07039	-0.0768	0.16001	0.047332	-0.02013		-0.13628	-0.12655
	-1.599	-2.647***	1.118	1.3	-0.18		-3.152***	-3.261***
mkutrp	-0.10548	-0.11705	0.114282		-0.09436	-0.07623	-0.12993	-0.12665
	2.724***	-3.648***	0.608		-1.087	-3.04***	-3.414***	-3.833***
D7275	0.607034	0.622817	-0.03812	0.0296				
	2.779**	3.037***	-0.099	0.161				
D7679	0.422217	0.407615	-0.55809	-0.39459				
	1.85*	1.951*	-1.298	-1.595				
D8081	0.286908	0.270873			-0.06336	-0.11203		
	1.256	1.341			-0.412	-0.981		
D8284	0.45696	0.426346			0.031896	0.026956		
	1.766*	1.786*			0.163	0.175		
D8586	0.044204	0.033884					-0.40913	-0.40289
	0.178	0.154					-2.679**	-2.856***
D8788	0.467098	0.430175					-0.04137	-0.05249
	1.718*	1.734*					-0.242	-0.329
D8990	0.061723	0.029251					-0.38111	-0.35137
	0.231	0.12					-2.436**	-2.484**
D9193	0.22541	0.180703					-0.29476	-0.28881
	0.812	0.735					-1.698*	-1.85*
n	103	103	25	25	38	38	60	60
R^2	0.6258	0.6198	0.9058	0.8932	0.8439	0.8354	0.6798	0.6691
Adj R^2	0.5241	0.5338	0.774	0.8291	0.7249	0.7658	0.5392	0.5661
F	6.157	7.207	6.87	13.936	7.094	11.997	4.836	6.499

Note: the prefix *m* represents ln(*gtomass*)**variable*

***: significance at the 1 % level

**: significance at the 5 % level

*: significance at the 10 % level

Table 3.5: Regression results, model 4, equations (3.9) and (3.10); dependent variable: ln(*ecpi80*).

Variables	pooled all	1964-93 best	split all	1964-79 best	split all	1976-84 best	split all	1982-93 best
Intercept	3.6475	3.800417	-1.203824	1.185979	4.102332	4.277176	4.700581	4.4070805
	6.993***	8.762***	-0.476	2.027*	4.466***	11.607***	8.631***	9.15***
ln(number)	-0.127701	-0.111568	-0.075603		-0.00924		-0.079634	
	-1.583	-1.434	-0.491		-0.078		-0.819	
gtomass	0.000282	0.000271	0.000453	0.000338	0.000725	0.000568	0.000116	0.0001405
	2.834***	3.039***	1.853*	2.885**	2.142**	3.08***	1.037	1.539
rdev	0.004669	0.0051	0.009584	0.010989	0.005567	0.004501	-0.001109	
	2.092**	2.424**	1.677	2.519**	1.386	1.551	-0.413	
eolpower	0.000107	9.006E-05	0.000514	0.000435	0.000423	0.000505	-4.86E-06	
	1.672*	1.574	1.34	1.649	1.744*	3.766***	-0.063	
lifetime	-0.042396	-0.033933	0.070171	0.063382	-0.039713		-0.057946	-0.058021
	-1.766*	-1.523	0.823	1.297	-0.93		-2.183**	-2.744***
sumtr	0.000643		0.006016		-0.065376	-0.061469	0.025668	0.0217657
	0.056		0.142		-2.079*	-5.341***	2.086**	2.343**
totbw	-0.000249	-0.00023	-0.000578	-0.000454	-9.55E-05		-0.000298	-0.000332
	-2.018**	-2.555**	-1.52	-1.958*	-0.363		-2.275**	-2.837***
hmpower	-0.001851		0.038953	0.04173	-0.007652	-0.006342	0.000404	
	-1.135		1.255	1.896*	-3.022***	-4.393***	0.214	
gmeirp	0.01491	0.009311	-0.009171		0.00346		0.014371	0.0201904
	1.546	1.222	-0.283		0.209		1.263	2.327**
D3a	0.149625	0.158319	0.694382	0.663804	-0.086154		0.215689	0.2145838
	1.519	1.673*	3.041**	3.977***	-0.525		1.635	1.967*
Dtwt	-0.303241	-0.30989			-0.357742	-0.426532	-0.370341	-0.384256
	-2.51**	-2.627**			-1.273	-1.882*	-2.864***	-3.792***
service	0.034685		0.184961		0.045665		0.044215	
	0.743		0.622		0.357		0.919	
mtrp	-1.473373	-1.364853		-1.486565	-2.893824	-2.585603	-1.488461	-1.4557
	-3.964***	-4.047***		-1.626	-1.426	-2.365**	-4.358***	-4.657***
ctrp	-0.69106	-0.740605	3.35784	0.629378	0.422014		-0.880037	-0.769766
	-2.203**	-2.994***	1.423	1.94*	0.494		-2.757***	-3.105***
kutrp	-0.88782	-0.913816	2.930634		-0.504631	-0.787357	-0.920081	-0.941521
	3.323***	-3.603***	1.309		-0.801	-4.712***	-3.236***	-3.917***
D7275	0.590805	0.597377	0.118889	0.309341				
	2.63**	2.976***	0.297	1.724				
D7679	0.471718	0.464984	-0.329438	-0.167051				
	1.989*	2.211**	-0.708	-0.628				
D8081	0.360271	0.349606			-0.097569	-0.148933		
	1.474	1.666*			-0.65	-1.319		
D8284	0.525172	0.511866			0.037378	-0.04369		
	1.986*	2.122**			0.201	-0.303		
D8586	0.066149	0.09466					-0.42771	-0.407946
	0.253	0.414					-2.867***	-2.96***
D8788	0.39938	0.420833					-0.11596	-0.104095
	1.482	1.672*					-0.664	-0.657
D8990	0.110702	0.119788					-0.399956	-0.365973
	0.4	0.477					-2.605**	-2.664**
D9193	0.275111	0.307622					-0.295319	-0.247374
	0.974	1.185					-1.743*	-1.625
n	103	103	25	25	38	38	60	60
R^2	0.6692	0.6624	0.9053	0.8939	0.8649	0.8527	0.6987	0.6839
Adj R^2	0.574	0.5811	0.7474	0.8041	0.7501	0.7982	0.5556	0.5855
F	7.035	8.144	5.733	9.956	7.531	15.634	4.882	6.954

***: significance at the 1 % level
**: significance at the 5 % level
*: significance at the 10 % level

As a summary of the general evolution of the coefficients, the following table represents the evolution of the sign of the estimates for the three pooled time periods.

Table 3.6: Sign variation of estimates of the characteristic variables and dummy variables across years and models.

Model	Variable	1964-93	1964-79	1976-84	1982-93	Variable	1964-93	1964-79	1976-84	1982-93
M1	gtomass	+	+	-	-					
M2		+	+	+	+					
M4		+	+	+	+					
M1	number	-	+	+	-	gmeirp	+	-	+	+
M2		-	-	+	-		+	-	+	+
M3		-	-	+	-		+	-	+	+
M4		-	-	-	-		+	-	+	+
M1	rdev	+	+	-	-	mtrp	-		+	-
M2		+	+	+	-		-		-	-
M3		+	+	+	+		-		+	-
M4		+	+	+	-		-	-	-	-
M1	eolpower	+	+	+	+	ctrp	-	+	+	-
M2		+	+	+	+		-	-	-	-
M3		+	+	+	+		-	+	-	-
M4		+	+	+	-		-	+	+	-
M1	lifetime	-	+	-	-	kutrp	-	-	-	-
M2		-	+	-	-		-	-	-	-
M3		-	+	-	-		-	+	-	-
M4		-	+	-	-		-	+	-	-
M1	sumtr	-	-	-	+	D3a	+	+	-	-
M2		-	+	-	+		+	+	-	+
M3		+	+	-	+		+	+	-	+
M4		+	+	-	+		+	+	-	+
M1	totbw	-	-	+	-	Dtwt	-		-	-
M2		-	-	-	-		-		-	-
M3		-	-	+	-		-		-	-
M4		-	-	-	-		-		-	-
M1	hmpower	-	+	-	-	service	+	-	-	+
M2		-	+	-	+		-	-	-	+
M3		-	+	-	+		+	-	-	+
M4		-	+	-	+		+	+	+	+

According to the split regressions per sub-period across all four models, the industry exhibits constant returns to scale due to the near zero estimate of the number of satellites ordered per contract. In contrast, small increasing returns to scale can be observed for the pooled regression. This difference may be attributable to the fact that a similar number of satellites are ordered in the same time period, resulting in the non-significance of the variable *number* in the split regressions, but not in the pooled regression. Table 3.1, presented earlier in this chapter, illustrates how the mean of the variable *number* evolved throughout the different sub-periods. As observed, the average number of satellites ordered per contract is greater than four in the 1960s, around three during the 1970s, around two during the 1980s and less than two in the first half of the present decade. This reduces the impact of the negative coefficient estimates of the variable *number* as an argument towards increasing returns to scale.

As expected, the positive impact of the development and production time (*rdev*) has diminished from the first (1964-79) to the transitory period (1976-84), to become negligible in the last sub-period (1982-93)[14]. It can then be postulated that in

[14] Refer to section 2.4 *Conjecture on the variables economic significance* for a prognostic on the significance of the variables included in this study.

the early days of satellite design, the longer engineers took to produce a spacecraft, the more complex and thus expensive it was. From the 1980s though, satellite design has become less of a craft associated with trial and error, but more a well run process, hence the non-significance of the coefficient of this variable.

Except for the first model where the coefficients are not significant in the last two sub-periods, the satellite launch mass, *gtomass*, seems to vary positively with the price, i.e. the heavier the satellite, the more expensive it is. This result seems to confirm the 'rule of thumb' commonly utilised by engineers to calculate the price of commercial communication satellites[15]. From the point of view of communication satellite operators, lighter and cheaper spacecraft are preferred, while space producers would prefer to design heavier and more expensive ones. This result does not however give any insight on incentives of the form of penalties/bonuses encountered by satellite builders for producing heavier/lighter satellites than was specified in the original contract. Unfortunately, the contract details necessary for this purpose were not available for this research. It is interesting to notice however, that although the coefficients are positive, they are not overwhelmingly significant. Perhaps the attenuating factors mentioned in chapter 2, such as increasingly powerful launchers reducing constraints on spacecraft mass and volume, have some influence.

As for the development time, the coefficient of the variable *eolpower* also looses its significance in the last sub-periods, for the last three models. From 1964 to 1984, the importance of the end-of-life power on the satellite price increased. Customers were then willing to pay more for an increased amount of power. As mentioned in the second chapter, satellite power is one of the key elements influencing the size, power and complexity of the necessary earth stations; the higher the power on-board the satellite, the smaller the antenna required on the ground and therefore the smaller the cost of the earth segment. Because users have to purchase their own mini-ground stations, power is certainly a major factor in the design of direct broadcasting satellites. The more affordable these satellite dishes are, the faster the system will spread, and the sooner broadcasting satellite operations will become profitable. Before the last sub-period, total power was synonym of amplifier power. Only recently, satellites have become more sophisticated[16], requiring more power to perform these additional tasks. As a consequence, customers' preferences have shifted from total power to EIRP (see below).

During the first decade of the communication satellite era, customers were willing to pay more for greater spacecraft lifetime. The situation has reversed since 1976 where the variable *lifetime* has a negative impact on the price. A lengthier lifetime corresponds to a greater quantity of on-board propellant which increases the launch weight of the satellite, and therefore limits the mass allocated to sophisticated instrumentation and its quantity. This has a potentially direct effect on the satellite communication capacity and on the power feeding the transponders.

As envisaged at the end of the second chapter, the results obtained for the coefficients of the variable *sumtr* are not as conclusive across all models than the previous variables were. Estimates are consistently negative for 1976-84 but positive

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[15] This rule of thumb consists of a price per kilogram of satellite weight. See section 3.1.

[16] More processing of the signal is performed on-board satellites requiring a supplement of power, refer to section 2.2.4.3 for more details.

on either side of this sub-period in most models (except model 1). In the first period, the effect of the number of transponders is ambiguous, while in the transitory period, customers are not willing to compromise lifetime and power to pay more for a greater number of transponders, as software compression techniques start to appear and reduce the need for hardware in orbit. In the last period, the pressure on the price from the mass is negligible, hence the return of the positive coefficient of *sumtr*.

An interesting result from these regressions is the fact that customers are not willing to pay more for greater bandwidth capacity in orbit. Coefficients are very negative for the first period, negligible in most cases for the transitory period, and negative again during the last period. A possible explanation for the negative bandwidth effect on the price in the first period, is that satellite communications were a new technology and satellites were rarely utilised to their full potential, hence reducing the need for greater capacity. The need for more bandwidth increased during the transitory period as demand for satellite communication augmented, but was more or less a consequence of the number of transponders. In the last sub-period, however, software compression techniques increased the effective bandwidth of satellites augmenting on-board hardware. Hence the return, in this last period, to a negative coefficient on the variable *totbw*.

In general, transponders of the first generation of satellites used most of the entire power of the satellite. Power was therefore a limiting factor on the expansion of satellite capacity. As a consequence, satellite operators were willing to pay more for amplifier power, hence the positive coefficient on the variable *hmpower*. During the transitory period, this coefficient becomes negative, following the coefficient of the variable *sumtr*. Advents in battery and antenna technology reduced the pressure from the power in the transitory period. For the same reasons as the end-of-life power, amplifier power becomes non-significant in the last period.

Effective isotropic radiated power, EIRP, described in the second chapter as a good measure of signal quality, influences the price positively only in the last sub-period. In the first period, customers are not willing to pay for higher EIRP because of the already considerable size of the ground antennas. During the transitory period, the coefficient of this variable looses its significance, to become positive in the last period. Since the introduction of direct broadcasting satellites, EIRP has become one of the most sought after characteristic in satellite design; the higher it is, the larger is the area where the signal can be received with standard equipment and the greater is the number of potential end-users.

In section 2.4, we postulated that the amplifier power and EIRP should have opposite effects on the price, and this is what we observe from the regression analysis. No formal data was available on antenna gain, but it could have been deduced using equation (2.1)[17]. Figure 3.5 illustrates this calculated antenna gain. Note again that because antenna gain is measured in decibels (dB)[18], improvements are represented in logarithms. In the latest period, the discrepancy between services is so vast that amplifier power does not affect the price anymore. Recall that direct broadcasting services require a greater amplifier power to be received by small satellite dishes.

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[17] Recall that effective isotropic radiated power is related to the amplifier power and antenna gain in the following relationship: $EIRP = P_T G_T$.

[18] For example, the standard formula for the gain in decibels is: $G_{dB} = 10 \ln G_T$.

Indeed, as observed, EIRP takes over in the positive contribution in satellite price. We suspect that this reversal in customers' tastes resulted in the sharp rise in antenna gain observed in figure 3.5. As postulated in the previous chapter, the type of service provided by the satellite, denoted by the variable of the same name, becomes weakly positive in the last sub-period, thus illustrating the fact that satellite operators pay more for HP-DBS satellites.

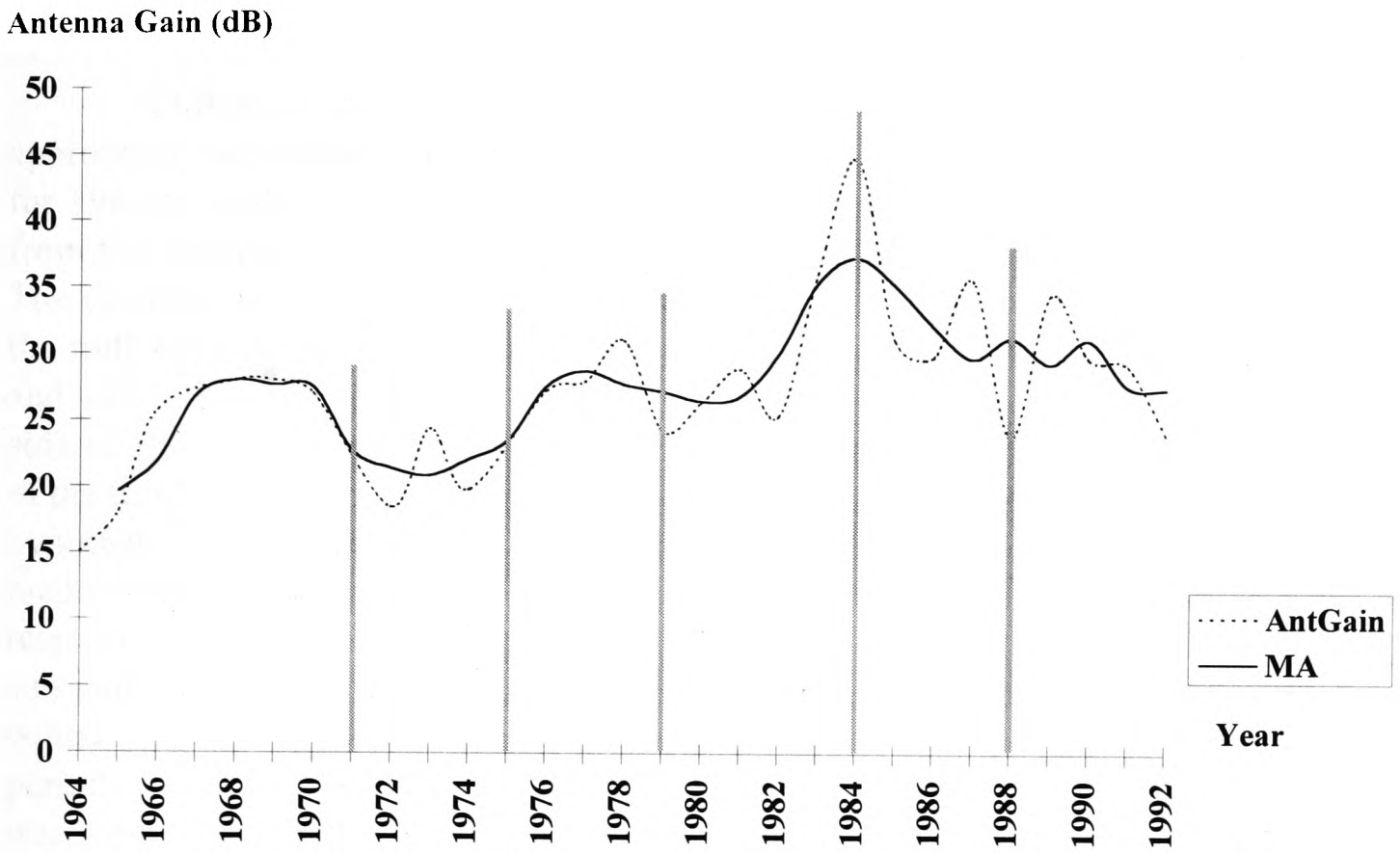


Figure 3.5: Evolution of the antenna gain. The dotted line represents the yearly average, and the solid line, its moving average.

In the second chapter, two stabilisation structures were presented: spinner and three-axis stabilised. The latter, not requiring a cylindrical structure, accommodates more components[19] within its volume and was therefore preferred by customers when it first appeared even though a cylindrical structure is more appropriate for launching purposes (most launch vehicles are cylindrical). During the transitory period where a greater number and variety of customers ordered satellites, the coefficient of the dummy variable *D3a* is negative, implying that most customers are no longer willing to pay a premium for this new type of stabilisation. Customers probably understood later, in the last period, the advantages of this three-axis stabilisation, and the dummy variable has a positive effect on the price again in this period. It is also possible that volume became a critical issue as satellites increased in equipment density levels and the spacecraft bay of launchers did not grow as fast as satellites would have needed.

As expected, the coefficients of the dummy variable *Dtwt* are all negative, implying that customers are willing to pay less when satellites only use travelling wave tube amplifiers, TWTAs, as opposed to a combination of solid state power amplifiers, SSPAs, and TWTAs. SSPAs being the latest technology, this kind of result is not surprising[20].

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[19] Theoretically, it is debatable whether a cylinder maximises the volume of a given area. It is however, much easier to mount instruments and subsystems on the four walls of a cubic shape. Refer to the second chapter for a more detailed comparisons of the two stabilisation mechanisms.

[20] Refer to the second chapter for more details on this technology.

The regression results concerning the proportion of transponders of each frequency are not consistent across all models, we therefore need to choose a model in order to evaluate their effect on the price. A common point can however be made, as all coefficients of frequency band variables are negative in the last sub-period, implying without any doubt that hybrid satellites have a positive effect on the price; indeed, the higher the percentage of transponders operating in a given frequency, the less likely it is to be a complex hybrid satellite. As deduced in the second chapter, hybrid satellites are more complex and generally more expensive as a consequence.

Different Chow-type tests have been applied to determine the most appropriate separation between the time periods. Two separate regressions were run for 1964-79 and 1980-93 and the residual sums of squares were compared with those from the pooled model, 1964-93, reported in the second columns of table 3.2 to 3.5. The calculated F-test statistics are reported in appendix I.1. In general, we can reject the null hypothesis of a common regression between the two sub-samples, 1964-79 and 1980-93, at the 5 % level. Although a technology difference was noted on either side of 1980, the rejection was stronger when comparing the residual sums of squares of the three-way split of the sample, 1964-75, 1976-84 and 1985-93. This supports the hypothesis of the technology difference between the three generations or vintages mentioned in the second chapter. In favour of this three generation hypothesis are the rejection of a common regression between the subset 1980-84 and the last generation sub-period, 1985-93, as well as the rejection of a common regression between the subset 1985-89 and the transitory period, 1976-84. Furthermore, the last two sub-periods could not reject the null hypothesis of a common regression when each subset was separated into two sub-periods, i.e. for 1976-84 (1976-79 and 1980-84) and 1985-93 (1985-88 and 1989-93). As a consequence, the entire period should be separated into three sub-periods corresponding to the three generations mentioned in the second chapter.

All models are not in accordance with the conjecture postulated in the second chapter. There is therefore a need at this point to narrow down the number of functional forms examined and choose the best fitting models for the data. Table 3.7 summarises the order of the models in descending order of residual variance and F-statistics, and with the help of table 3.6, the best fitting models will be chosen.

Table 3.7: Classification of the four models according to adjusted R^2 and F-statistics.

Model	1964 -93		1964 -79		1976 -84		1982 -93	
	all	best	all	best	all	best	all	best
M1	2	2	1	1	4	4	1	1
M2	1	1	4	2/3	3	3	4/3	3
M3	4	4	2	3/2	2	2	3/4	4
M4	3	3	3	4	1	1	2	2

Note that the occurrence of 2 numbers separated by a slash (/) in this table implies that the rank of the model differs for the residual variance (numerator) and the F-statistic (denominator). It was to be expected that the first model would yield different results from the other models because the former uses a double-log functional form while the other three models use a semi-log functional form for the majority of characteristics. It is also interesting to notice that the second model gives the highest residual variance for the pooled regression, and at the same time does not reject the hypothesis of a common regression for the years 1964-93 while all other

models support the non-homogeneity of the data. This casts some doubts on the apparent superiority of the second model. Moreover, this model does not yield the best results for the split regressions, generally ranking as third or fourth. Since the only difference between the second and fourth models is the logarithm of the variable *gtomass*, this would suggest that this variable should be integrated in the complexity measure of the satellite.

At this point in the analysis, it seems very difficult to eliminate any more models from the future analysis due to the lack of a consistently bad performing model. For the overall regression, the last and two functional forms are preferred. In the next two sections, we will verify whether this is so at a more disaggregated level. All models will therefore be further analysed before a final decision is made on them.

In addition to the tests for structural change across time periods presented earlier in this section, we have also performed the same tests to identify differences across regions of manufacturing and ownership. Comparing manufacturers we have found a significant difference between North American and European vendors. All the Chow tests for structural change reject the null hypothesis of a common regression between North American and European satellite producers at the 1 % significance level. These tests are presented in appendix I.2. The customers' case is more ambiguous though, and table 3.8 presents the main Chow test results.

Table 3.8: Summary of tests for structural change across ownership regions.

Region comparisons	Variables	64-79	X	76-84	X	80-93	X	64-93	X	Overall
US/Europe	**U**			Y		Y		Y		Y
	E					Y		Y		Y
US/International	**U**			N		Y		Y		~
	I	N				~Y	2,4	Y		~
US/Others	**U**			N		N		Y		~
	O					Y		Y	2	Y
Europe/International	**E**					Y		Y		Y
	I	Y	2			N		Y	2	~
Europe/Others	**E**					Y		Y		Y
	O					Y	3	Y	2	Y
Others/International	**O**					Y		Y		Y
	I	N	3			Y		Y		~
US+Europe/International	**I**	N								N

X: model exception

First, a few explanations are required concerning this table. The second column shows the variables associated with each country's regressions[21] used to test the hypothesis of common regression between the two countries mentioned in the first column. The subsequent columns illustrate the obtained results with the models that are different outlined on the right-hand side of the results (Y for rejection of the null hypothesis, and N for a non rejection). The last column illustrates the overall results to determine if the regions differ completely or partially. Analysing the exceptions, it is easily noticed that the second model is the most common exception, outlying again the flaws of this model. Model 4 gives different results only when the base for the test

[21] These Chow tests were performed using the variables that suited best each region of ownership as shown in section 3.3.3: U refers to the variables used for US customers' regressions, E for European, I for international organisations, and O for other countries.

is the model obtained for international customers in 1980-93. Model 3 gives different results only when the model is based on other countries' satellites in 1980-93 and international satellites in 1964-79. Ignoring the second model, there seem to be structural change across the four regions of manufacturing for the entire period, 1964-93. However, for the period 1980-93, there is ambiguity concerning the test for a common regression between US and other countries' customers, and between European and international customers. It may be the case that US and international satellites have a greater variety of characteristics while European and other countries' satellites are a sub-group of these two previous groups. This would explain the difference in results obtained.

In the first sub-period, 1964-79, as well as in the transitory period, 1976-84, US satellites cannot be rejected as being different from international spacecraft, while this lack of difference disappears in the last sub-period. Intelsat's annual reports (1983 onwards) show that international voice communications constitute the majority of the organisation's revenue, while television transmission only produces less than 6 % of total revenue. Although the use of Intelsat television channels has increased steadily over the years, it has always been much lower than the international voice traffic. In contrast, US domestic satellites were primarily used for television feeds across the country. Albeit the fact that the satellites were intended for different purposes, the underlying technology was relatively similar in these early days of satellite design, and this is why satellites from both US and international organisations cannot be distinguished. In the first sub-period, the primary function of North American domestic satellites, and that includes Canadian satellites, was to provide television feeds. Remember that Canadian-owned satellites are included in the 'other countries' category. Therefore the non-rejection of a common regression between other countries and international organisations can be explained in the same way as between US and international organisations. The only rejection of a common regression in the period 1964-79, is between Europe and international customers. This distinction is entirely due to the introduction of Ku band satellites in Europe, a frequency only rarely used in other parts of the world before the 1980s. In the transitory period, US-owned satellites cannot be distinguished from international organisations' satellites and other countries' spacecraft, but from European spacecraft. Ku band transponders, however, are only part of the story in this transitory period. Indeed, European satellite service operators introduced direct-to-home broadcasting services requiring spacecraft with five to ten times the average amplifier power. Apart from the ambiguity mentioned in the previous paragraph, in the latest period, most customers are distinct in the satellites they purchase, and this is the case for the entire period. This last result was to be expected since the majority of satellites were purchased in the later period of the sample.

The next two sections will focus on the differences between North American and European builders, as well as the noted discrepancies between the four ownership regions. Hedonic regressions will be estimated for each group of builders/buyers.

3.3.2 Different manufacturers

Most of the communication satellites examined in this thesis were built in the US. In this chapter, further analysis of the difference between North America and Europe will be carried out. Table 3.9 lists the number of satellites produced by each region throughout the whole sample period.

Table 3.9: Number of observations of each category, sub-periods versus manufacturers.

Periods	US	Europe	Total
1964-71	6	0	6
1972-75	6	2	8
1976-79	10	1	11
1980-84	18	8	27
1985-88	15	7	23
1989-93	21	6	29
Total	76	24	104

The subsequent four tables (tables 3.10 to 3.13) show the hedonic regressions' results split by region of manufacturing. Pooled regressions for North American and European builders, respectively, are presented in the first two columns.

Table 3.10: Regression results for different regions of manufacturing, model 1, equations (3.3) and (3.4); dependent variable: ln(*ecpi80*).

Variables	NA 1964-93	Europe pooled	NA 1964-79 no tD	NA 1976-84	NA 1982-93 no tD	Europe 1982-93 no tD
Intercept	1.69903 **	14.28224	0.46806	-0.20276	3.72922 *	31.16938 **
ln(number)		0.63168 *				
ln(gtomass)	0.57253 ***	-11.66487 *		1.42776 ***	0.57928 ***	-5.49747 **
ln(rdev)				0.22770	-0.16622	-0.43408
ln(eolpower)		6.04985 **	0.86650 ***	-0.96529 **		
ln(lifetime)	-0.20839		0.73811 **	0.24146	-0.45931 **	
ln(sumtr)		-4.38834 **	-0.46692 **			-2.72952 ***
ln(totbw)	-0.13440	3.86623 **	-0.32983 *	-0.24410 **		3.29700
ln(hmpower)	-0.12857	-1.35507 **	-0.42461 ***	0.40311 **		1.10884 **
ln(gmeirp)		6.33485 *			-0.53302	
D3a	0.13176		0.31007 *	0.34087 **		
Dtwt	-0.23208 **	-1.51257 **		-0.46812 **	-0.15653	-2.84434 ***
service	0.06822	1.37759 *	-0.76329 ***		0.14053 ***	0.55764
ln(mtrp)	-1.84265 ***	7.74591 *			-1.29440 **	-5.13618 **
ln(ctrp)	-0.80833 *		0.52019		-0.71472	
ln(kutrp)	-0.97372 **			-0.68518 **	-0.76096	-1.12550 *
D7275	0.02252					
D7679	0.31314 *	-3.23081 **				
D8081	0.05929	-3.69023 **		-0.18201 *		
D8284	0.47077 **	-4.30260 **		0.18344		
D8586	0.24663	-3.58355 **				
D8788	0.39794 *	-2.56894 **				
D8990	0.32506	-3.13378 **				
D9193	0.23493	-3.84209 **				
n	76	24	22	28	42	15
R^2	0.7517	0.9299	0.9038	0.8983	0.6779	0.9606
F	9.59	4.68	15.26	12.84	7.48	13.54

***: significance at the 1 % level
**: significance at the 5 % level
*: significance at the 10 % level

Period-split regressions for the North American manufacturers are shown in the next three columns, while the last column represents the regression for European manufacturers in the last period. The *no tD* indication signifies that the time dummies were not significant and their omission improved the fit of the models. Recall that the

Canadian firm Spar Aerospace Ltd is included in the North American group because it used to be part of RCA until the Montreal branch was bought by Spar in 1977.

Table 3.11: Regression results for different regions of manufacturing, model 2, equations (3.5) and (3.6); dependent variable: ln(*ecpi80*).

Variables	NA 1964-93	Europe pooled	NA 1964-79 no tD	NA 1976-84	NA 1982-93 no tD	Europe 1982-93 no tD
Intercept	1.51521 **	-26.83577 ***	2.11672 ***	-12.71072 ***	0.94395 ***	31.25025 **
ln(number)	-0.08832	1.29348 ***		-0.20301 **		
ln(gtomass)	0.45590 ***	6.81812 ***	0.17999	2.49116 ***	0.54664 **	-4.14144 **
rdev		0.03937 ***	0.00352		-0.00380	-0.01300 **
eolpower		0.00080 **	0.00121 **	-0.00083 ***	-0.00013	0.00096 ***
lifetime	-0.04236 *	-0.14942 **			-0.05535 **	
sumtr	0.01124	0.45993 ***		-0.02445	0.01133	-0.09507 ***
totbw	-0.00016	-0.01275 ***	-0.00064 **	-0.00030 *		
hmpower		-0.02125 ***	-0.04529 **			
gmeirp		-0.41286 ***		0.01782 *		0.12247 **
D3a	0.09903		0.35523 **	0.16146	0.15731	
Dtwt	-0.24363 **			-0.72057 ***	-0.17767	-2.93723 ***
service	0.10200 ***	0.47390 **	-0.33115 **	0.22337 **	0.13323 ***	-0.37829 ***
mtrp	-1.20199 ***	-10.24322 ***	-2.51289	-2.68616 *	-0.94060 ***	-2.54615
ctrp	-0.67182 **	-11.03755 ***		0.48964 **	-0.51738	
kutrp	-0.76851 **				-0.50631 *	
D7275	-0.03630					
D7679	0.11857	0.94130 *				
D8081	-0.13149	2.94820 **		-0.34664 ***		
D8284	0.29768	2.83634 **		0.12763		
D8586	-0.02634	0.92768				
D8788	0.18360	3.17101 **				
D8990	0.05470	1.29576				
D9193	0.11100	-2.08814 **				
n	76	24	22	28	42	15
R^2	0.7575	0.9882	0.8986	0.9197	0.6900	0.9451
F	9.21	17.57	14.41	12.34	6.07	12.90

***: significance at the 1 % level
**: significance at the 5 % level
*: significance at the 10 % level

One of the first results noticed in these regressions is the lack of significance of time dummy variables in the first and last period split regressions. In the transitory period, the first dummy variable is negative, while the second is positive. This is however consistent with the results obtained in the regressions including all manufacturers. We could deduce from these results that satellites produced in the first period are similar, and the same can be applied to the last sub-period, while they are different from one period to the next.

Chow-type tests were applied to verify this claim and, except from the second model, using 1964-79 regression variables reject the hypothesis of a common regression between 1964-79 and 1980-93, at the 5 % level, for North American satellite vendors. These structural change test results are presented in appendix I.2. The other rejection of the null hypothesis is between 1976-84 and 1985-93, and for models 3 and 4 only, at the 5 % level. In Europe, so few satellites were purchased before 1980 that this kind of test is pointless for the entire sample period. However, testing 1980-84 versus 1985-93 rejected the hypothesis of a common regression at the

5 % level for the last three models. A possible explanation for this result is that the majority of direct broadcasting satellites using very high amplifier power were ordered between 1980 and 1984, thus establishing the main difference between the two time periods.

Table 3.12: Regression results for different regions of manufacturing, model 3, equations (3.7) and (3.8); dependent variable: ln(*ecpi80*).

Variables	NA 1964-93	Europe pooled	NA 1964-79 no tD	NA 1976-84	NA 1982-93 no tD	Europe 1982-93 no tD
Intercept	2.34368 ***	-48.99979 ***	2.05945 ***	4.24948 ***	3.65598 ***	34.69160 **
ln(number)		1.29543 ***				
mrdev	4.38E-04	5.22E-03 ***	6.18E-04			-1.76E-03 **
meolpower		1.01E-04 **	1.08E-04		-1.62E-05	1.30E-04 ***
mlifetime		-0.02098 **	0.01072 *			
msumtr	0.00219 ***	0.06072 ***		0.00375 ***	0.00438 ***	-0.01309 ***
mtotbw		-1.69E-03 ***	-5.91E-05			
mhmpower		-0.00284 ***			0.00038	
mgmeirp	0.00240 ***	-0.05415 ***				0.01639 **
mD3a	0.01669	9.83756 ***	0.05477 **		0.03547 **	-4.59908 **
mDtwt				-0.03902		-0.39170 ***
mservice	0.01226 **	0.06455 **	-0.02666		0.01924 ***	-0.05346 ***
mmtrp	-0.04714	-1.43031 ***	-0.16131	0.16677 **	-0.11375 **	-0.32912 *
mctrp		-1.44225 ***	0.07150 **	-0.15374 ***	-0.09286 **	
mkutrp	-0.03552 **			-0.12237 ***	-0.08400 **	
D7275	0.22002					
D7679	0.20458	0.41300				
D8081	-0.04444	2.26282 **		-0.15106		
D8284	0.38887 **	2.15014 **		0.16095		
D8586	0.12425	0.29643				
D8788	0.32603	2.55808 **				
D8990	0.21400	0.69036				
D9193	0.14029	-2.70228 **				
n	76	24	22	28	42	15
R^2	0.7024	0.9865	0.8794	0.8400	0.6081	0.9502
F	9.44	15.41	11.85	15.00	6.40	14.31

Note: the prefix *m* represents *ln(gtomass)*variable*
***: significance at the 1 % level
**: significance at the 5 % level
*: significance at the 10 % level

Many distinctions between North American and European satellite vendors can be noticed in these results. First, the coefficient of the variable number appears to be consistently positive in the case of European producers, in the pooled regression, whereas it is mostly negative, but rarely significant, on the other side of the Atlantic. This positive value clearly signifies decreasing returns to scale. A mitigating factor for the sake of the European industry is that the coefficient looses its significance in the last period, suggesting that constant returns to scale are the case in the space industry more recently.

A second distinction is the negative value of the European launch mass coefficient in the last sub-period, compared with a positive coefficient for the whole sample and the North American built satellites. Have customers succeeded in financially pressurising European manufacturers to reduce the mass of the their

satellites? This is one possible explanation, but most likely is the lack of fit of the model to the European-built satellite data.

Table 3.13: Regression results for different regions of manufacturing, model 4, equations (3.9) and (3.10); dependent variable: ln(*ecpi80*).

Variables	NA 1964-93	Europe pooled	NA 1964-79 no tD	NA 1976-84	NA 1982-93 no tD	Europe 1982-93 no tD
Intercept	3.70747 ***	15.88043 **	2.70530 ***	4.11478 ***	4.57402 ***	4.46920 ***
ln(number)	-0.09585	1.24733 **		-0.08864		0.22059
gtomass	0.00028 ***	0.00272 *	0.00027 ***	0.00079 ***	0.00024 **	-0.00098
rdev	0.00298	0.03687 **			-0.00410	
eolpower	-0.00008	0.00128 **	0.00089 **	-0.00021	-0.00012	0.00073 ***
lifetime		-0.13228	0.06521 *		-0.04750 **	
sumtr	0.01478	0.43570 **		-0.03729 ***	0.01271	-0.09322 ***
totbw	-0.00015	-0.01195 **	-0.00049 *			
hmpower	0.00212	-0.02184 **	-0.03515 **			
gmeirp		-0.37752 **				0.05504
D3a	0.11312		0.35609 **		0.15269	
Dtwt	-0.13625			-0.32522 **	-0.16978	-2.18608 ***
service	0.11372 **	0.53127		0.08092	0.14411 ***	-0.34336 ***
mtrp	-1.28884 ***	-9.05764 **	-3.03992 *	-1.96137 **	-1.09876 ***	-2.27782
ctrp	-0.76192 **	-11.44076 **			-0.69350 **	
kutrp	-0.92586 ***	-0.74038		-0.49957 ***	-0.62623 **	
D7275	0.21661					
D7679	0.26640	1.77986 *				
D8081	0.02095	3.63098 **		-0.18080 **		
D8284	0.41351 *	3.67940 **		0.08992		
D8586	0.13027	1.77273				
D8788	0.22204	3.88189 **				
D8990	0.18156	2.13973 *				
D9193	0.12459	-1.95252				
n	76	24	22	28	42	15
R^2	0.7512	0.9855	0.8985	0.9135	0.6878	0.9179
F	7.77	10.22	17.71	17.95	6.01	8.39

***: significance at the 1 % level
**: significance at the 5 % level
*: significance at the 10 % level

In the last sample sub-period, there is a tendency towards negative, however partially significant, pressure on the price from the length of development time. It is possible that satellite operators may have to pay for a faster production, and in that sense, customers under less pressure on the demand side may obtain cheaper deals. This does not appear to have been the case in earlier periods. The difference at this level between North American and European manufacturers regressions is that in the former, the coefficient of the variable *rdev* is not significant.

One of the problems encountered in the European regressions and to some extent in the early periods of North American regressions, is the small number of degrees of freedom. The coefficients are less precise and this renders the results less robust and more difficult to interpret.

A summary table of the sign and significance of the coefficients of the regression variables is presented in table 3.14 to facilitate the comparison of both variables and regions of manufacturing.

Table 3.14: Sign variation of the estimates of the characteristic variables and dummy variables across years and models; by region of manufacturing, NA: North America, E: Europe.

Model	Period / Variable	64 -93 NA	64 -93 E	64-79 NA	76-84 NA	82 -93 NA	82 -93 E	Period / Variable	64 -93 NA	64 -93 E	64-79 NA	76-84 NA	82 -93 NA	82 -93 E
M1	gtomass	+	-		+	+	-							
M2		+	+	+	+	+	-							
M4		+	+	+	+	+	-							
M1	number		+					gmeirp		+			-	
M2		-	+		-					-		+		+
M3			+						+	-				+
M4		-	+		-		+			-				+
M1	rdev				+	-	-	mtrp	-	+			-	-
M2			+	+		-	-		-	-	-	-	-	-
M3		+	+	+			-		-	-	-	+	-	-
M4		+	+			-			-	-	-	-	-	-
M1	eolpower		+	+	-			ctrp	-		+		-	
M2			+	+	-	-	+		-	-		+	-	
M3			+	+		-	+			-	+	-	-	
M4		-	+	+	-	-	+		-	-			-	
M1	lifetime	-		+	+	-		kutrp	-			-	-	
M2		-	-			-			-				-	
M3			-	+					-			-	-	
M4			-	+		-			-	-		-	-	
M1	sumtr		-	-			-	D3a	+		+	+		
M2		+	+		-	+	-		+		+	+	+	
M3		+	+		+	+	-		+	+	+		+	-
M4		+	+		-	+	-		+		+		+	
M1	totbw	-	+	-	-		+	Dtwt	-	-		-	-	-
M2		-	-	-	-				-			-	-	-
M3			-	-								-		-
M4		-	-	-					-			-	-	-
M1	hmpower	-	-	-	+		+	service	+	+	-		+	+
M2			-	-					+	+	-	+	+	-
M3			-			+			+	+	-		+	-
M4		+	-	-					+	+		+	+	-

In comparing the various functional forms used for the manufacturers' regressions, it is not surprising to obtain the same ambiguity concerning a 'best' model as before (see table 3.15).

Table 3.15: Classification of the four models according to adjusted R^2 and F-statistics; manufacturing regions.

Model	1964 -93 NA	1964 -93 Europe	1964-79 NA	1976-84 NA	1982 -93 NA	1982 -93 Europe
M1	2/1	4	1/2	3	3/1	1/2
M2	1/3	1	2/3	1/4	1/3	3
M3	4/2	2	4	4/2	4/2	2/1
M4	3/4	3	3/1	2/1	2/4	4

Ignoring the second model, because of the contradictions observed before, the following results are obtained in comparing the achieved F-statistic from different functional forms: the third model seems to be more appropriate for European manufacturers, the fourth model fits better the first and transitory sub-periods, while the first model better represents the latest sub-period as well as the entire sample (see table 3.16).

Table 3.16: Classification of the four models according to adjusted R^2 and F-statistics; manufacturing regions; model 2 eliminated.

Model	1964 -93		1964-79	1976-84	1982 -93	
	NA	Europe	NA	NA	NA	Europe
M1	1	3	1/2	2/3	2/1	1/2
M3	3/2	1	3	3/2	3/2	2/1
M4	2/3	2	2/1	1	1/3	3

This separation between models is very interesting indeed, it suggests not only a structural change difference, but also a functional form discrepancy between regions.

3.3.3 Different customers

In the previous section, it was discovered that the separation into two regions of manufacturing does not provide a perfect solution to the problems encountered in the pooled regressions. For instance, this does not eliminate the need for time dummy variables. In this section, disaggregation into four different regions of ownership will be examined. The number of observations included in each regression as well as their situation in time is presented in table 3.17.

Table 3.17: Number of observations of each category, sub-periods versus customers.

Periods	US	Europe	International	Others	Total
1964-71	0	0	5	1	6
1972-75	4	1	3	0	8
1976-79	3	1	2	5	11
1980-84	11	7	4	5	27
1985-88	3	6	3	11	23
1989-93	5	7	5	12	29
Total	26	22	22	34	104

As before, four tables (tables 3.18 to 3.21) present the hedonic price regressions, one for each model, for the four regions of satellite operators. Pooled regressions over the entire sample are shown in the first five columns, two columns are used for international organisations because including the time dummies in this case significantly reduces the fit of the regression. Both results, with and without time dummies, are then shown as a measure of comparison. The sixth column shows the only first period regression that could be performed, as only international organisations were ordering satellites in enough quantities. During the transitory period, only the United States could provide enough observations to analyse the data, and this regression is shown in the seventh column. Finally, the last three columns present regressions for the last sub-period for all but one region, international organisations not having purchased enough satellites throughout this period. Tables 3.22 and 3.23 summarise the results obtained by the regression analysis by presenting the variation in sign and significance of the variables' coefficients.

Economies of scale seem to be in place in the case of US-owned spacecraft and satellites purchased by other countries. It is very surprising not to find a negative coefficient for the number of Intelsat satellites ordered because they consistently order on average more than four spacecraft per contract. A combination of two possible factors can explain this apparent constant returns to scale.

Table 3.18: Regression results for different regions of ownership, model 1, equations (3.3) and (3.4); dependent variable: ln(*ecpi80*).

Variables	US	Europe	Int'l 1964-93 no tD	Int'l with tD	Others	Int'l 1964-79 no tD	US 1976-84	US with tD	Europe 1982-93 no tD	Others
Intercept	0.50518	34.53485 ***	4.85705 **	5.55662	4.10061 ***	7.89439 ***	15.14861 *	4.71917 **	-86.85851	8.74588 ***
ln(number)	-0.28933 ***	0.24348 *			-0.31009 ***					
ln(gtomass)		-2.85747 **	1.00102 ***	0.83737	-0.37097 *				17.56985 *	-1.18082 **
ln(rdev)		-0.56447 *	0.26271 *	0.41863		0.71653 ***			-0.71322	-0.21787 *
ln(eolpower)	0.29981 ***	4.00207 ***			0.48188 ***				13.66567	0.52060 ***
ln(lifetime)						0.68328 **			-25.19776 *	
ln(sumtr)	0.40750 ***		-0.61330 ***	-0.49831			-0.51637			0.43793
ln(totbw)	0.23439 ***	-0.56131 **							-8.22957 *	
ln(hmpower)		-1.14320 ***					1.46783 **		-14.56540 *	
ln(gmeirp)		-7.41114 ***	-2.15646 ***	-2.19479		-2.37996 ***	-3.18900			
D3a			-0.28470	-0.56458			0.35729 *		-20.10176	0.16827
Dtwt	-0.50638 ***		-0.39896 ***	-0.64257	-0.22118 **		-0.75321 **		43.09527	-0.31882 **
service		0.48504 ***	-0.14732	0.00247	0.04229		-0.15169	0.38038		0.15870 *
ln(mtrp)	1.26860 **		1.27100 *	0.47725	-0.96371 **		8.93917 **	-3.16268	121.00565	-0.77940
ln(ctrp)	-1.09602 ***	-11.55039 ***			-0.87966 ***		-1.55095 *	-1.02859	94.76886	-0.79240 **
ln(kutrp)	-0.82960 **		1.92263	2.51109	-0.92111 ***		-3.46152 **	-1.45174		-0.49896
D7275				0.01944						
D7679	-0.06547	-0.77532 **		0.21240	-0.19742					
D8081	-0.56743 ***	0.07040		0.00642	-0.02115		-0.00037			
D8284	-0.55126 **	-0.19898		-0.52419	0.03258		-0.38265			
D8586	-1.36263 ***	-1.60874 ***		-0.54875	-0.12472			-0.48671		0.08593
D8788	-0.75122 ***	1.43641 **		-0.21723	0.07193			0.90783		0.27852
D8990	-1.36511 ***	-1.36632 ***		-0.03178	-0.21198			0.19350		-0.06509
D9193	-0.91985 ***			-0.03554	-0.14606			0.38819		-0.19203
n	26	22	22	22	34	10	14	10	15	26
R^2	0.9735	0.9878	0.9370	0.9548	0.8742	0.9608	0.9963	0.9867	0.9713	0.8813
F	24.49	32.38	19.84	4.97	8.34	49.08	48.75	9.31	13.56	5.84

***: significance at the 1 % level
**: significance at the 5 % level
*: significance at the 10 % level

Table 3.19: Regression results for different regions of ownership, model 2, equations (3.5) and (3.6); dependent variable: ln(*ecpi80*).

Variables	US	Europe	Int'l 1964-93 no tD	Int'l with tD	Others	Int'l 1964-79 no tD	US 1976-84	US with tD	Europe 1982-93 no tD	Others
Intercept	4.59256 ***	31.65680 ***	3.10685 ***	3.49914	4.16377 ***	2.05012 ***	10.86319 **	4.71326 **	54.21103 **	13.77286 ***
ln(number)	-0.31248 ***				-0.40516 ***					
ln(gtomass)		-3.11148 **	0.59861 ***	0.16033					-7.90749 *	-1.30557 ***
rdev		-0.01776 **	0.00480	0.00611		0.00837			-0.01356	-0.00578 **
eolpower		0.00144 ***	0.00023 **	-0.00031	0.00013 ***	0.00125 *				
lifetime			0.14135 *	0.20707		0.11897			0.73297 *	0.06589 **
sumtr	0.06847 ***		-0.09545 ***	-0.03344						0.08049 ***
totbw	-0.00017 ***		0.00096 ***	0.00084		-0.00056	-0.00094 *		0.00523 *	-0.00095 **
hmpower		-0.00464 *					0.16257 **		0.03337 *	
gmeirp		-0.09254 ***	-0.08788 ***	-0.04693			-0.06689			
D3a	0.09591		-0.89646 ***	0.18001			0.30796 *		3.22434 **	0.60805 ***
Dtwt	-0.49154 ***	-2.34021 ***			-0.21232 **		-0.67130 **		-6.54332 **	-0.30155 **
service		0.23628 *			0.05481			0.35488	0.33921	0.18349 ***
mtrp		-4.78979 ***			-0.60159 *		2.59034 **	-2.16272	-13.17439 **	-2.32106 **
ctrp	-1.59645 ***	-9.09918 ***	-1.42204 ***	-1.12219	-0.32990		-4.91615 **	-0.87835	-16.42206 *	-1.90871 ***
kutrp	-0.95301 ***				-0.23287		-6.93176 **	-0.99444		-1.48652 **
D7275				-0.00688						
D7679	0.04175	0.44162		-0.95935	-0.01018					
D8081	-0.46093 ***	2.01691 ***		-1.19857	0.29337		-0.06714			
D8284	-0.23857	1.52245 **		-0.68628	0.20579		-3.07653 **			
D8586	-1.20836 ***	-0.20089		-0.64260	0.06571			-1.48281		-0.17341
D8788	-0.68083 ***	1.20386 **		-0.37087	0.13111			0.66112		0.02281
D8990	-1.57077 ***	-0.08134		-0.10496	0.01898			0.16944		-0.26623
D9193	-0.82988 ***			-0.19716	-0.04244			0.32481		-0.54227
n	26	22	22	22	34	10	14	10	15	26
R^2	0.9772	0.9856	0.9300	0.9458	0.8103	0.9333	0.9911	0.9828	0.9703	0.8767
F	33.73	27.41	17.72	4.11	5.80	17.50	33.34	7.13	13.07	4.74

***: significance at the 1 % level
**: significance at the 5 % level
*: significance at the 10 % level

Table 3.20: Regression results for different regions of ownership, model 3, equations (3.7) and (3.8); dependent variable: ln(*ecpi80*).

Variables	US 1964-93	Europe	Int'l no tD	Int'l with tD	Others	Int'l 1964-79 no tD	US 1976-84	US 1982-93 with tD	Europe no tD	Others
Intercept	6.43062 ***	10.59543 ***	0.82225	5.88310	3.91747 ***	3.02580 ***	11.00979 **	4.72431 **	6.33666 **	4.01677 ***
ln(number)	-0.29214 ***				-0.29953 **					-0.39110 **
mrdev		-0.00206 **			-0.00047	0.00209 ***				-0.00045
meolpower	-1.26E-05 **	5.36E-05	8.53E-05 **	-1.12E-04	1.49E-05				-1.04E-04	1.64E-05 **
mlifetime		-0.00739 *	0.02344	0.10706		0.03779 ***			0.02258	-0.00677 *
msumtr	0.01784 ***		-0.01314 **	0.00121						
mtotbw	-9.43E-05 **		8.80E-05				-1.22E-04 *		2.21E-04	
mhmpower		-0.00031	-0.01287 *	0.00106			0.02475 **		0.00237	-0.00036
mgmeirp	-0.00403	-0.01711 **	-0.00849 *	-0.00369		-0.00851 **	-0.01097		-0.00940	0.00295 **
mD3a			-0.15972 ***	0.53421			0.05091 *		0.14263 *	
mDtwt	-0.04481 ***	-0.71940 **			-0.03080 **		-0.08023 *		-0.24072 **	-0.04691 ***
mservice		0.04766	0.06328	-0.07132	0.00755			0.05631 *		
mmtrp	-0.15241	-1.19954 **	0.69103 *	-1.09004	-0.04468		0.75879 **	-0.33621 *	-0.86631 **	-0.05101
mctrp	-0.50761 ***	-0.89269 ***	0.67458 **	-0.91946	-0.02085		-0.70001 *	-0.12494	-0.39562	
mkutrp	-0.32473 **	0.60610	1.41880 ***	-1.09322			-0.99670 **	-0.13341		
D7275				-0.04615						
D7679	0.14156	0.21076		-2.82580	0.14288					
D8081	-0.26743 **	3.10465 **		-3.12995	0.47238 **		-0.09732			
D8284	0.46923	2.28987 **		0.31673	0.30476		-3.08845 *			
D8586	-0.69840 **	0.93380		-3.31533	0.31778			-0.46786		-0.11002
D8788	-0.58374 ***	1.03013 **		-3.13381	0.28535			0.97038		0.02560
D8990	-1.27422 ***	1.07567		-2.42498	0.19514			0.24339		-0.15700
D9193	-0.04898			-2.48168	0.09693			0.40996		-0.19598
n	26	22	22	22	34	10	14	10	15	26
R^2	0.9861	0.9881	0.9366	0.9533	0.8166	0.9439	0.9898	0.9911	0.9526	0.8019
F	39.91	26.02	13.44	3.40	6.04	33.66	29.20	13.89	11.18	4.38

Note: the prefix *m* represents *ln(gtomass)*variable*

***: significance at the 1 % level

**: significance at the 5 % level

*: significance at the 10 % level

Table 3.21: Regression results for different regions of ownership, model 4, equations (3.9) and (3.10); dependent variable: ln(*ecpi80*).

Variables	US	Europe	Int'l 1964-93 no tD	Int'l with tD	Others	Int'l 1964-79 no tD	US 1976-84	US with tD	Europe 1982-93 no tD	Others
Intercept	4.59256 ***	10.84000 ***	3.06106 ***	2.87392 **	4.81633 ***	3.10162 ***	10.86319 **	4.71326 **	5.07630 ***	7.85129 ***
ln(number)	-0.31248 ***				-0.33556 **	0.17412				-0.20681
gtomass		-0.00165 **	0.00116 ***	0.00079	-0.00033					-0.00151 **
rdev		-0.01756 **				0.00872			0.00484 *	
eolpower		0.00132 **			0.00010	0.00061 **				-0.00019
lifetime			0.34105 ***	0.32590	0.03772					0.19533 *
sumtr	0.06847 ***		-0.12949 ***	-0.09708	0.03520					0.16720 **
totbw	-0.00017 **	-0.00077	0.00093 ***	0.00077	-0.00050		-0.00094 *			-0.00172 **
hmpower		-0.00557				-0.08624 **	0.16257 **		0.00264 ***	0.00670
gmeirp		-0.16375 **	-0.09352 ***	-0.07196			-0.06689			-0.05416
D3a	0.09591	3.90202 *	-0.27691 *	0.13433	0.21135		0.30796 *			0.93271 **
Dtwt	-0.49154 ***		1.03006	0.68869	-0.27446		-0.67130 **			-0.49466 ***
service		0.45621 *			0.09852	0.37694 **		0.35488		0.38853 **
mtrp		-3.35836 **			-1.65395 *		2.59034 **	-2.16272	-2.95406	-3.72726 **
ctrp	-1.59645 ***	-14.49454 ***			-1.26973 *		-4.91615 **	-0.87835		-3.90080 **
kutrp	-0.95301 ***	-1.73974 **			-1.02481		-6.93176 **	-0.99444	-1.69028	-2.29886 **
D7275				0.01582						
D7679	0.04175	0.37091		-0.27709	-0.05278					
D8081	-0.46093 ***	2.59353 *		-0.41167	0.12779		-0.06714			
D8284	-0.23857	1.80647 *		0.11706	0.26297		-3.07653 **			
D8586	-1.20836 ***	0.26488		-0.63151	0.02447			-1.48281		-0.28535
D8788	-0.68083 ***	5.20347 *		-0.44751	0.17820			0.66112		-0.13527
D8990	-1.57077 ***	0.48120		-0.29130	-0.03138			0.16944		-0.48428
D9193	-0.82988 ***			-0.43849	-0.15503			0.32481		-0.84263
n	26	22	22	22	34	10	14	10	15	26
R^2	0.9772	0.9916	0.9312	0.9421	0.8535	0.9564	0.9911	0.9828	0.8976	0.9175
F	33.73	27.90	27.08	6.51	4.29	17.55	33.34	7.13	21.92	4.33

***: significance at the 1 % level
**: significance at the 5 % level
*: significance at the 10 % level

Table 3.22: Sign variation of the estimates of the characteristic variables across years and models; ownership regions.

Variable	Model	1964-93					1964-79	1976-84	1982-93		
		US	Europe	Int'l	Int'l-tD	Others	Int'l	US	US	Europe	Others
number	M1	-	+			-					
	M2	-				-					
	M3	-				-					-
	M4	-				-	+				-
gtomass	M1		-	+	+	-				+	-
	M2		-	+	+					-	-
	M4		-	+	+	-					-
rdev	M1		-	+	+		+			-	
	M2		-	+	+		+			-	-
	M3		-			-	+				-
	M4		-				+			+	
eolpower	M1	+	+			+				+	+
	M2		+	+	-	+	+				
	M3	-	+	+	-	+				-	+
	M4	+				+	+				-
lifetime	M1						+			-	
	M2			+	+		+			+	+
	M3		-	+	+		+			+	-
	M4			+	+	+					+
sumtr	M1	+		-	-			-			+
	M2	+		-	-						+
	M3	+		-	+						
	M4	+		-	-	+					+
totbw	M1	+	-							-	
	M2	-		+	+		-	-		+	-
	M3	-		+				-		+	
	M4	-	-	+	+	-		-			-
hmpower	M1		-					+		-	
	M2		-					+		+	
	M3		-	-	+			+		+	-
	M4		-				-	+		+	+
gmeirp	M1		-	-	-		-	-			
	M2		-	-	-			-			
	M3	-	--	-	-		-	-		-	+
	M4		-	-	-			-			-
mtrp	M1	+		+	+	-		+	-	+	-
	M2		-			-		+	-	-	-
	M3	-	-	+	-	-		+	-	-	-
	M4		-			-		+	-	-	-
ctrp	M1	-	-			-		-	-	+	-
	M2	-	-	-	-	-		-	-	-	-
	M3	-	-	+	-	-		-	-	-	
	M4	-	-			-		-	-		-
kutrp	M1	-		+	+	-		-	-		-
	M2	-				-		-	-		-
	M3	-	+	+	-			-	-		
	M4	-	-			-		-	-	-	-

First and foremost, Intelsat being a non-profitable organisation comprising more than 130 member states, all decisions concerning the winning bid must be voted upon by all the members, with a biased result; e.g. European member states will lobby to prefer the bid with the highest European manufacturing content. Knowing this complex decision structure and the percentage of the vote attributed to each country,

satellite producers ensure to incorporate enough foreign partners to please as many member states with a space related industry. Because prime-contractors may not as a consequence prefer the best sub-contractor, but the one associated with the greatest political gain instead, satellites are not as cheap as they should be. In a sense, manufacturers are price discriminating against non-competitive customers with highly complex internal structures. A second possible reason for this non-significant coefficient is that because Intelsat possesses its own R&D engineering team, the organisation keeps at the cutting edge of technology and imposes its new discoveries to its prime-contractors[22]. Intelsat therefore pushes the boundaries of satellite design in its own way, and as new technology is expensive, the lack of economies of scale is understandable. Intelsat not only buys the most expensive satellites, it also launches the heaviest. Recall the quasi-linear relationship between the price and launch mass presented in section 3.1. The coefficient of the mass is consequently positive and significant for international organisation regressions while it is negative for European and other countries' customers. Perhaps the European launcher Ariane[23] puts less pressure on producers and customers because of its greater size and power? To verify this claim, a detailed study of launch vehicles would be needed and clearly goes beyond the scope of this thesis.

Table 3.23: Sign variation of the estimates of the characteristic dummy variables across years and models; ownership regions.

Variable	Model	1964-93					1964-79	1976-84	1982-93		
		US	Europe	Int'l	Int'l-tD	Others	Int'l	US	US	Europe	Others
D3a	M1			-	-			+		-	+
	M2	+		-	+			+		+	+
	M3			-	+			+		+	
	M4	+	+	-	+	+		+			+
Dtwt	M1	-		-	-	-		-		+	-
	M2	-	-			-		-		-	-
	M3	-	-			-		-		-	-
	M4	-		+	+	-		-			-
service	M1		+	-	+	+		-	+		+
	M2		+			+			+	+	+
	M3		+	+	-	+			+		
	M4		+			+	+		+		+

Another variable differing in Europe is the number of months from contract signature to delivery for launch. It appears that the lengthier the development time, the cheaper the satellite. This was observed as well in the case of European manufacturers.

Regarding satellite capacity, US customers seem to put a strong emphasis on the number of transponders included in the design, with a positive and significant coefficient on this variable, whereas the opposite is true in the case of international buyers. It is possible that Intelsat transponders are rarely used to their full capacity, while in the US, increasing demand for communication channels has put pressure on customers to order more capacity. As it is undoubtedly less expensive to increase the number of transponders on-board a given satellite, than to order an extra satellite unit,

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[22] Remember in the second chapter, the new type of batteries that Intelsat incorporated in the design of the Intelsat V family. See section 2.2.4.3.

[23] Most European satellites are launched by Ariane who possesses 60 % of the world commercial launch market.

this pressure on capacity pushes the price of satellites upwards. A very bizarre result of these regressions is the consistently negative coefficient for the variable *gmeirp*, which was positive in the pooled overall regression as well as for the last sub-period. As this variable varies considerably with the type of service provided, it is more affected by a reduction in sample size than most variables.

As for satellite vendors, Chow tests for structural change between time periods were performed for each region of ownership. Only in the case of US customers did we find a significant structural change (at the 5 % level), between 1976-84 and 1982-93. A structural change between the first and transitory periods was found at the 5 % level but only for the first and fourth models. In all other cases, no significant difference was noted across periods, even for international customers which have launched satellites since the very beginning of the sample. The Chow test results are presented in appendix I.3. With the small number of observations available for each region, it is not surprising to find no strong rejections of the structural change hypothesis.

Choosing a model is equally difficult as it was in the pooled and manufacturing regressions as shown in tables 3.24 and 3.25.

Table 3.24: Classification of the four models according to adjusted R^2 and F-statistics; ownership regions.

Model	1964-93					1964-79	1976-84	1982-93		
	US	Europe	Interna tional		Europe	Int'l	US	US	Europe	Others
M1	3	3/1	1/2	1/2	1	1	1	2	1/2	2/1
M2	2	4/3	4/3	3	4/3	4	2	3	2/3	3/2
M3	1	2/4	2/4	2/4	3/2	3/2	3	1	3/4	4/3
M4	2	1/2	3/1	4/1	2/4	2/3	2	3	4/1	1/4

Table 3.25: Classification of the four models according to adjusted R^2 and F-statistics; ownership regions; model 2 eliminated.

Model	1964-93					1964-79	1976-84	1982-93		
	US	Europe	Interna tional		Europe	Int'l	US	US	Europe	Others
M1	3	3/1	1/2	1/2	1	1	1	2	1/2	2/1
M3	1	2/3	2/3	2/3	3/2	3/2	3	1	2/3	3/2
M4	2	1/2	3/1	3/1	2/3	2/3	2	3	3/1	1/3

On the one hand, the third model imposes itself in the case of US customers for the entire sample and the last sub-period. On the other hand, the first model characterises better the early periods of the sample as well as other countries' customers. In contrast, in the case of international organisations we hesitate between the first and fourth models.

So far, the second model seems to contain a contradiction and should be eliminated because of this ambiguity. The first model seems to fit reasonably better for certain categories of customers. But the third and fourth functional forms are over all preferred. A final decision concerning which models are more appropriate will follow the calculation of hedonic price indices in the next section.

3.4 Price indices

One of the purposes of estimating hedonic regressions is to calculate hedonic price indices from the obtained coefficient estimates. In section 3.2.1, different

methods of computing quality-adjusted price indices were examined. The time dummy variable approach was chosen as the most suitable for commercial communication satellites. This section is separated into three headings following the three types of regressions performed previously, i.e. with the pooled sample, and the sample split into 2 regions of production and four regions of ownership.

3.4.1 General price indices

In the table 3.26, price indices have been extracted from the hedonic regressions performed in the previous chapter. From the pooled and split regressions, we have constructed three price indices: the first was obtained from the coefficients of the time dummy variables of the pooled regression; the second and third price indices were calculated for two split regressions, one which has as a base the 1964-79 regression, and the rest of the price index calculated using a chain (split low), and the other one, based on the 1982-93 regression, and chained 'backwards' (split high).

Table 3.26: Hedonic price indices

Model	1			2			3			4		
Periods	pooled modal	split low	split high	pooled modal	split low	split high	pooled modal	split low	split high	pooled modal	split low	split high
1964-71	1.099	0.844	0.855	0.963	1.457	1.637	0.763	1.660	1.907	0.705	1.372	1.524
1972-75	1.304	1.189	1.204	1.226	1.534	1.723	1.422	1.710	1.964	1.281	1.869	2.076
1976-79	1.165	1.120	1.134	1.125	1.136	1.277	1.147	1.119	1.285	1.122	1.161	1.289
1980-81	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
1982-84	1.132	0.904	1.012	1.231	0.989	1.123	1.168	1.027	1.149	1.176	0.957	1.111
1985-86	0.766	0.615	0.689	0.767	0.647	0.736	0.789	0.687	0.768	0.775	0.637	0.739
1987-88	1.034	0.938	1.051	1.140	1.052	1.195	1.173	0.975	1.090	1.074	0.863	1.001
1989-90	0.751	0.660	0.739	0.802	0.693	0.787	0.785	0.723	0.809	0.795	0.664	0.770
1991-93	0.887	0.709	0.794	0.988	0.747	0.849	0.914	0.770	0.861	0.959	0.747	0.868

Three graphs have been generated directly from this table comparing the four models, per type of price index calculated: one for the pooled results, figure 3.6; one for the split low results, figure 3.7; and one for the split high results, figure 3.8.

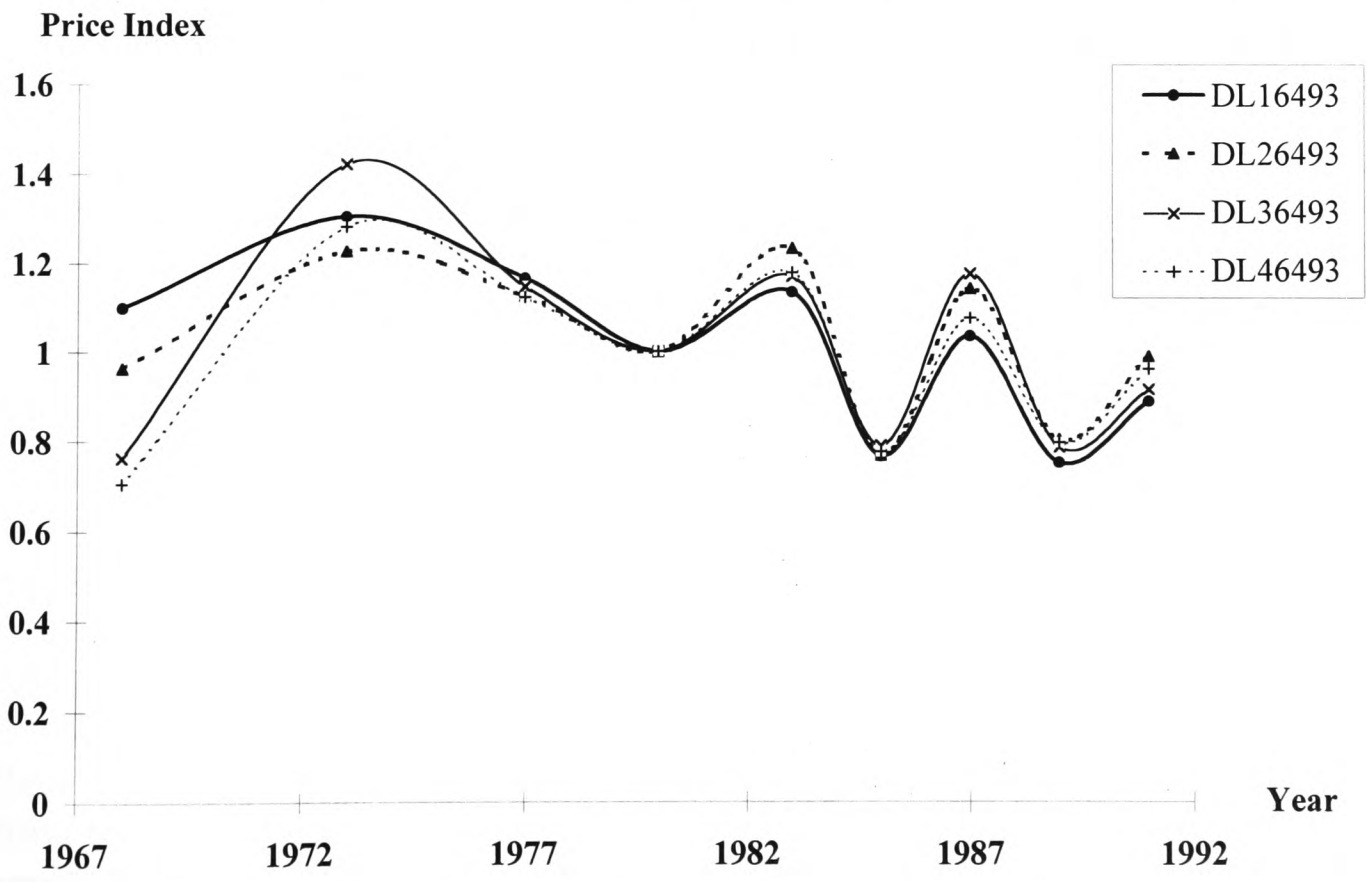


Figure 3.6: Hedonic price indices; all models; pooled results.

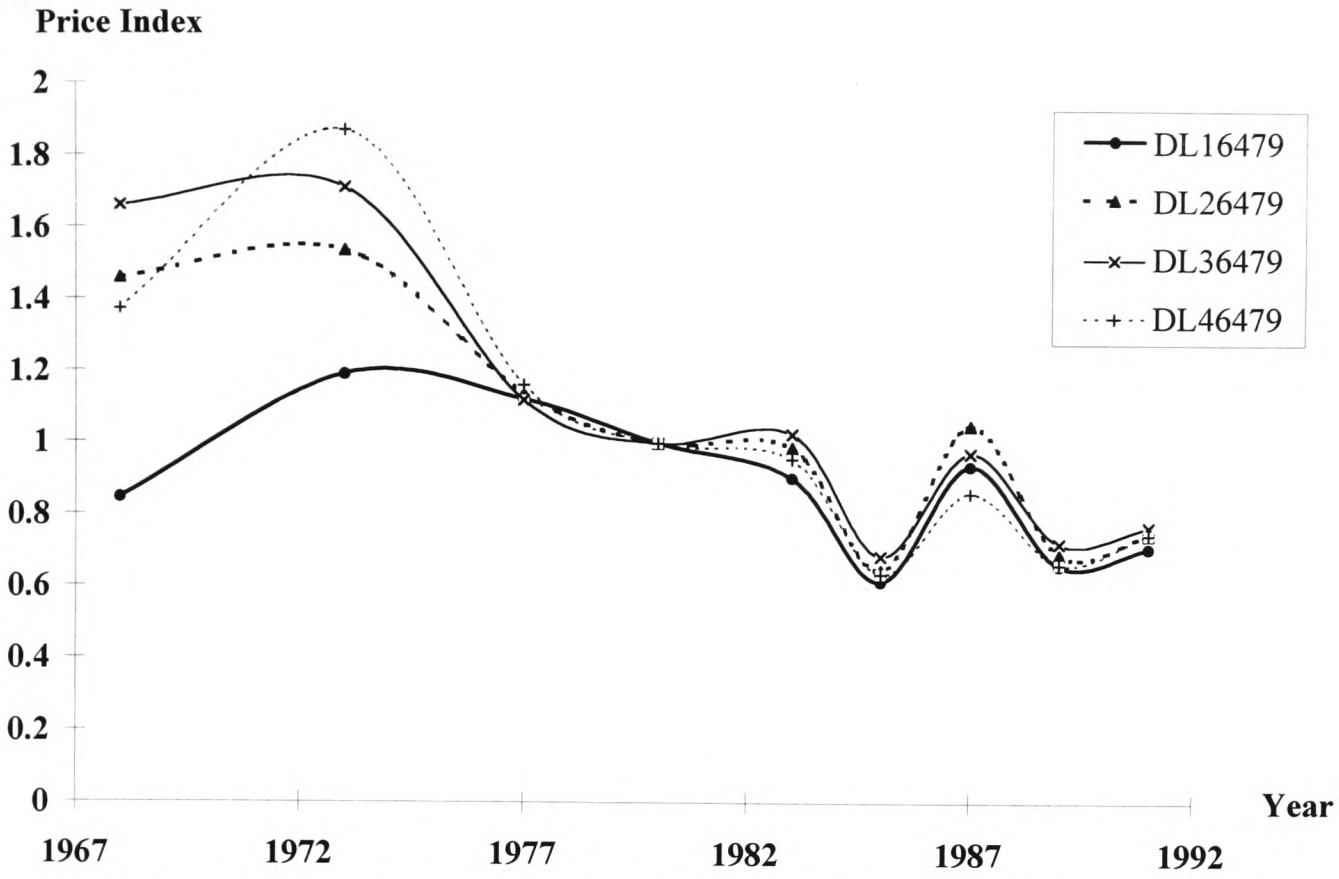


Figure 3.7: Hedonic price indices; all models; split low results.

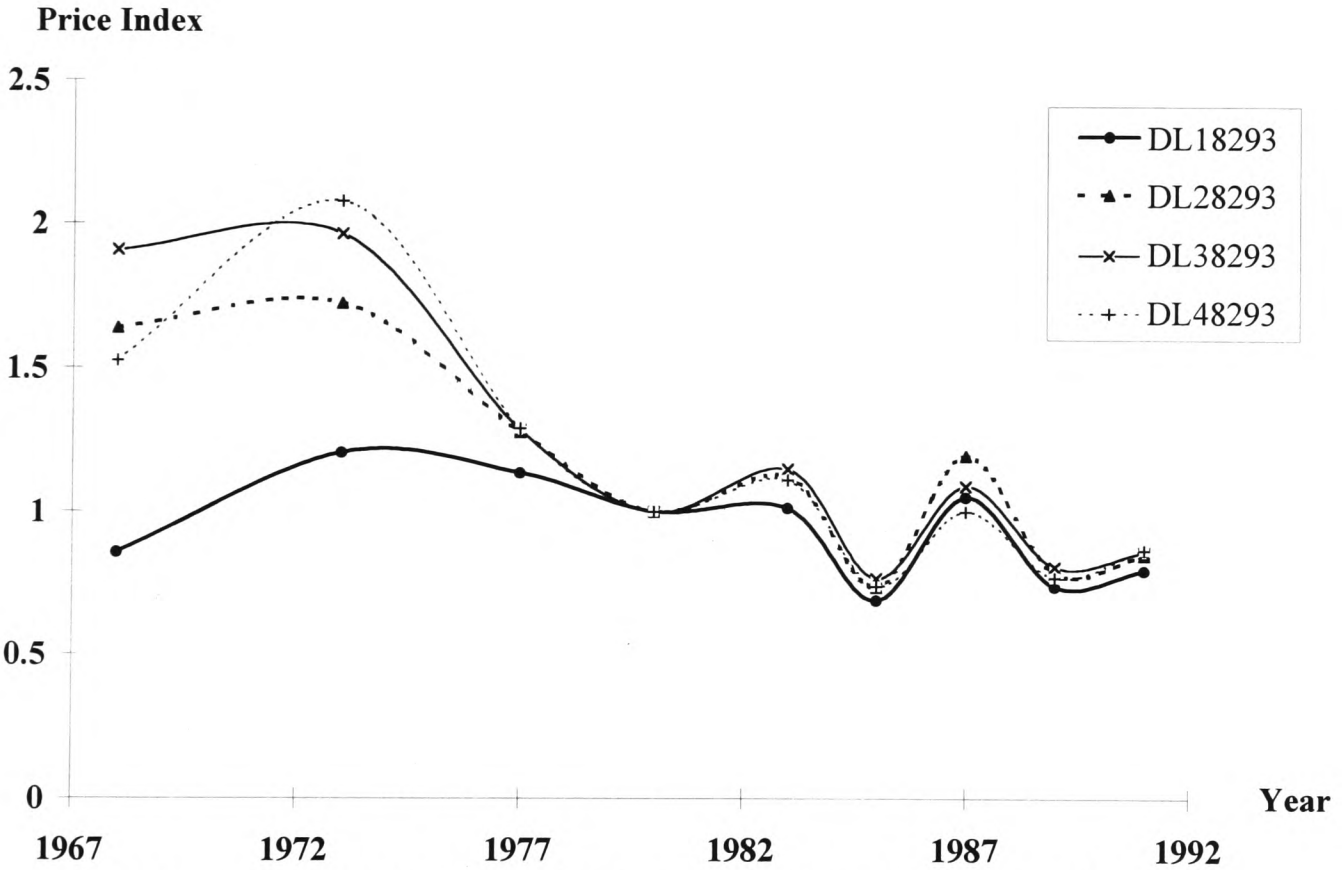


Figure 3.8: Hedonic price indices; all models; split high results.

As noted in the hedonic regressions section, the third and fourth models appear to be the most appropriate in the case of commercial communication satellites. As expected, the price index calculated from the pooled regressions does not decrease as fast as the two price indices calculated from the split regressions. The former results assume a continuous structure throughout the entire sample, while the latter assume a change in structure over the years of the sample. Recall that the previous Chow tests suggested that a significant structural change was present between the three sub-periods chosen. As a consequence, the hedonic price indices calculated from the split regressions constitute a closer view on reality. The first model will be rejected equally from further study because coefficient estimates were counterintuitive

and yielded the opposite sign as the three other models. Moreover, according to the first functional form, the price of a constant quality satellite does not seem to have declined over the years, while the other three models show a significant diminution. We will therefore keep the last two functional forms for further analysis.

Figures 3.9 and 3.10 illustrate the three types of price indices calculated for each of the two favoured models, 3 and 4. During the first decade of the communication satellite era, the price appears to increase slightly towards the middle of the period, then decrease sharply during the transitory period, to stabilise (although it undulations appear thereafter) around 1, but slightly decreasing, in the last sub-period.

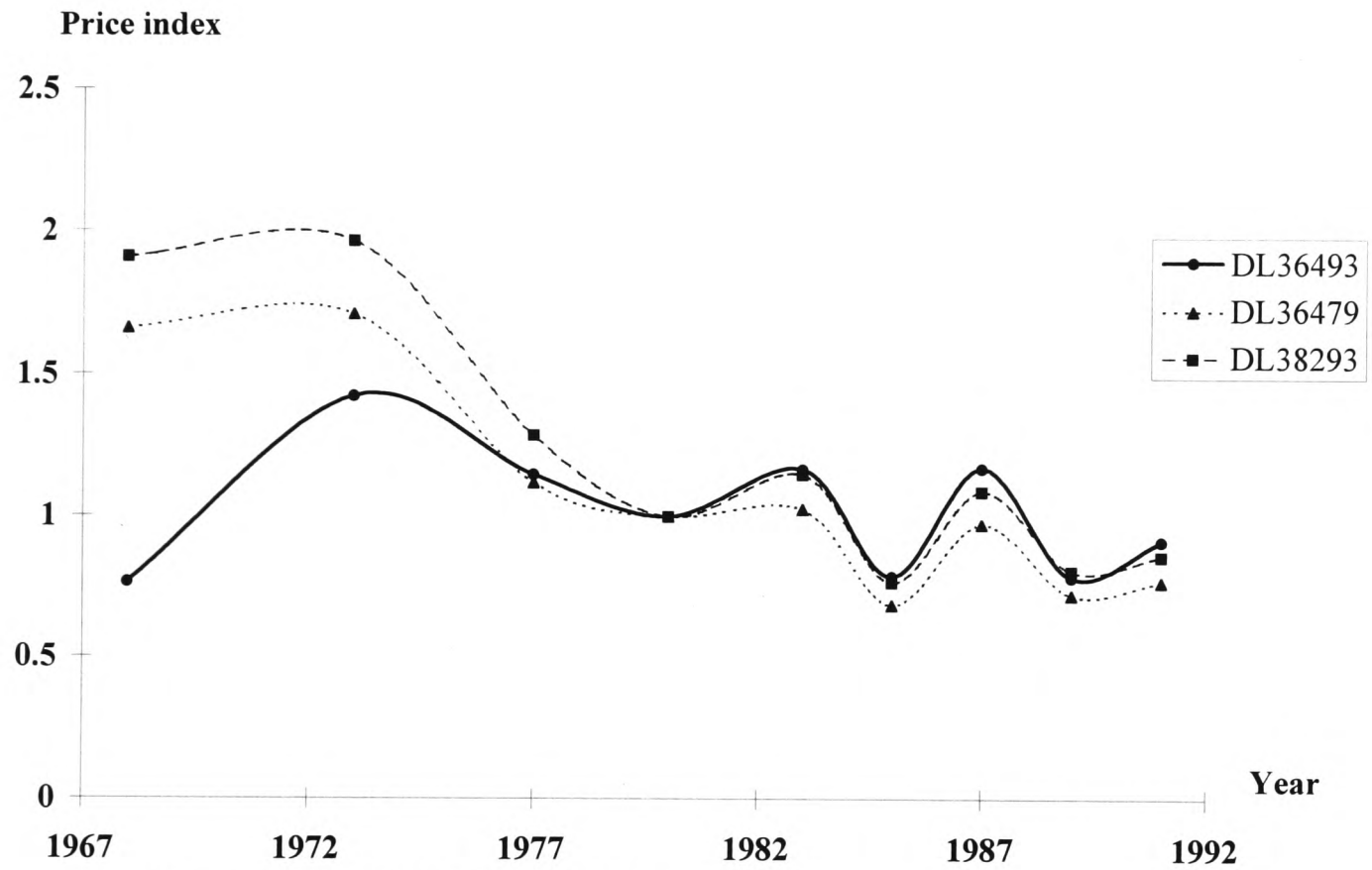


Figure 3.9: Hedonic price indices; model 3.

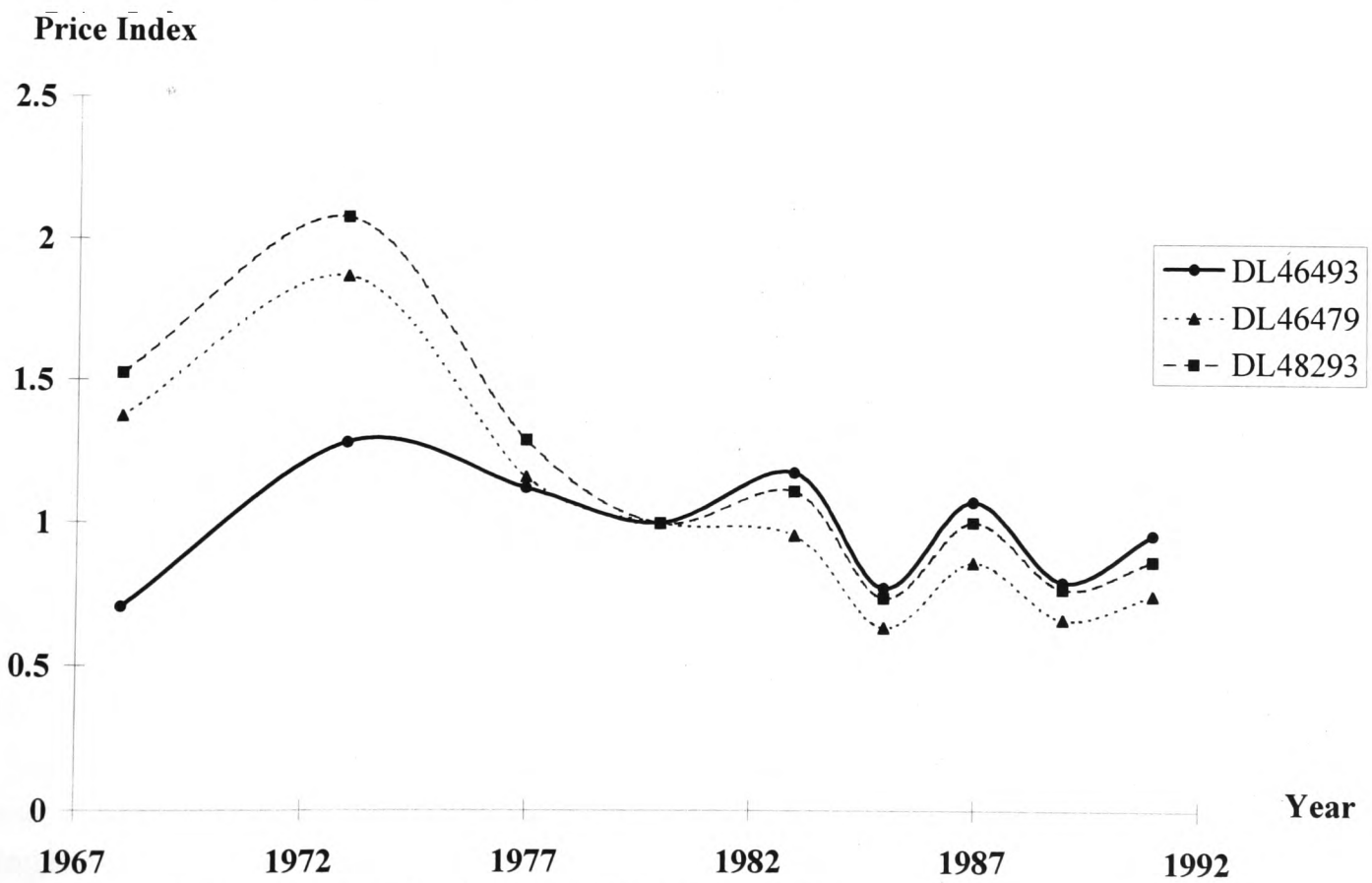


Figure 3.10: Hedonic price indices; model 4.

In the first part of the chapter, price performance ratios in the form of price to mass and other characteristics ratios were examined. We have calculated an index of the price to launch mass ratio based on the results illustrated in figure 3.2. This index is compared with the hedonic price indices obtained from the third model in figure 3.11.

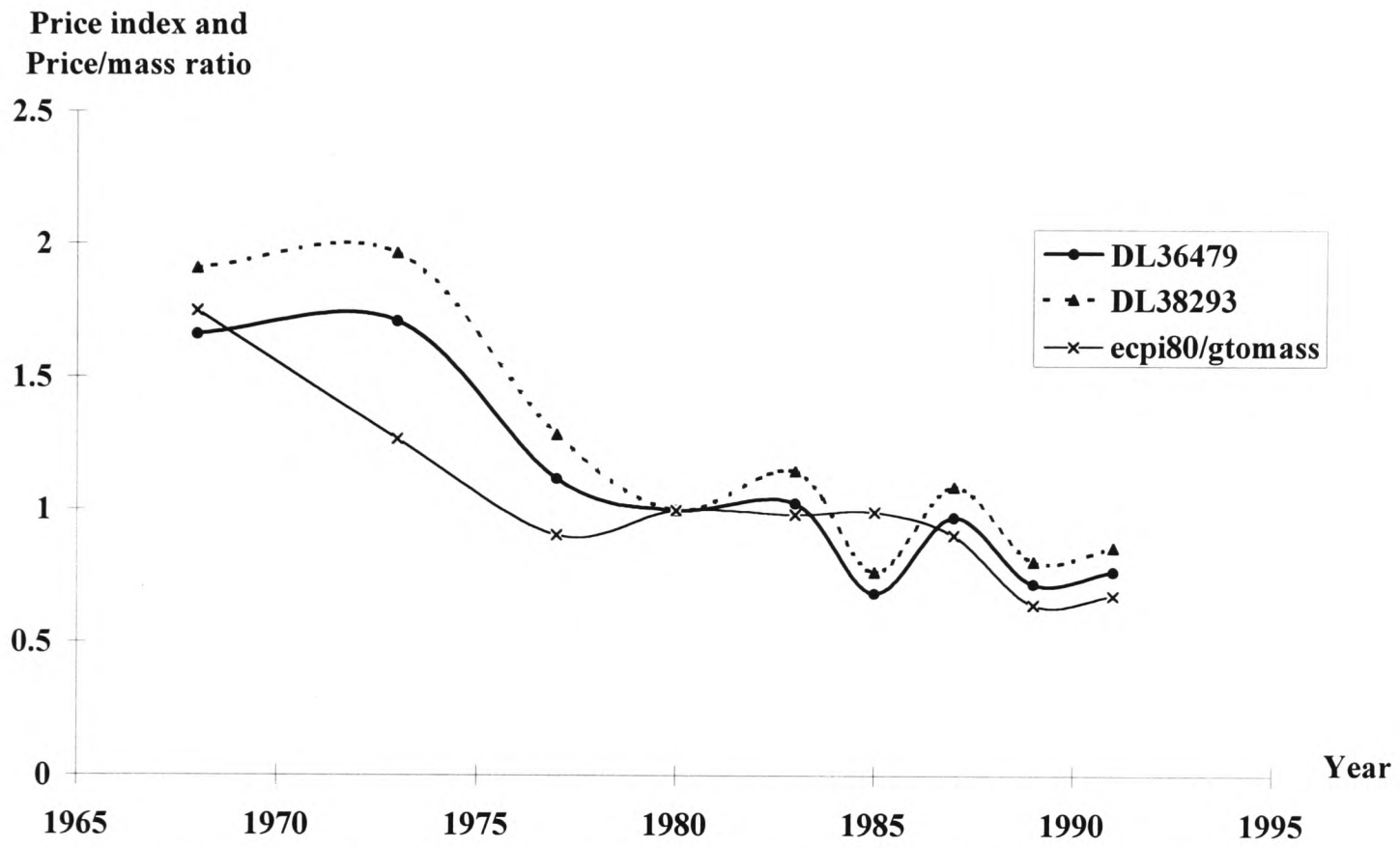


Figure 3.11: Hedonic price indices; model 3 (DL36479, DL38293), compared with an index of price to mass ratio (ecpi80/gtomass).

In general, in figure 3.11, the price performance ratio follows the hedonic price index. In the first few years of the sample, where the launch mass of satellites was increasing rapidly, the price to mass ratio is less than the hedonic price index. Although the signal capacity of satellites increased during this period, with a rise in the number of transponders and the associate augmentation in required power, the most important part of the mass increase was due to extended lifetime. In the second chapter, the relationship between spacecraft longevity and its mass at launch was described as the quantity on fuel necessary to reposition the satellite in its proper location. Consequently, the mass representing only part of the satellite complexity, and in the case of the third model, the mass being a consequence of the spacecraft complexity, a smaller price to mass ratio index was to be expected in the first period. Thereafter, the close relationship between the price to mass ratio and the price indices calculated from the third model support the engineering rule of thumb as a long run price setting mechanism. The next chapter will examine the price setting mechanism of the satellite manufacturing industry in greater detail.

For comparison purposes, the next graph (see figure 3.12) plots the non quality-adjusted price index and compares it with the hedonic price index calculated above. As expected, the non quality-adjusted price index increases with time, while the hedonic price index decreases over time, as the price of a constant quality satellite diminishes. As we have estimated different regressions for various regions of manufacturing and ownership, we can now calculate hedonic price indices for these regions and compare them with one another.

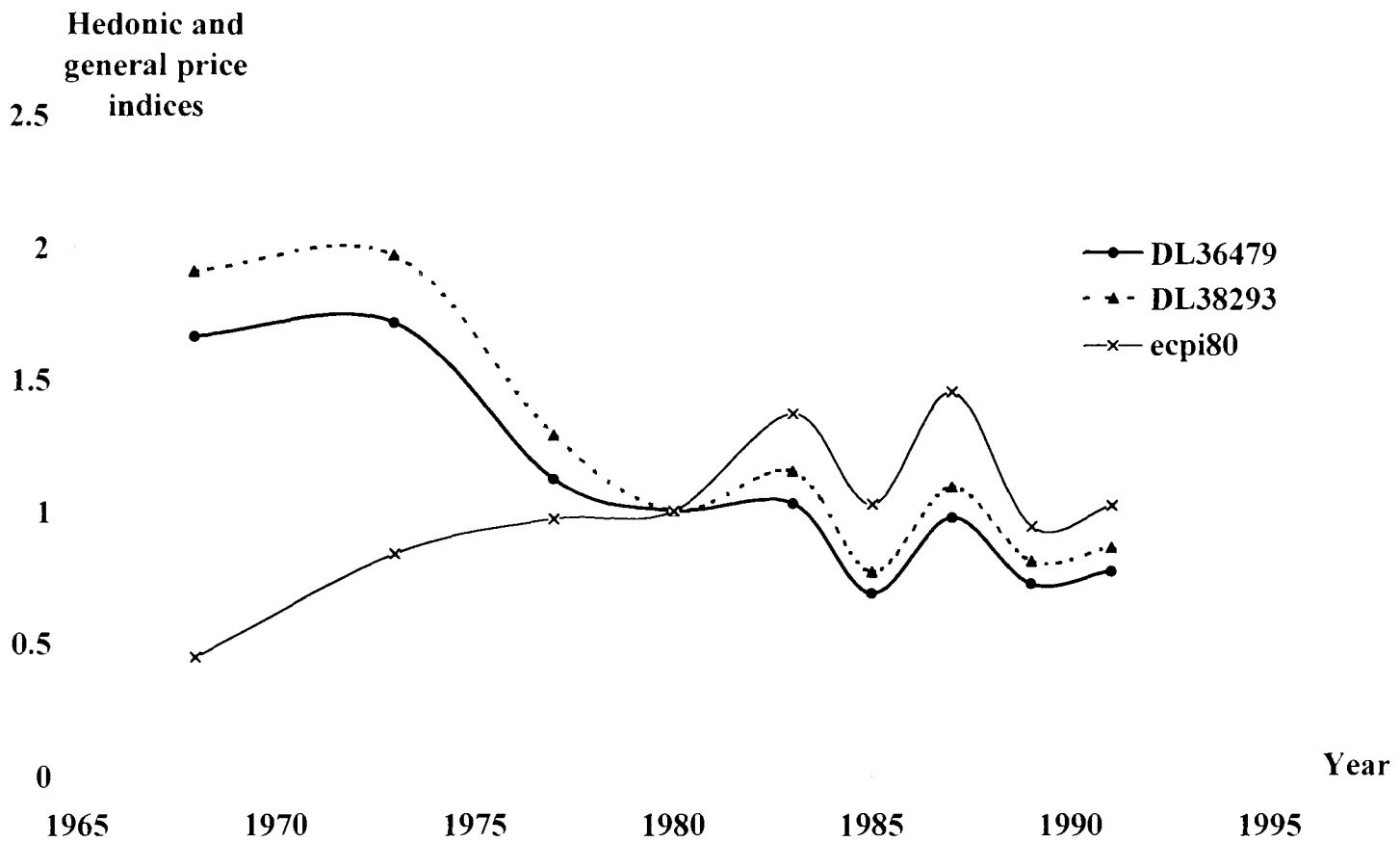


Figure 3.12: Hedonic price index; model 3 (DL36479, DL38293), compared with the non-quality adjusted price index (ecpi80).

3.4.2 Different manufacturers

Recall from the first chapter that three of the main spacecraft manufacturing firms are located in the United States: these are Hughes Aircraft, Lockheed Martin, Loral. In fact, these three companies account for 66 of the 104 contracts considered in this study. In contrast, only 24 contracts were attributed to European manufacturers. Table 3.27 shows the price indices calculated for North American manufacturers[24].

Without the European built spacecraft in the sample, the North American hedonic price indices are slightly more stable than that for the entire group of all manufacturers presented in the previous section. In the case of North American manufacturers, the fourth model seems to give the least oscillation in the latter part of the sample, and will therefore be chosen to illustrate the results of this section.

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[24] When hedonic regressions were calculated for the European manufacturers, the fit of the equation was considerably poorer than that for North American manufacturers. As a consequence, price indices for European satellite builders will not be calculated. In any case, because of the lack of data, only a European pooled regression could be estimated because European manufacturers truly started their main commercial operations in the 1980s, and no index chain could have been calculated. Various reasons for the lack of fit of the European regressions have already been examined. First, the number of degrees of freedom available for the European builders is small, only 24 contracts were included in our sample, and this represents most of the commercial market for communication satellites caused a lack of precision of the coefficient estimates. As a consequence, possible outliers in the regression cause more damage than if the sample was bigger. Second, there were rumours, mentioned in the first chapter that European satellites were purchased partly with the help of subsidies in order to establish the industry more quickly than the market forces would allow. This can potentially have increased the price of these spacecraft beyond the competitive price. As some European satellites were built for telecommunications and other focused on the very lucrative direct-to-home satellite television market, commercial customers versus monopolistic government-based PTTs may have paid a different price for their spacecraft. The former buying from a more competitive market and willing to buy outside Europe, and the latter buying European at almost any price in order to support the growing European satellite manufacturing industry. This discrepancy in prices may cause the constructed price index to be completely irrelevant. Unfortunately there are no satisfactory ways to solve this problem at the moment as the number of satellites produced in Europe is still small. In many years to come, with many more spacecraft built in Europe, maybe then, a proper hedonic price index for Europe may be constructed.

Table 3.27: Hedonic price indices; North American manufacturers.

Model	1			2			3			4		
Periods	pooled modal	split low	split high	pooled modal	split low	split high	pooled modal	split low	split high	pooled modal	split low	split high
1964-71	0.942	1.288	1.857	1.141	1.635	2.626	1.045	1.559	2.129	0.979	1.554	2.037
1972-75	0.964	1.384	1.994	1.100	1.642	2.638	1.303	1.621	2.214	1.216	1.378	1.806
1976-79	1.289	1.200	1.729	1.284	1.414	2.273	1.283	1.163	1.589	1.278	1.198	1.571
1980-81	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
1982-84	1.509	1.201	1.441	1.536	1.136	1.607	1.542	1.175	1.366	1.481	1.094	1.311
1985-86	1.206	1.113	1.335	1.111	0.964	1.363	1.184	0.920	1.070	1.116	0.938	1.124
1987-88	1.403	1.160	1.391	1.370	1.066	1.508	1.448	1.205	1.401	1.223	1.003	1.202
1989-90	1.304	0.519	0.622	1.205	1.161	1.642	1.295	1.195	1.390	1.174	1.104	1.322
1991-93	1.192	0.972	1.166	1.274	0.935	1.322	1.203	0.957	1.113	1.109	0.883	1.058

The next graph (see figure 3.13) presents the comparison of the three types of price indices, pooled (DL46493), split low (DL46479), and split high (DL48293).

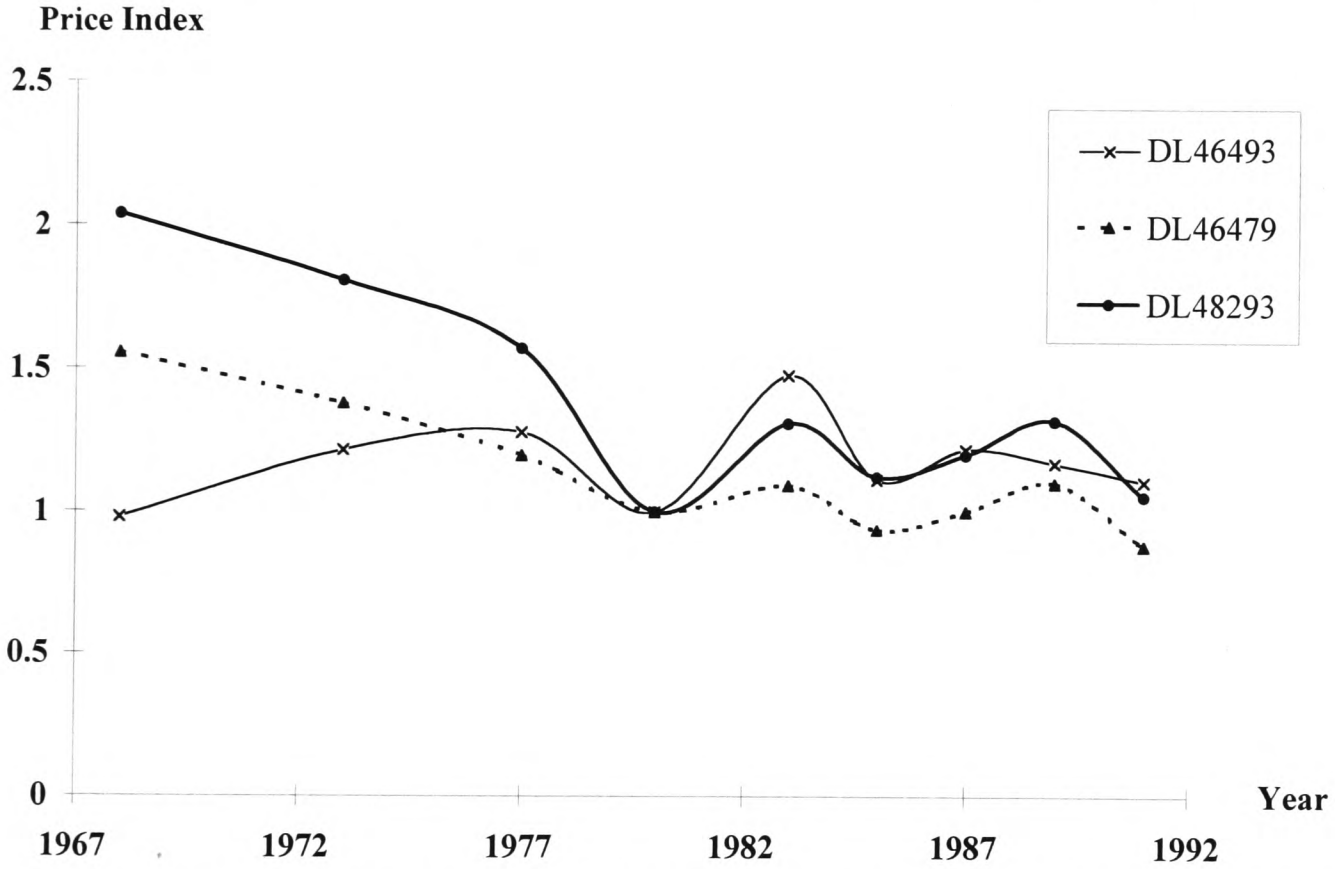


Figure 3.13: Hedonic price indices, North American manufacturers; model 4.

According to the two split versions of the fourth model, the quality-adjusted price index of commercial communication satellites built in North America has decreased until 1980 and has roughly stabilised thereafter (although there still is a slight ripple effect due to the lack of precision of the coefficient estimates). In general, the two hedonic price indices calculated from the split regressions will be more accurate than that from the pooled regression because of the significant structural change discovered from the Chow tests in section 3.3.2. Consequently, the hedonic price index calculated from the pooled regression appears to be slightly increasing while the other two indices diminish.

3.4.3 Different customers

In contrast with the manufacturers, customers are more evenly spread across the four groups under study: US and European satellite operators, international organisations and customers from other countries. In the following two tables, we present the price indices constructed using the customers regressions estimated in

section 3.3.3. As was the case for European manufacturers, no price index could be built from split regressions because of the small number of observations for all four groups. Basically, there are not enough observations to estimate a regression for each of the three sub-periods: 1964-79, 1976-84, 1982-93. Moreover, in the case of European-owned satellites, the same problem of outliers that pulled the regression line in the case of European-built satellites occurs here - mainly because Europe buys European, with the consequences on the price that this entails. Tables 3.28 and 3.29 therefore represent the constructed price indices from the pooled regressions of section 3.3.3.

Table 3.28: Pooled price indices for different regions of ownership, models 1 and 2.

	model 1				model 2			
Model 1	**US**	**Europe**	**International**	**Others**	**US**	**Europe**	**International**	**Others**
1964-71			0.994				3.315	
1972-75	1.764	0.932	1.013	1.021	1.586	0.133	3.293	0.746
1976-79	1.652	0.429	1.229	0.838	1.653	0.207	1.270	0.738
1980-81	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
1982-84	1.016	0.764	0.588	1.055	1.249	0.610	1.669	0.916
1985-86	0.451	0.187	0.574	0.902	0.474	0.109	1.744	0.796
1987-88	0.832	3.920	0.800	1.098	0.803	0.444	2.288	0.850
1989-90	0.450	0.238	0.963	0.826	0.330	0.123	2.985	0.760
1991-93	0.703	0.932	0.959	0.883	0.691	0.133	2.722	0.715

Table 3.29: Pooled price indices for different regions of ownership, models 3 and 4.

	model 3				model 4			
Periods	**US**	**Europe**	**International**	**Others**	**US**	**Europe**	**International**	**Others**
1964-71			22.873				1.509	
1972-75	1.307	0.045	21.841	0.624	1.586	0.075	1.533	0.880
1976-79	1.505	0.055	1.355	0.719	1.653	0.108	1.144	0.835
1980-81	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
1982-84	2.089	0.443	31.396	0.846	1.249	0.455	1.697	1.145
1985-86	0.650	0.114	0.831	0.857	0.474	0.097	0.803	0.902
1987-88	0.729	0.126	0.996	0.829	0.803	13.598	0.965	1.052
1989-90	0.365	0.131	2.024	0.758	0.330	0.121	1.128	0.853
1991-93	1.244	0.045	1.912	0.687	0.691	0.075	0.974	0.754

Without the European-owned satellites which clearly yield poor results, the price indices for the three other regions can be presented in the following graph (see figure 3.14). The degree of oscillation of the price indices in the latter part of the sample is probably due again to the small number of degrees of freedom, and the consequent lack of precision of the coefficient of the time dummy variables calculated earlier. The reason we propose this explanation is that the undulations diminish with an increase in degrees of freedom. Recall that other countries' customers account for 34 contracts, US satellite operators for 26 contracts, and international organisations for 22 contracts. And indeed, the ripples observed in figure 3.14 are the strongest for international organisations and the weakest for other countries.

A very interesting observation from this graph is that the price index for other countries' customers increased towards the 1980s and seems to have decreased thereafter (taking the average line through the undulations). It is possible that in the beginning, other countries' satellites were using technology that had been developed for their predecessors, and that, as a consequence, their price was cheaper for

whomever came after. Remember that in the first few years, the only countries in this category to launch and order satellites was Canada with the Anik series, and India with the Insat series. Canada accounts for 4 out of the 6 contracts for other countries' customers before 1980. Apart from the last two Anik series (D and E) which were built in Canada, and the second, Anik B, which was built by RCA, the first and third families of Anik spacecraft were built by Hughes Aircraft, and so were three of the first five Intelsat programs[25]. Most of the Canadian satellites have 'siblings' in the US fleet. Westar 1, ordered in 1972 and launched in 1974 had as predecessor Anik A, ordered in 1970 and launched in 1972, and both spacecraft have almost identical features. The second Anik series (B), built by RCA had similar characteristics as the first Satcom series ordered and launched three years earlier than the Canadian satellite. Furthermore, the third Canadian satellite program was also very similar to the first three SBS satellites ordered to Hughes Aircraft a year before Anik C. India, in contrast has modelled its satellite orders on the fifth Intelsat series of satellites. Unfortunately, price comparisons cannot be made directly for these cases as different numbers of satellites were ordered, and the number of transponders altered from one contract to the next for what we consider here as 'similar' spacecraft. For instance, the Anik C series was ordered after, and was more expensive than, SBS, but also included 6 more transponders.

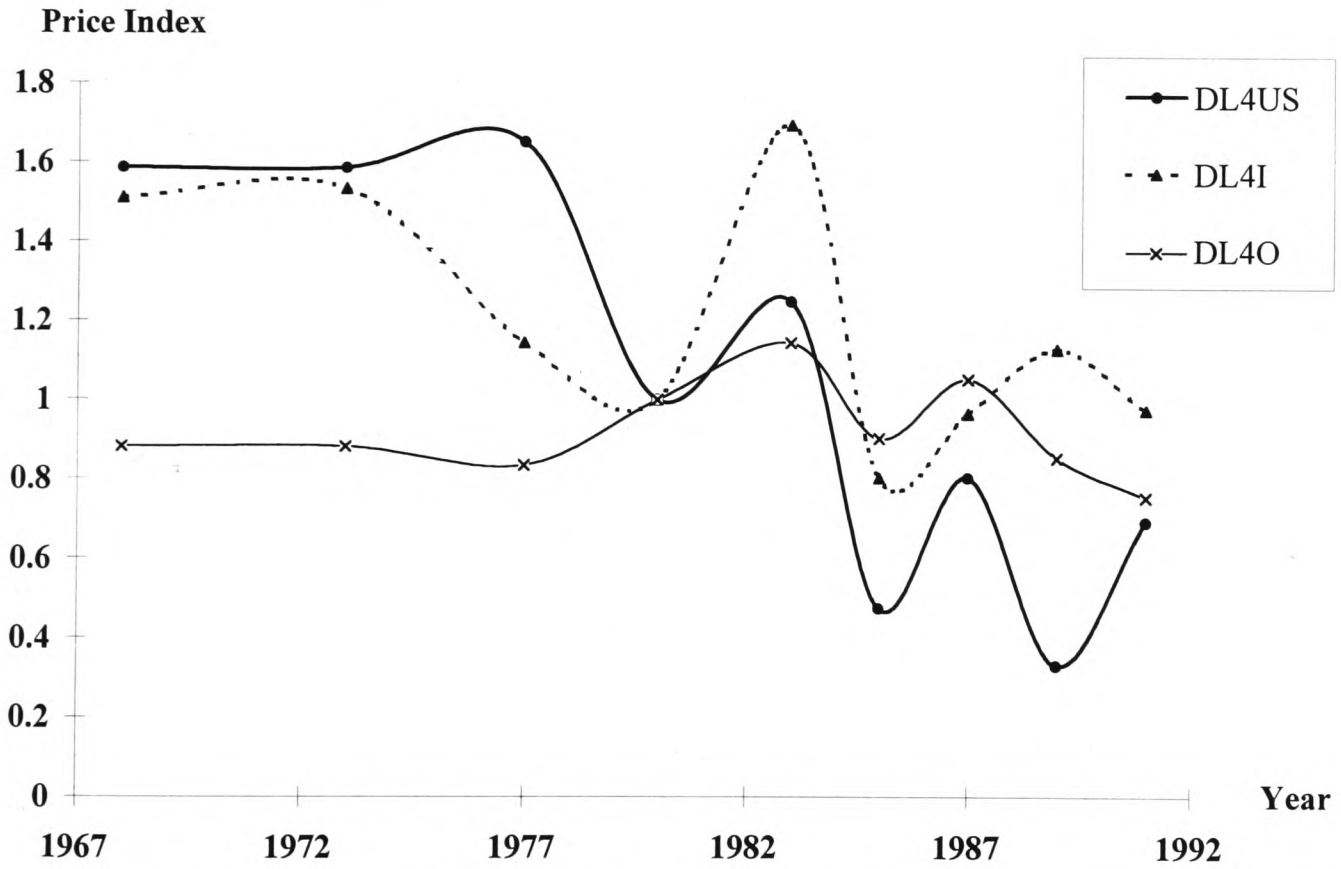


Figure 3.14: Hedonic price indices, model 4, US, international (I) and other customers (O), pooled results.

3.5 Conclusion

In the first part of this chapter, the traditional engineering 'rule of thumb' to price a satellite, price per kilogram, was found to be reasonably accurate but not perfect. Indeed, the relationship between the price of commercial communication satellites and the launch mass was seen to oscillate between 0.2 and 0.4 in the last 25 years of the sample with a general tendency towards 0.2 during the last 10 years.

[25] A list of satellites, their owners and manufacturers is provided in appendix A.

There are still some improvements to be made from this price/performance ratio as was discovered from the hedonic regressions fitted to the data. The results confirmed that the industry exhibits constant returns to scale, in other words, there are not enough satellites produced to justify significant economies of scale. Further, confirming the engineering rule of thumb mentioned above, there is a positive and significant relationship between the price and the launch mass of satellites, but in the early period only. In addition, the customers' willingness to pay for power has shifted from crude total end-of-life power of the entire spacecraft, in the beginning of the sample, to the more focused effective isotropic radiated power, *EIRP*, which is a measure of the geographical coverage and the quality of the signal, in recent years. The effects of sophisticated compression techniques were noted on the coefficients of the number of transponders and capacity: from the 1980s onwards, the coefficient on the capacity is negative, implying that customers are not willing to pay for more capacity on-board the spacecraft, as they can remedy the lack of capacity by acquiring software compression technology.

During the course of this analysis, we have examined the residuals in order to try to refine the data, and label the satellites as new or old technology. The question we were attempting to answer was whether there exist two industries, one concerned with developing new technology and the other simply selling the old technology. Some patterns were found, but not exactly the one just described. Amongst the high residual satellites, we found two Intelsat series, VIIA and VIII, OTS, Marecs, TDRSS, Olympus, TVSat, ACTS, Italsat 1, BS 2X, Telstar 4, Palapa B4. The Intelsat series are not very well fitted both because they provide new technology and order a great number of satellites all at once; separating these two effects is not possible. We suspect that although significant economies of scale were not observed in the sample, i.e. the coefficient on the variable *number* was close to 1 maybe because the majority of contracts consists of two spacecraft, they have an influence on the price when more than 4 satellites are purchased in one go. Four of the other satellite programs, were not solely used for commercial communications, they are OTS, Olympus, ACTS and TDRSS, and all contained part experimental payloads. We also noticed that while TDRSS is part of the multi-orders mentioned above, the two former satellite series, OTS and Olympus, where purchased and built by European parties. In contrast, Palapa B4 was an old technology satellite launched at a later date - it uses a spin-stabilisation system and its payload consists of 24 C band transponders, very much an early second generation satellite - but overpriced, possibly because it differed too much from the current production process. BS 2X also is an old technology satellite. Telstar 4 is very similar to Anik E, which was ordered and launched three years before, as they both possess the same platform produced by Hughes Aircraft, but the payload of the latter was built by Spar Aerospace. Telstar 4 is not therefore a new technology satellite, nor are BS 2X and Palapa B4. In fact, apart from the two Intelsat series, the old technology spacecraft, TDRSS and ACTS, most of the other satellites were built in Europe, for European customers. In our sample, there is therefore no evidence that there is a separation between new and old technology. This was to be expected as each satellite is custom-made to the specifications of the customer up to a certain degree, which depends upon the type of buyer. Each spacecraft in itself is unique, and 'production lines' are relatively short. The presence of the new technology, being constantly improving, thus does not affect the regression significantly. Following this residual analysis, separating manufacturers into two

groups, North American versus European producers, provided an improvement of the regressions for North America, but proved disastrous for Europe.

After the first series of regressions on the pooled sample, tests for structural change across time periods were performed. It was discovered that there is evidence of structural differences across three sub-periods corresponding to the three generations of satellites introduced in the latter part of the first chapter. With this in mind, three regressions, one for each period with overlapping years, were fitted to the data. Furthermore, similar Chow tests confirmed the claim that there are significant differences between spacecraft built in Europe and in North America as well as some discrepancies between the four types of customers. However, in the latter, the separation between customer regions was not as clear cut as between European and North American producers. Customers from Europe and the US were found to be significantly different from one another, so were European and other countries' satellite operators. But regarding other combinations, international organisations versus US customers for instance, the Chow tests were rejected only in certain periods. Indeed, during the first generation, satellites were more or less the same across the world as they were all manufactured in North America. Later on, as we expected, these similarities have almost disappeared. So not only did we find heterogeneity over time, implying important technology changes over the years, but also across various regions of ownership and production.

We have also discovered that the last two functional forms of the four postulated at the beginning of the chapter fitted the data better. The third model considers the launch mass as a consequence of the complexity of the satellite (i.e. its characteristics), while the last model incorporates the mass in the complexity. This notion of complexity will be examined in further detail in the next chapter. Also, in the following chapter, we will depart from the focus on individual satellite characteristics but will concentrate instead on the notion of complexity as being the main object of competition between manufacturers. Price indices will be compared with that of other similar high technology goods and the general productivity of the commercial communication satellite industry will be assessed.

From the coefficients on the time dummy variables of the hedonic regressions, price indices were calculated. In general, the price of satellites of constant quality has declined over the years. Moreover, the first period has experienced a stronger decrease than the second half of the sample. Not surprisingly, price indices calculated for North American satellite manufacturers offer a similar decline over the years to that of the pooled sample. European spacecraft, produced and owned, are not very well fitted by either of the four models considered and were eliminated from this study. The three other regions of ownership were considered and US and international organisations' satellites were found to experience a similar price decline for a constant quality spacecraft. In contrast, the hedonic price index for satellites owned by other countries has increased until the mid-1980s, and declined thereafter. A possible explanation for this result is that satellites built for other countries in the first period were not the latest technology, but close copies of earlier designs. Savings on development time thus permitted sale of these spacecraft at a cheaper price than their predecessors.

Chapter 4

Supply conditions and technology change

4.1 COMPLEXITY MEASURES 144
4.1.1 Pooled sample 146
4.1.1.1 Time series of predicted complexity 146
4.1.1.2 Price with respect to complexity 149
4.1.2 Split sample 153
4.2 PRICE INDICES 155
4.2.1 General price indices 155
4.2.2 Different manufacturers 158
4.2.3 Different customers 159
4.3 BUYER/SELLER PRICE COMPARISON BETWEEN US AND EUROPE 160
4.4 PRODUCTIVITY 163
4.4.1 Model and data 163
4.4.2 Partial factor productivity 166
4.4.3 Total factor productivity 167
4.5 LEARNING 170
4.5.1 Model 170
4.5.2 Results 172
4.6 CONCLUSION 173
ANNEX 4.1 176
ANNEX 4.2 179

4. Supply conditions and technology change

In this, the second part, we turn to examine the forces operating on the supply and demand sides of the market for communication satellites, taking up supply factors in this chapter and demand side factors in chapter 5. The observation (in chapter 1) that the structure of the industry on the vendors side is a tight oligopoly, and the further observation (in chapter 2) that the products of the industry are quite differentiated, being essentially custom-made in their configurations of engineering characteristics, the maintained hypothesis is that the vendors are price setters, not price takers. Since there is a substantial time required to build the satellites already on the order books, at any moment in time it is likely that only a small number of the firms are credible bidders for near term delivery. Furthermore, it is likely that one of the firms acts as a price leader for the industry, allowing others to compete in terms of design specifications affecting capacity and launch costs, as well as in terms of the delivery date. This strongly suggests the absence of a supply curve in the identification problem first described in the introduction to this thesis, and consequently simplifies this econometric problem considerably.

If that were so, then it would be reasonable to regard the prices as reflecting a proportional mark-up on estimated costs, and to suppose that there were commonly understood 'costing' rules, which translated satellite specifications into some cost, and hence price quotation. The engineering convention of characterising satellites by a summary measure, the 'complexity' (see chapter 3), supports this hypothesis: conventional formulae that combine various engineering specifications to provide a scalar magnitude would be useful in arriving at an approximate unit cost magnitude, to which vendors and buyers alike could refer.

Following that line of supposition, and the mark-up pricing hypothesis, the present chapter explores the relationship between 'complexity' measures derived from the hedonic regression estimates, and the contract prices of satellites within a technological regime. It will be seen that the evidence is strikingly in accord with the view that in the short-run the oligopoly structure of this industry is accompanied by a simple form of cost-plus price-setting.

Over longer intervals of time, however, the relationship between the 'complexity measure' of satellite 'quality-and-cost' and the real unit price of the product, i.e. satellite price expressed as a relative of the general price level, shows a much less pronounced positive elasticity. Technological change would tend to have such an effect, by raising the productivity of the industry in the production of satellites of a given quality ('complexity'). An inquiry into this is the second task of the present chapter. Making use of the mark-up pricing relationship (whose existence is supported by the proportionate changes in real unit prices and the 'complexity' index of unit costs) it is possible to interpret the hedonic price index numbers found for successive dates as indices of the unit costs of satellites of a constant 'quality'. In other words, by proceeding under the assumption of a constant degree of monopoly power in the industry, it is possible to estimate changes in multi-factor productivity by using the cost-dual of the conventional production function approach to productivity measurement. So because of the constant mark-up, the cost-dual approach allows us to interpret the price indices as cost indices, and when the cost-share weighted indices

of input prices rise faster than the prices of satellites of a constant kind (i.e., the hedonic price index), we interpret the estimated index of change as measuring the index of technological advance in this branch of industry. It is then possible to compare the contributions of productivity advance achieved by the satellite builders with that arising from technological change in the production of satellite components purchased from other industries. The latter are found to have been a major driver of the long run overall fall in the real unit prices of satellites of equivalent quality.

Examining the proximate sources of such productivity improvements, that can be identified as having occurred within the satellite building industry, is the third of the tasks addressed in this chapter. Specifically, the available estimates of multi-factor productivity, and measures of industry 'experience' based upon cumulative production of satellites (measured in units of constant complexity) are employed to test the hypothesis that there has been learning-by-doing at the industry level, of the sort that has been found historically in the case of airframe production, ship-building and other complex assembly operations. The econometric findings are consistent with the presence of learning-by-doing at the industry level. The absence of significant proprietary technology in the commercial communications satellite industry, and the serial circulation of engineers among the industry's firms, following the uneven temporal flows of contract work, are entirely compatible with the notion that learning effects tend to spill-over quickly and extensively from the individual firm to the industry at large.

The chapter is divided into six parts. In a first part, complexity measures are calculated in order to study technology shifts. The second and third sections concentrate on the price of commercial communication satellites: the former compares the price of European and US, built and purchased, satellites, while the latter compares the price indices calculated in the previous chapter with price indices of other high technology goods such as aircraft, computers and communication equipment. Then, a fourth section calculates productivity measures from the hedonic price indices. A fifth section evaluates learning effects in the industry based upon the productivity measures calculated in section four and a constructed experience measure based upon spacecraft complexity. Finally, the last section concludes on the supply conditions of the commercial communication satellite industry.

4.1 Complexity measures

So far, no evidence of proprietary technology in the commercial communication satellite industry has been found. Furthermore, the commercial communication satellite building industry is advancing because it is building more complex spacecraft, i.e. in the long run, technology improvements shift supply outwards. A way to measure these supply shifts, is to examine the evolution of the satellite complexity over time. Although the temporal evolution of the complexity measure will show a general increase in level, in order to examine supply shifts, complexity is compared with the price. Comparing quantity (satellite or capacity) with the price over the years (see chapter 1) also exhibits shifts in supply that can be related to the technology, but complexity measures are more accurate because of the fast evolution of technology. For instance, comparing quantity of satellite capacity with its price over the years shows that the quantity does not increase as fast as the price level. This could either mean that: (a) there is less need for satellites because of the rise in

popularity and use of alternative technologies such as fibre optics and their quantity has actually declined; or (b) effective capacity[1] has increased due to technology change and quality improvement of the good, implying that less physical capacity is needed as a consequence. Comparing complexity with the price eliminates this ambiguity and therefore examines technical change directly.

Complexity is a summary measure of satellite quality based on engineering specifications of communication satellites, many of which relate to its capacity and most of which have bearings on spacecraft production costs. In specifying the hedonic regressions estimated in the third chapter, complexity was defined as a combination of weighted satellite characteristics that were judged the most relevant in assessing satellite quality. Satellite quality depends upon many factors, some of the most important being transmission capacity, power and lifetime. In this thesis, complexity relates solely to engineering specifications, and not to economic attributes such as production processes (although the development time, *rdev*, represents the length of the production process). The main reason to use an engineering complexity measure is that data required to implement economic complexity is not available on the wide scale necessary for this research. Moreover, the previous chapter was concerned with the evolution of technical attributes and their effect on the price. Complexity in this thesis is therefore nothing more than the shadow price of a group of technical characteristics of satellites. Two functional forms from the preceding chapter were retained (repeated below), the third and fourth models, the former defining complexity as a linear combination of satellite characteristics excluding launch mass, and the latter, as an exponential function of a linear combination of these characteristics including the launch mass. As mentioned in the third chapter, the third model is based on an engineering cost function (commonly used in the engineering costing software described in the third chapter), while the fourth model is a standard economic semi-log formulation. The main reason to compare these two formulations is two-fold. First, it addresses the question as to whether the mass is a consequence of the technical attributes of the satellite or a distinct characteristic. Second, it compares the engineering and economics methods of assessing the price.

$$Complexity_{3i} = \sum_j \alpha_j X_{ji} + \sum_k \beta_k Dx_{ki} \tag{4.1}$$

$$Complexity_{4i} = e^{\lambda_1 m_i + \sum_l \alpha_l X_{li} + \sum_k \beta_k Dx_{ki}} \tag{4.2}$$

Using the shadow prices of the characteristics estimated from the hedonic regressions of the previous chapter, we can calculate complexity measures for each of the commercial communication satellites in our sample. For the subsequent analysis, three typical satellites from the three sub-periods will be chosen from the characteristics' analysis of the third chapter. Table 4.1 describes the characteristics of the three types of satellites for which complexity measures will be calculated.

The obtained complexity measures for all observations using both pooled and split hedonic regressions are presented in two types of graphs, complexity versus time and price versus complexity. The former uses the same representation utilised to illustrate the characteristic temporal comparisons in the last part of the second chapter.

---

[1] Effective capacity is the actual number of channels that can be transmitted rather than the physical bandwidth capacity.

The latter are presented in an attempt to verify whether there is a simple relationship between the actual price of the satellites and their level of complexity. This relationship would justify the notion of 'engineering rule of thumb' between price and mass but also between price and characteristics. As before, the analysis is separated into three categories: the pooled sample is first examined, then it is disaggregated into manufacturing and ownership regions.

Table 4.1: Stylised characteristic satellites of various complexity

Characteristics	low	high	modal	Characteristics	low	high	modal
gtomass	600	2400	1200	*gmeirp*	25	40	45
rdev	24	54	36	*mtrp*	1	1	1
eolpower	250	3000	800	*ctrp*	2	1	1.75
lifetime	7	10	10	*kutrp*	1	2	1.25
sumtr	12	24	20	*D3a*	0	0	0
totbw	432	864	720	*Dtwt*	1	1	1
hmpower	5	30	30	*service*	0	0	3

4.1.1 Pooled sample

The complexity measures presented in the following paragraphs were calculated using the coefficients from the hedonic regressions presented in section 3.3.1. The analysis of the time series obtained from the calculation of complexity measures will be presented, followed by the examination of the relationship between these measures of satellite quality and their contracted price.

4.1.1.1 Time series of predicted complexity

The temporal evolution of complexity will be represented as follows: a scattergram of the calculated complexity of all satellites successfully launched with respect to their launch date, with the envelope of all satellites, minimum and maximum, identified by dotted lines and the moving average of the year mean by a solid line. On the y-axis, the difference in apparent complexity between models is due to the fact that they originate from different regressions. A way to alleviate this problem would be to compare everything with the mean value in 1980. This will be done in the next section, when the complexity is compared with the price and the difference between the pooled and split results really matters.

The third model shows a measure of complexity that increases with time. The split[2] version (figure 4.2) of the model gives a more steady increase with less year to year variation than the pooled version (figure 4.1), which is to be expected since the hypothesis of a common regression throughout the sample period was rejected.

The pooled version of the fourth model (figure 4.3) shows a complexity measure that increases very slowly until the mid-1980s and then suddenly augments sharply to reach a plateau in the 1990s. The split version (figure 4.4), however, gives a more steady increase through the whole period which is similar to the third model.

All in all, there appears to be have been a faster increase in complexity improvement for satellites launched in the later part of the 1980s, compared with the entire post-1985 period. This is the case for both models. These satellites were

[2] The split version of the complexity measure is constructed by splicing the three complexity measures obtained from each of the three split regressions, 1964-79, 1976-84 and 1982-93, for the overlapping years.

ordered earlier in the decade, corresponding approximately to the last generation of satellites. On all these graphs, the name of some satellites outlying the envelope (minimum and maximum) of all observations are identified. This allows the identification of the new and old technology encountered in the sample.

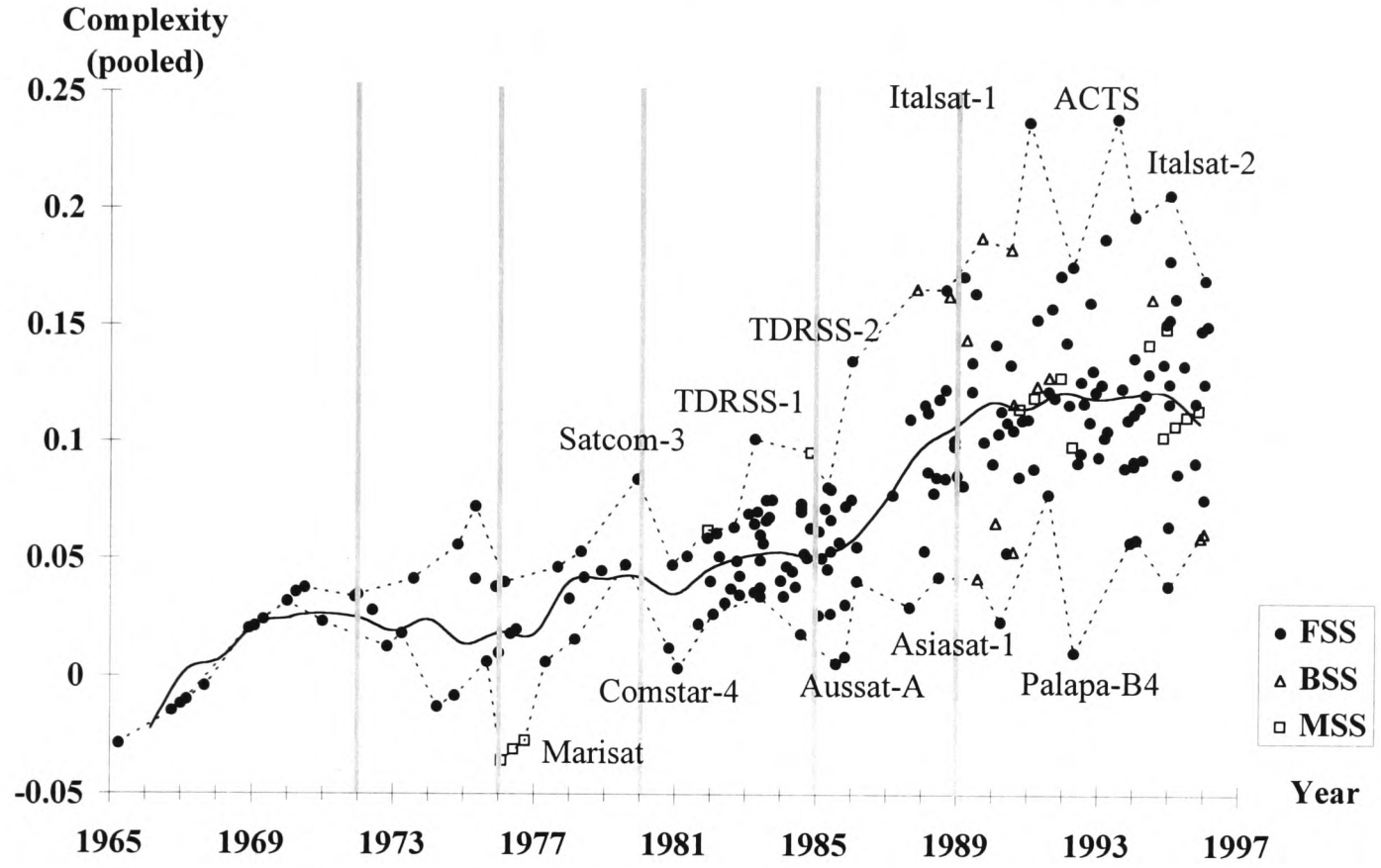


Figure 4.1: Calculated complexity at launch[3] for the sample period 1965-96; pooled results, model 3.

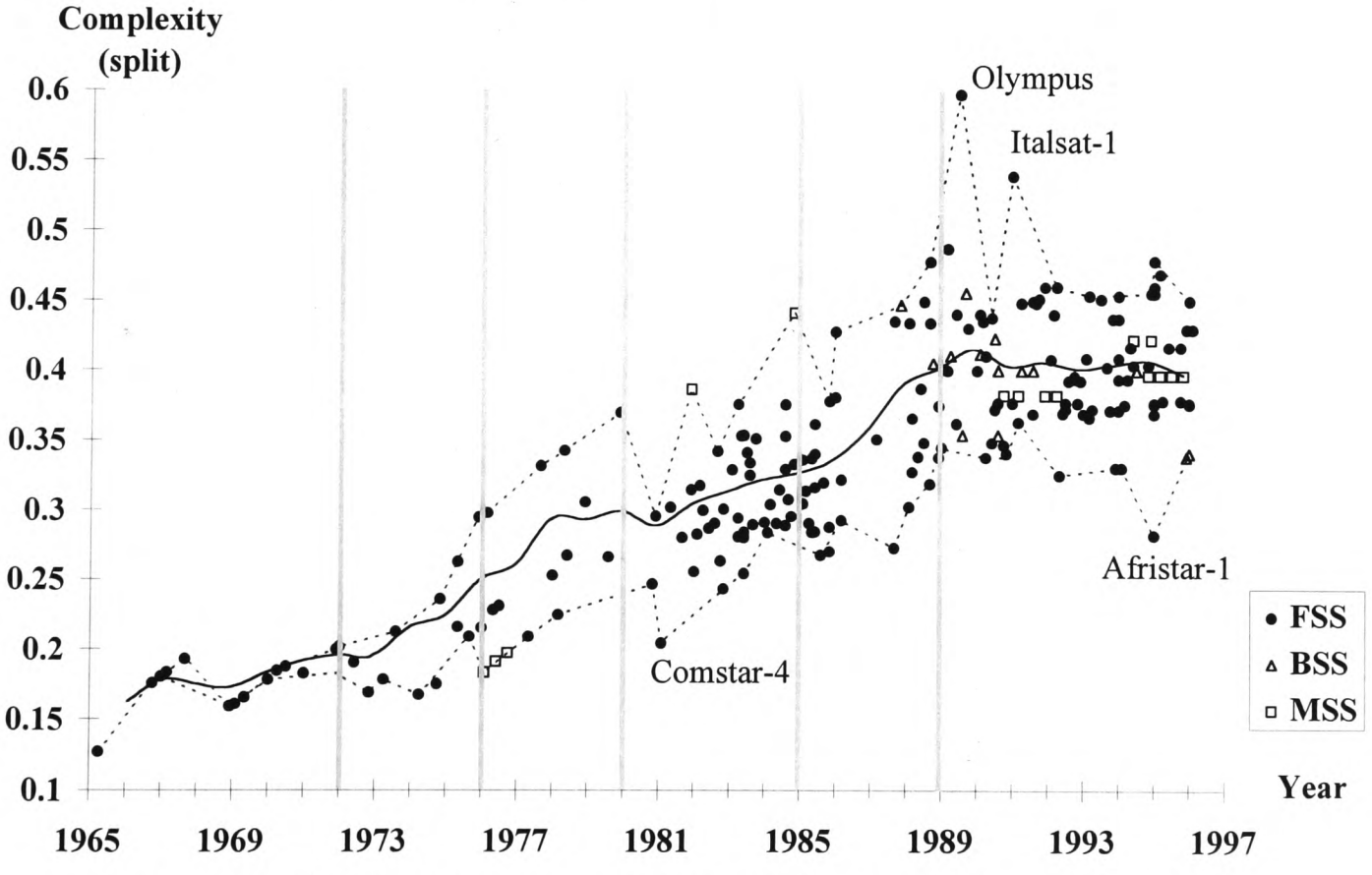


Figure 4.2: Calculated complexity at launch for the sample period 1965-96; split results, model 3.

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[3] *At launch* only means that the complexity of each satellite is shown according to its launch date rather than to its contract date. This representation is preferred as it offers a smoother curve and corresponds to the actual usage of these satellites. A graph according to contract dates would not take into consideration the development time that may be longer for a more complex satellite.

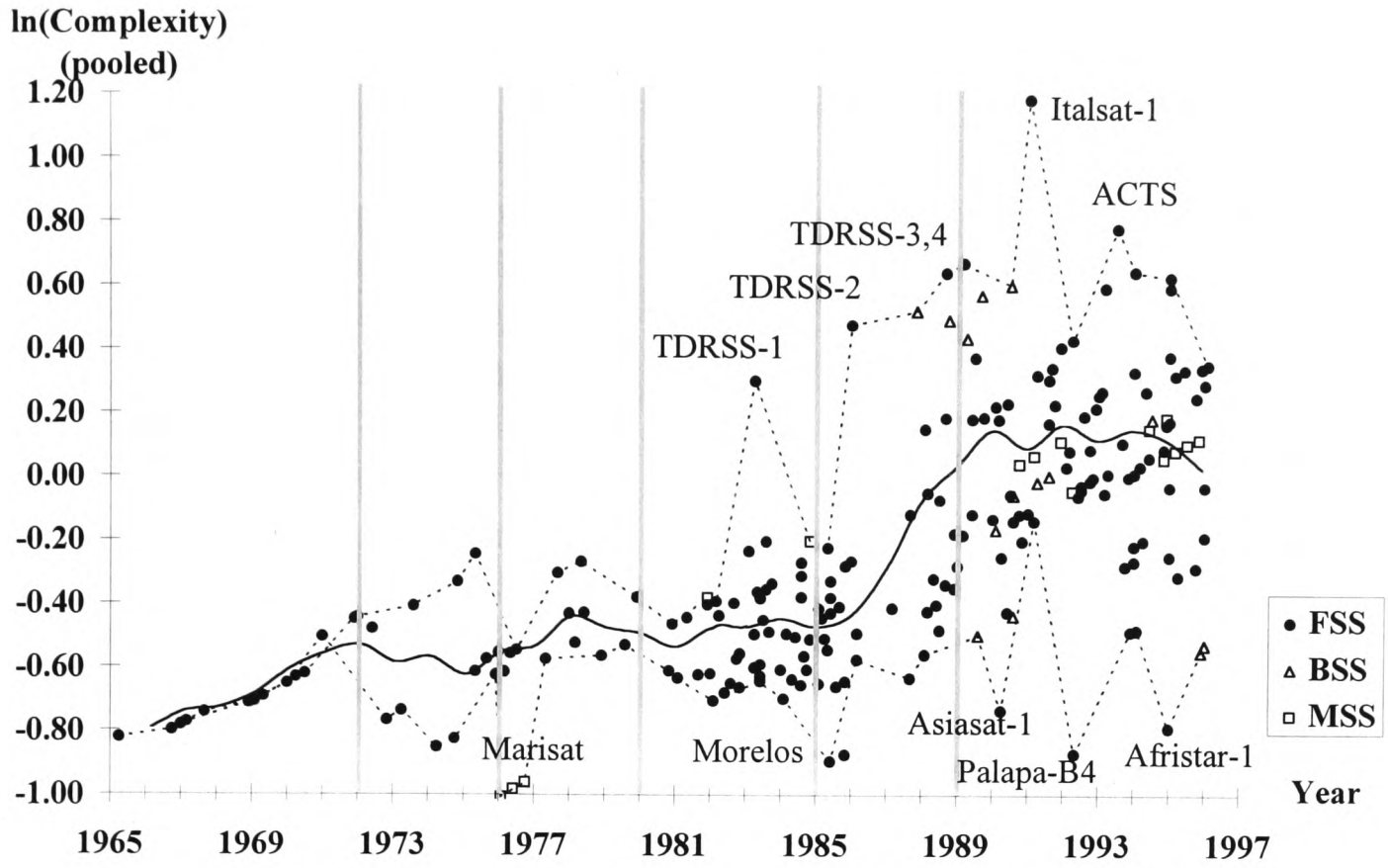


Figure 4.3: Calculated complexity at launch for the sample period 1965-96; pooled results, model 4.

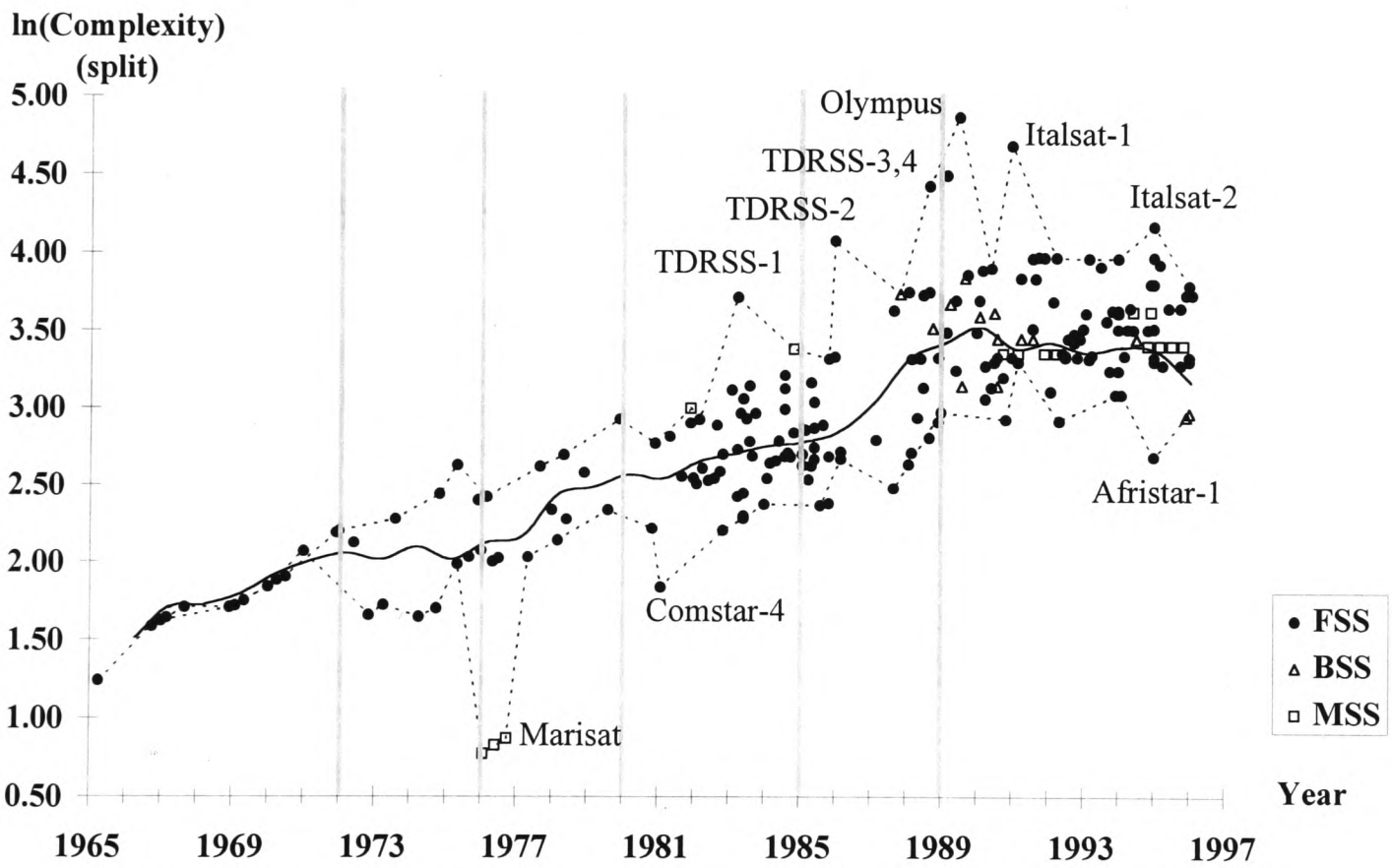


Figure 4.4: Calculated complexity at launch for the sample period 1965-96; split results, model 4.

The new technology satellites commonly identified on these graphs are: CS-2 (Japan), the first satellite to include transponders in the higher Ka-band (26.5-40 GHz) frequency; Satcom (US), OTS (Europe) and Marecs (Europe), the first few satellites to use three-axis stabilisation; OTS, the first satellite series to transmit signals in the Ku-band. Olympus, Italsat and ACTS are also outlined because they are very complex satellites.

The level of complexity of these satellites does not appear to be matched by any other spacecraft in the present sample, but remember that the sample only contains satellites whose contract had been signed by the end of 1992. Many more satellites

have been ordered since then, and undoubtedly, the level of complexity must have increased accordingly. It is important to note that satellites belonging to the same contract family rarely appear to have the same level of complexity, this is due to the inclusion of the variable *rdev* in the complexity measure. This variable was included in the complexity measure because a greater development time would allow a greater complexity of technology. One could argue against the inclusion of such a variable, but the longer development time allows manufacturers to solve problems encountered in the versions of the satellites of a common series, launched earlier, hence potentially increasing the 'quality' of the spacecraft.

Complexity, perhaps, is not the most appropriate terminology to use in referring to the technical attributes of the satellites. A rise in complexity does not signify that a new, technologically more advanced satellite has been introduced. The most vivid illustration of the absence of such a connection appears in the position of the mobile communication satellite Marisat on the foregoing graphs. Because Marisat, when it was first introduced in the mid-1970's, used a small number of transponders and small bandwidth (indeed, its bandwidth was far smaller than the fixed satellite service spacecraft of the time), it always appears at the bottom of the complexity scale. Yet Marisat was the pioneer mobile communication satellite on the market.

4.1.1.2 Price with respect to complexity

This section presents the relationship between the logarithm of the contracted price and the calculated complexity described above. We have reasons to believe that the culture of military cost-plus contracts has remained and evolved into a price rule, where the cost depends upon the characteristics of the spacecraft and the price is the cost plus a mark-up. Following this argument, if we can find a relationship between the price and the complexity, i.e. the shadow value of the characteristics, that is stable over time, then the mark-up implied is relatively constant over the same period. Also, examining complexity versus price allows us to determine whether there are supply shifts in the long run and what they are attributable to.

One of the major problems in comparing complexity across functional forms, whether calculated from pooled or split models, is that absolute values of complexity vary. One way to partially circumvent this problem is to calculate a relative measure of complexity by standardising with respect to a particular year. For this precise case, the mean value of complexity in 1980 was chosen as the reference. But even with this relative measure, complexity is not comparable across models. For the split versus pooled discrepancy, the problem is more complex: the intercept and the time dummy variables absorb part of the difference between one generation and the next, making the direct comparison of levels more difficult.

The next two graphs (see figures 4.5 and 4.6) present the relationship of the natural logarithm of the price and the calculated complexity measure constructed from equation (4.1). These two graphs show a significant difference between the pooled and split results, both offering a close to linear relationship between the price (in logs) and the complexity. Moreover, the split version still offers a slight improvement over the pooled version as the yearly average points are less distant from a hypothetical regression line. It is easy to distinguish short-run and long-run patterns in the two previous graphs; the split results represent the former, and the pooled results characterise the latter.

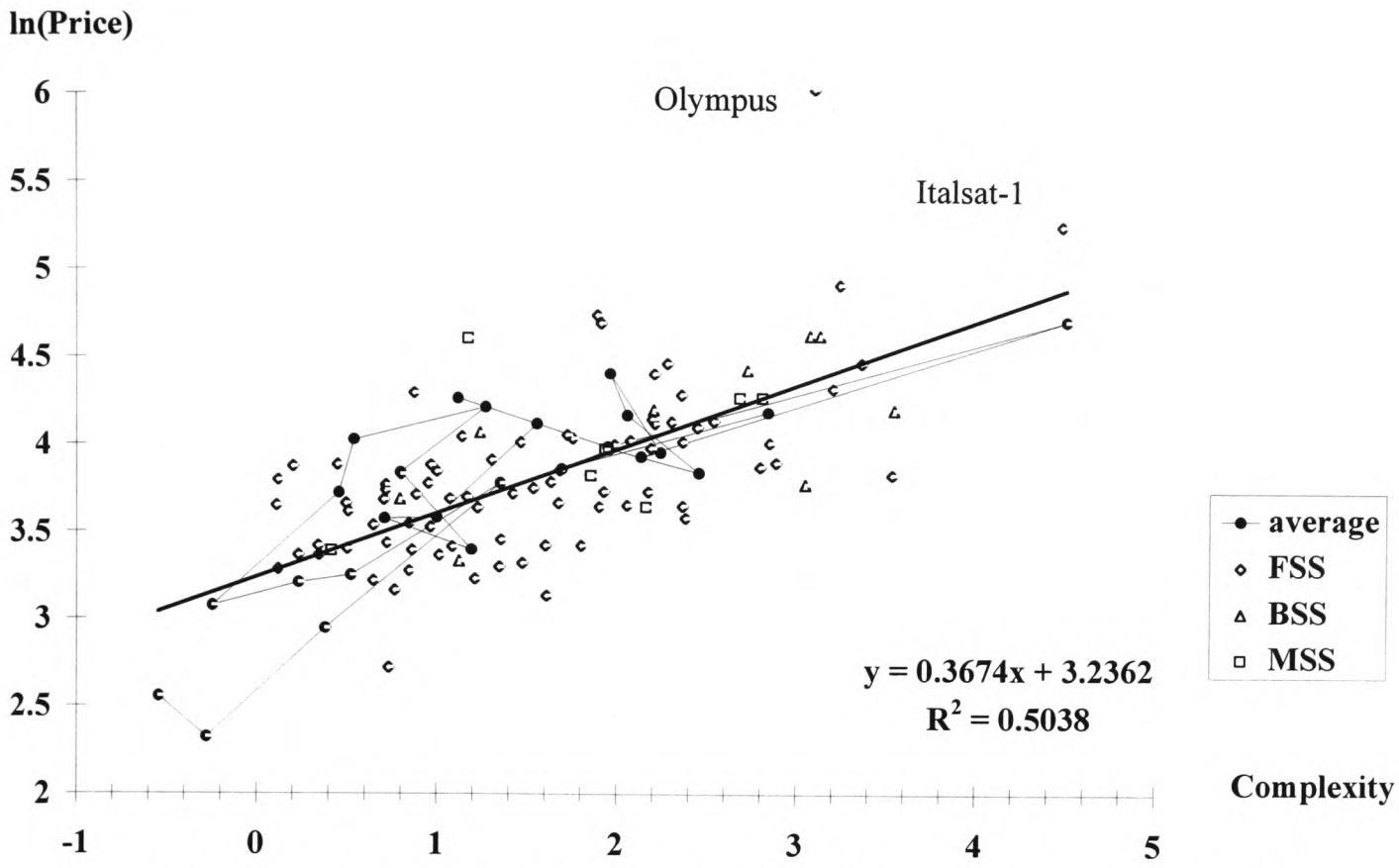


Figure 4.5: Awarded price of each satellite with respect to the calculated complexity measure, in logarithm; pooled results, model 3[4].[5]

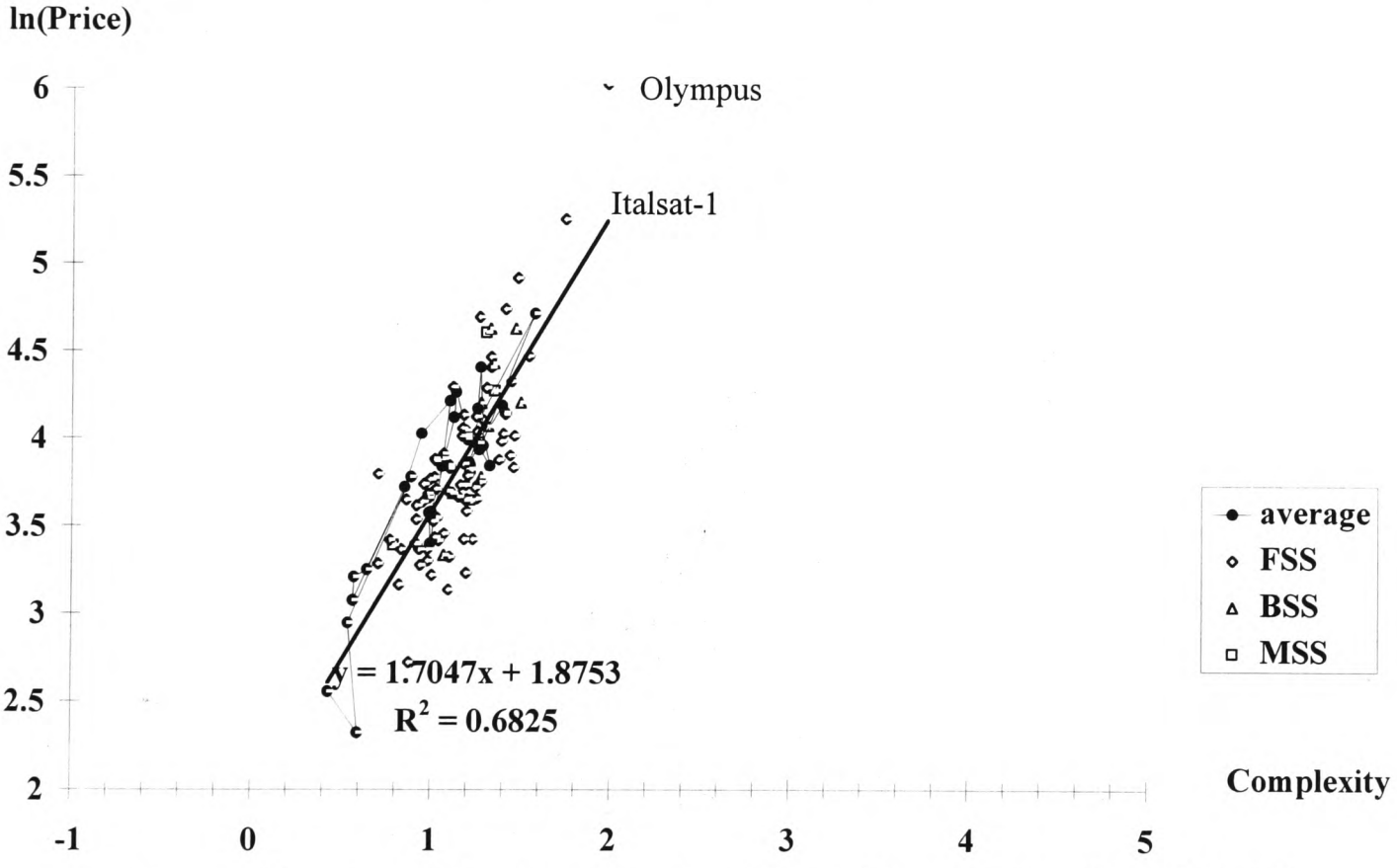


Figure 4.6: Awarded price of each satellite with respect to the calculated complexity measure, in logarithm; split results, model 3.

In order to verify this claim, we have plotted the price (in logs) versus the non-chained split complexity measures as well as a line through the mean price/complexity ratio of each split regression. The results are shown in figure 4.7.

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[4] Remember that the complexity, as defined in the third model is a linear combination of characteristics, while for the fourth model, the complexity is formed in a multiplicative way from the characteristics.

[5] FSS: Fixed Satellite Services; BSS: Broadcasting Satellite Services; MSS: Mobile Satellite Services. In addition, the thick solid line represents the regression line through the yearly average of the price and complexity values.

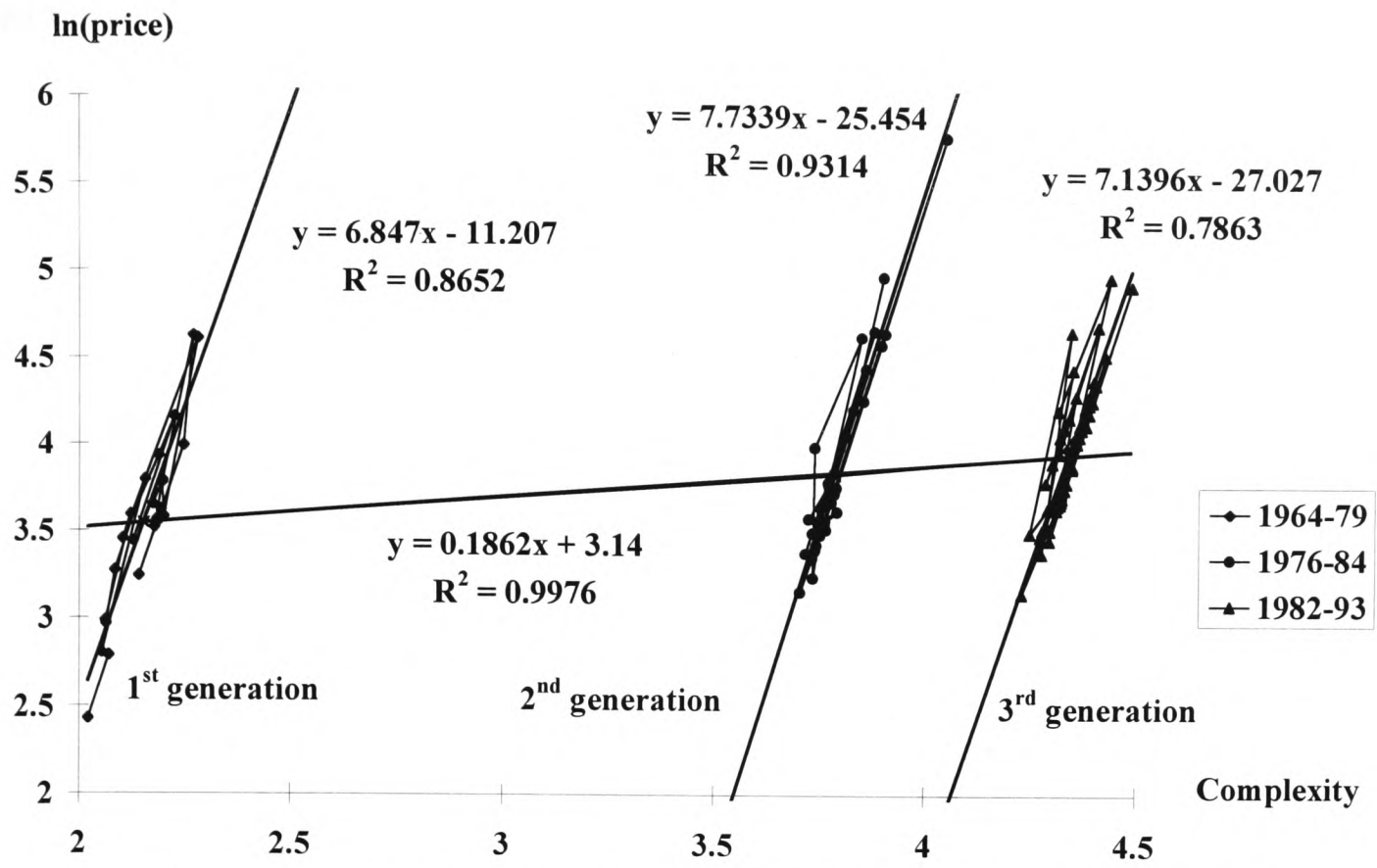


Figure 4.7: Awarded price of each satellite with respect to the calculated complexity measure, in logs; non-chained split results, model 3.

Figure 4.7 shows three very similarly-sloped short-run curves corresponding to each of the three generations of commercial communication satellites. A pseudo long-run curve was calculated from the mean point of each of the short-run curves. The slope obtained for this long-run curve (m = 0.1862) is roughly half of the slope obtained in figure 4.5 (m = 0.3674). This result is not very surprising as separating the sample in this fashion causes many second generation satellites ordered late to appear in the third time period, thus decreasing the slope of the 'long-run' curve of figure 4.7. Unfortunately, there is no straight forward method in separating satellites into different vintages as there is in the case of computers (for instance in Berndt & Griliches, 1993; and Dulberger, 1989). In each period however, the slope of the relationship between price and complexity is maintained for the three generations. And indeed, there is no significant difference between the slopes 6.85, 7.14 and 7.74.

These long-run/short-run results are not replicated with the fourth model as is illustrated in the two graphs below (figures 4.8 and 4.9); The pooled version of the fourth model resembles that of the split version of the same model. Both relationships appear to be equally linear (in the logs) with the year mean of the split version slightly more clustered than the pooled version.

From the point of view of engineers, the third model is the one preferred. In this model, the price is a function of the mass to the power complexity, while in the fourth model, the mass is included in the complexity measure. Engineers therefore have two rules to predict the price of their spacecraft. The first is simply the rule of thumb mentioned before where the price is a multiple of the mass; this is equivalent to the third model's long-run rule (pooled). In this model, as the mass is separate from complexity. In order to increase the complexity of a satellite of a given mass, it is necessary to miniaturise components which will drive the price upwards in the short run (second rule), hence the difference between the pooled and split complexity measures for the third model. Second, because of this rule of thumb between mass and price, when the mass is part of the complexity, as in the fourth model, the price

and this new measure of complexity increase proportionately, whether in the long run or the short run.

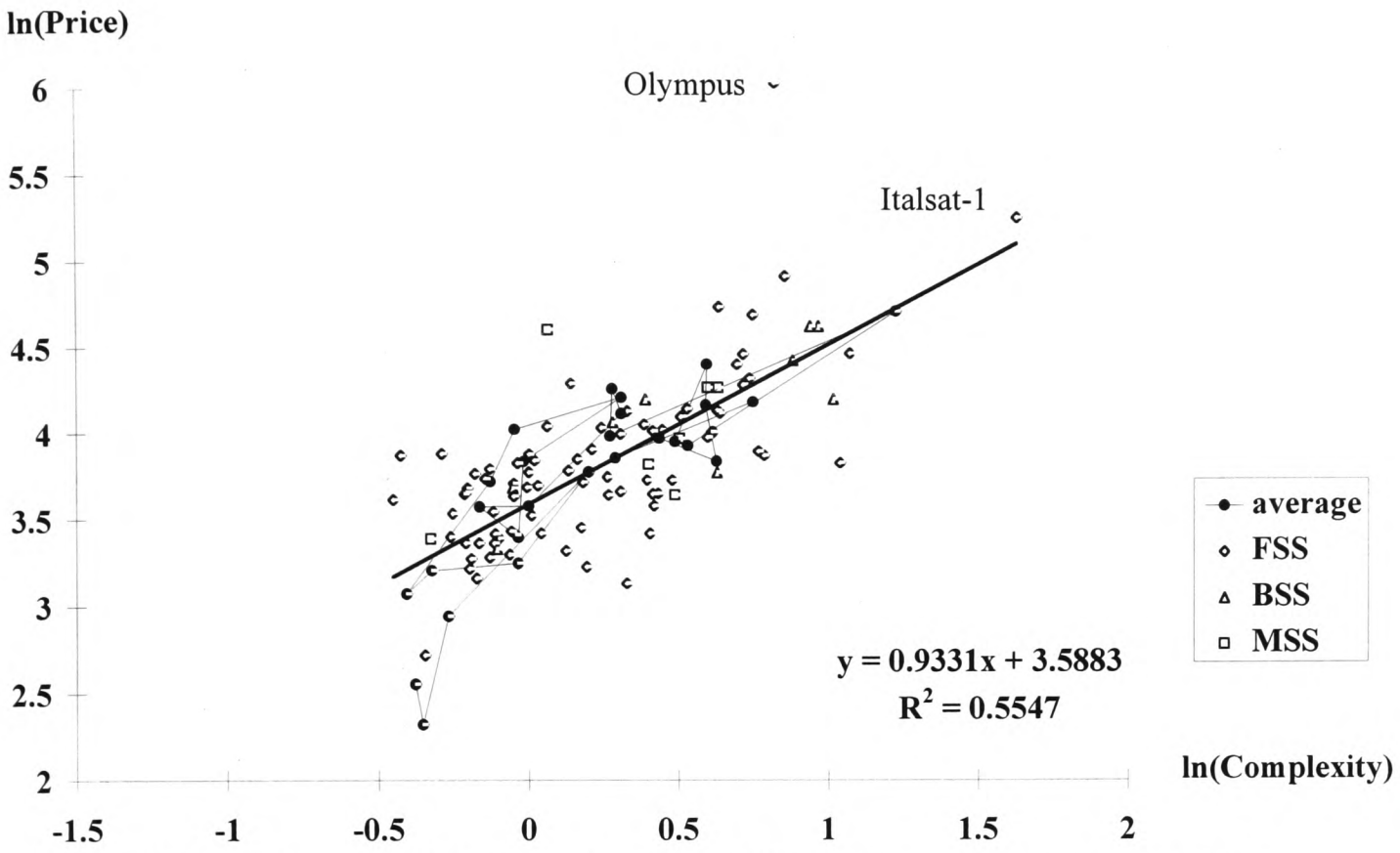


Figure 4.8: Awarded price of each satellite with respect to the calculated complexity measure, in logs; pooled results, model 4.

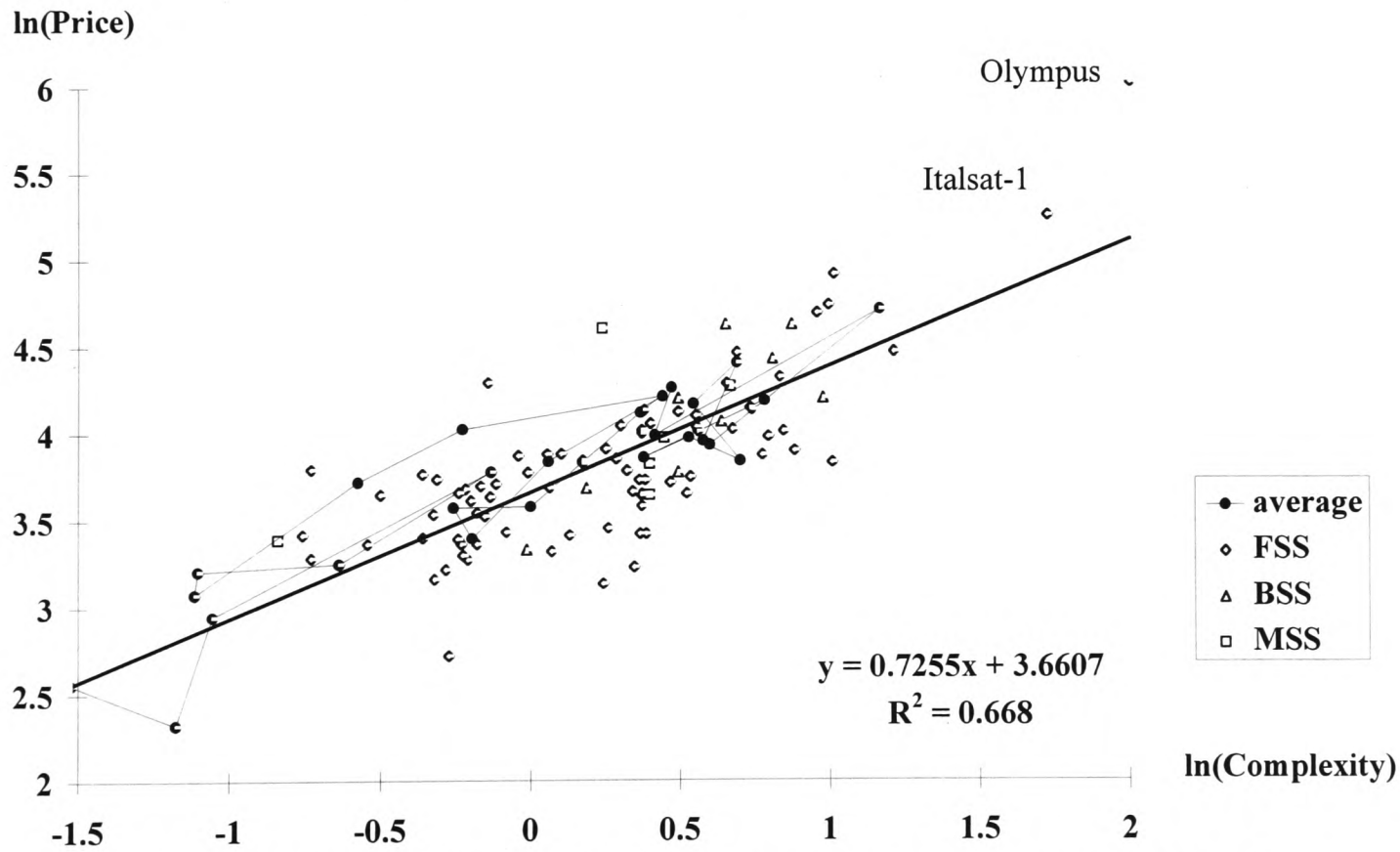


Figure 4.9: Awarded price of each satellite with respect to the calculated complexity measure, in logarithm; split results, model 4.

Figure 4.10 assesses the long run model obtained from the split regression using the third model. Comparing the relationship of the price with the mass as well as the complexity measure obtained from the split regression of the third model, we get a very similar slope suggesting that this long run relationship is indeed the price to mass ratio mentioned at the beginning of the third chapter. If the mark-up is constant, as we expect it is from the previous analysis, in the long run, we have an increasing marginal cost industry. This industry is therefore not learning in the classic sense

because satellites become more and more expensive; their complexity increases but so does their mass and price. If we interpret the price as the cost, assuming for a moment a competitive industry, the price increases faster than the complexity, so there are diminishing returns to complexity. The productivity and learning aspects of this industry will be examined in the last two sections of this chapter.

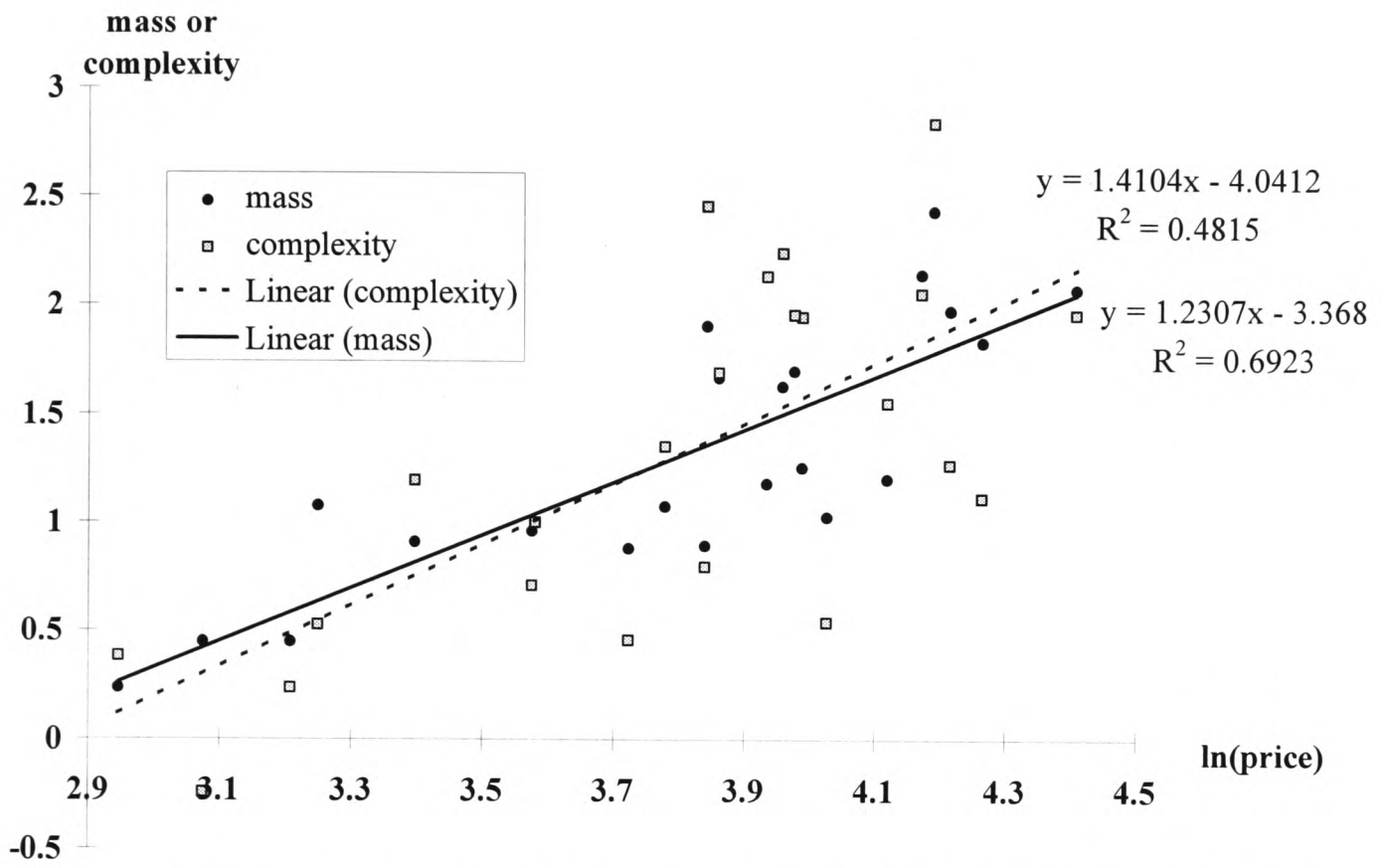


Figure 4.10: Relative (1980 = 1) yearly average of the mass and complexity (model 3, split results) versus the price (in logs).

4.1.2 Split sample

There seems to be a significant difference between manufacturers from different regions. Furthermore, in this industry, there is a clear bias towards US manufacturers, for they have constructed more than a half of all commercial communication satellites (again, this excludes Russia and China). Consequently, complexity measures for US-built satellites will be much more accurate than that of the other manufacturing countries. In section 4.1.1.1, we have found that the complexity measures calculated from the split regressions offer a more gradual increase over the years and only these results will be shown here, the 'pooled' complexity results are included in the annex to this chapter. The temporal evolution of complexity using the split results from the third model are presented in figure 4.11. Using the third model, we obtain a relatively stable increase in complexity over the years (see figure 4.11). This is not the case for the fourth model which is strongly influenced by the three Marisat satellites that appear with negative complexity measure. The hedonic regressions of the third chapter for Europe are not very well fitted, for various reasons, and as a consequence, the graphs are not included in the chapter. In the next two graphs (see figures 4.12 and 4.13), the relationship between the price and the constructed complexity is examined for the third model, pooled and split. The previous long run versus short run pattern is replicated in this case, but the difference between the slopes is not as pronounced as it was in the previous section. The complexity measures follow less of straight line than they did before, which may be due to the elimination from the sample of some of the important outliers such as satellites built by the European industry. These outliers have a tendency to pull the

regression line towards them and thus affect the results. In reality, when complexity is calculated, the variety of satellites is much wider. Also, the results may be affected by the sample size reduction resulting from the elimination of European satellites from the regression underlying this complexity measure.[6]

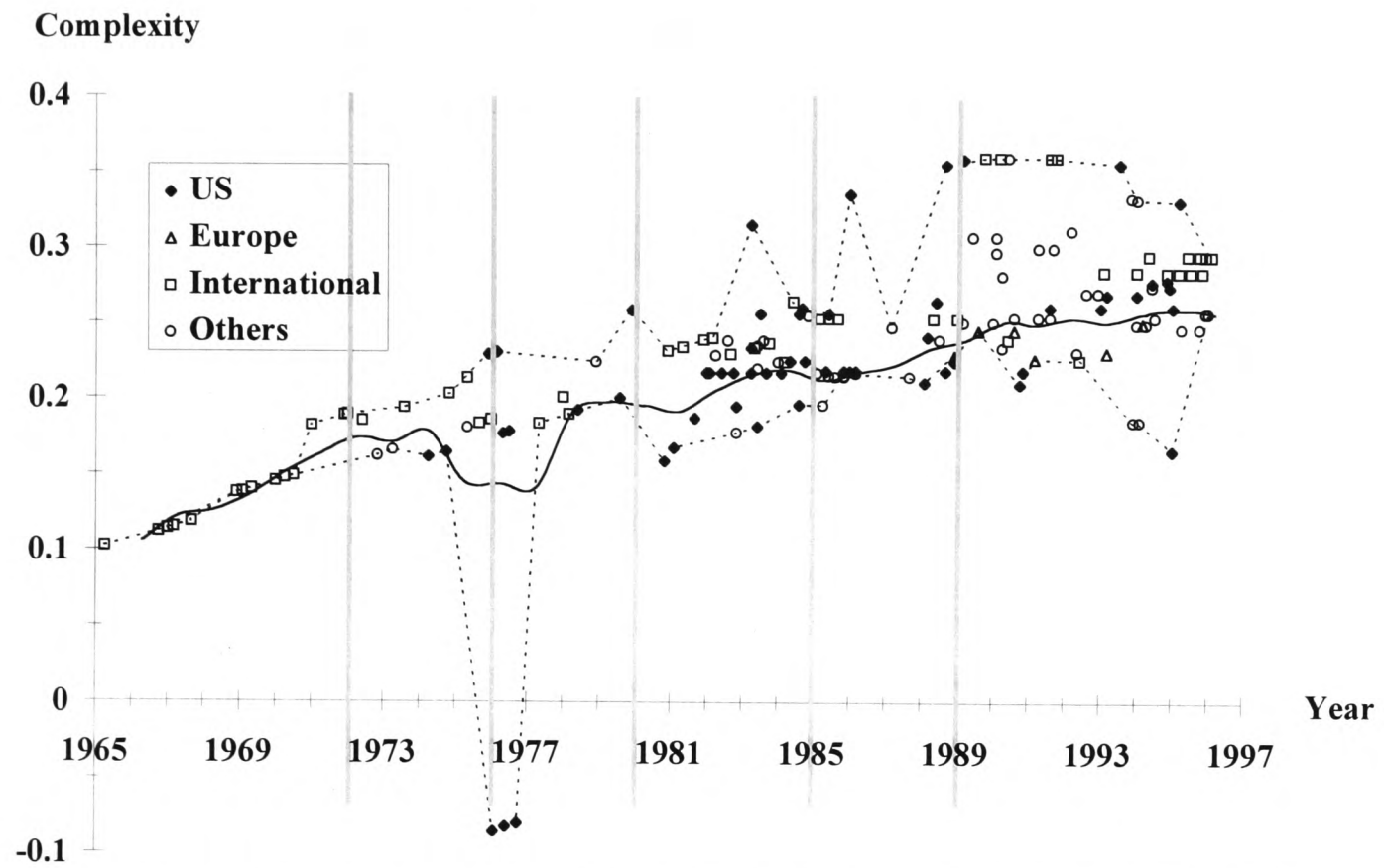


Figure 4.11: Temporal evolution of complexity (in logs); North American manufacturers; 1964-93; split sample, model 3.

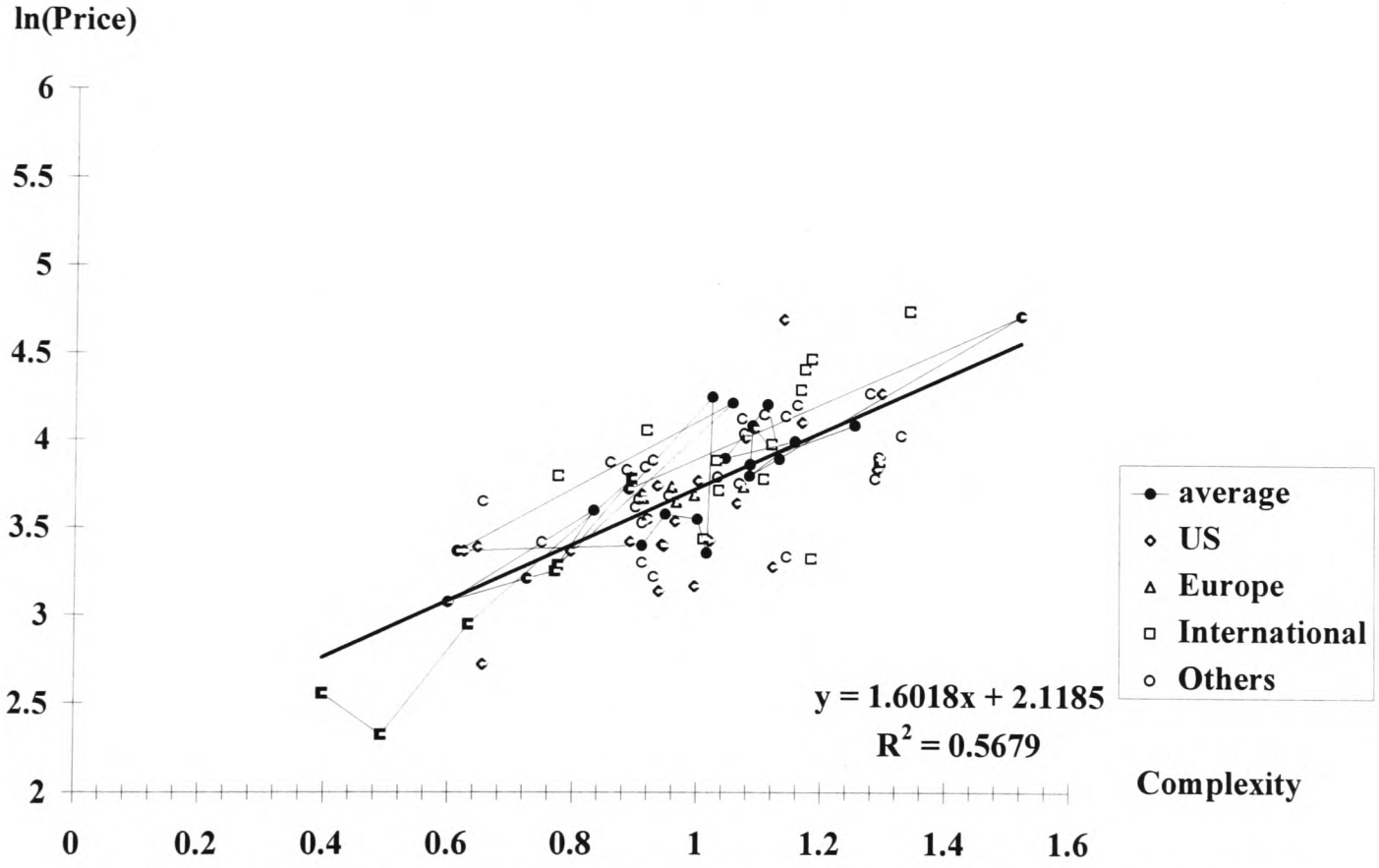


Figure 4.12: Price versus normalised complexity (1980 = 1); North American manufacturers; 1964-93; pooled sample, model 3.

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[6] In contrast with manufacturers, customers are more evenly divided through the four regions/groups under study. Unfortunately, because of the small number of observations in each region, dividing the sample into four separate sub-sample may provide enough information to calculate price indices, but not for constructing complexity measures, as satellites are too disparate and no particular pattern can be found.

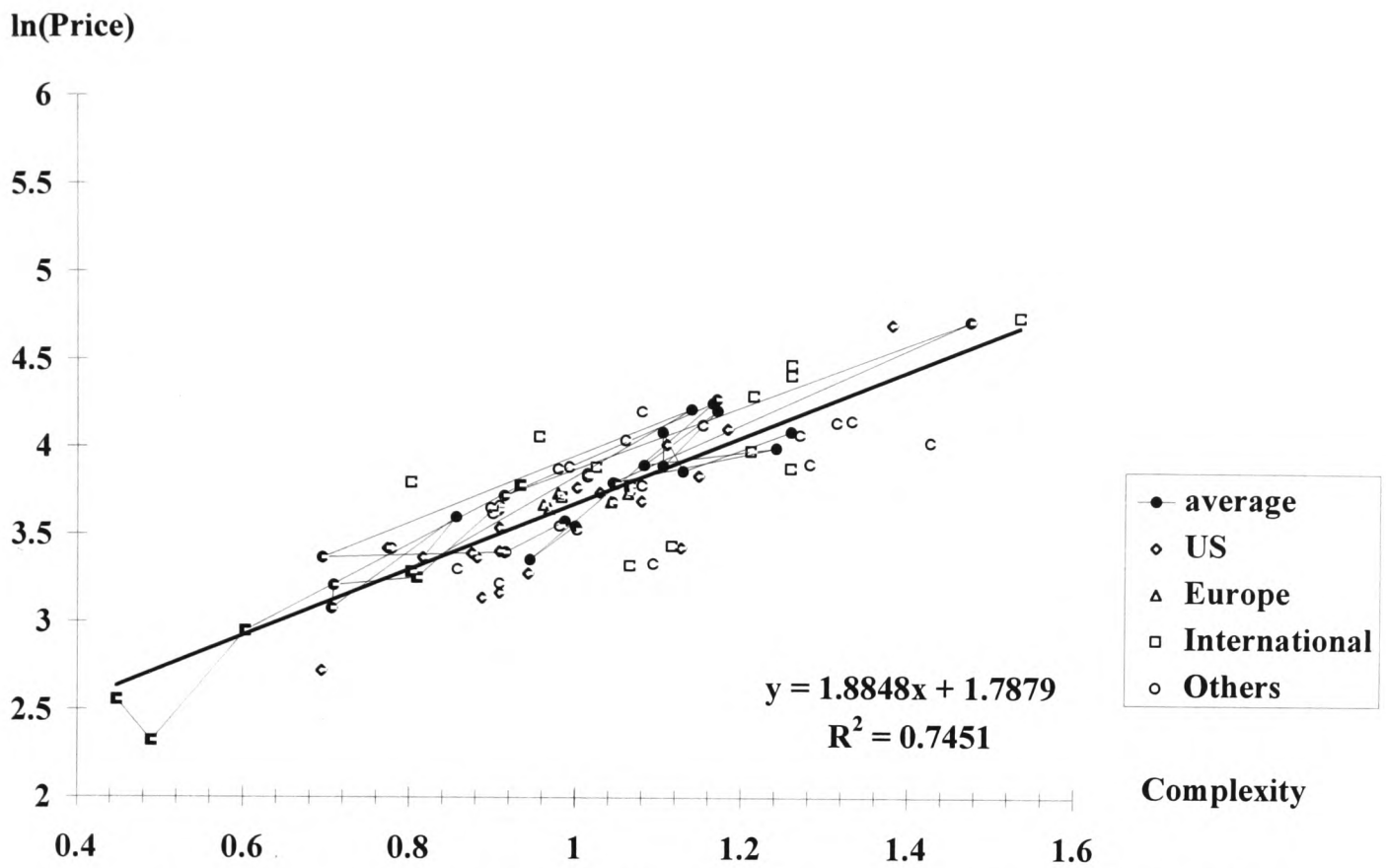


Figure 4.13: Price versus normalised complexity (1980 = 1); North American manufacturers; 1964-93; split sample, model 3.

4.2 Price indices

In the third chapter, hedonic price indices for commercial communication satellites were calculated using the coefficients of the time dummy variables. A general price decline for satellites of constant quality was observed. In this section, we will compare this price diminution with that of other high technology goods.

4.2.1 General price indices

Before we can actually postulate the reasons influencing these price indices, let us compare them with other price indices that have been calculated for other commodities in similar high technology fields. The third model, which we judge the best fitting, will be compared with a general NASA composite price index[7], the OECD price index for Radio, television and communication equipment, as well as Gordon's (1990) hedonic price indices for aircraft, computer and communication equipment (see figure 4.14). Unfortunately, the price indices of the latter were not computed for later than 1983, and thus are not available for the later part of our sample period.

A significant difference can be observed in figure 4.14 regarding the hedonic price index of computers and that of aircraft, spacecraft (our hedonic calculation), and communication equipment. All four indices are quality-adjusted price indices, and while the price of computers has decreased very sharply, spacecraft prices have only declined moderately. The other two price indices, however, have increased over the first and second periods of our sample. The NASA composite and the OECD radio TV and communication equipment price indices seem to increase, and we doubt that these particular price indices are adjusted for quality, hence the observed increase.

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[7] Source: Rusch database (1992). The composite price index was constructed using the NASA procurement inflation index, NASA R&D new start escalation index, USAF (OSD) inflation index and Department of Defense, research and development, tests and engineering inflation index.

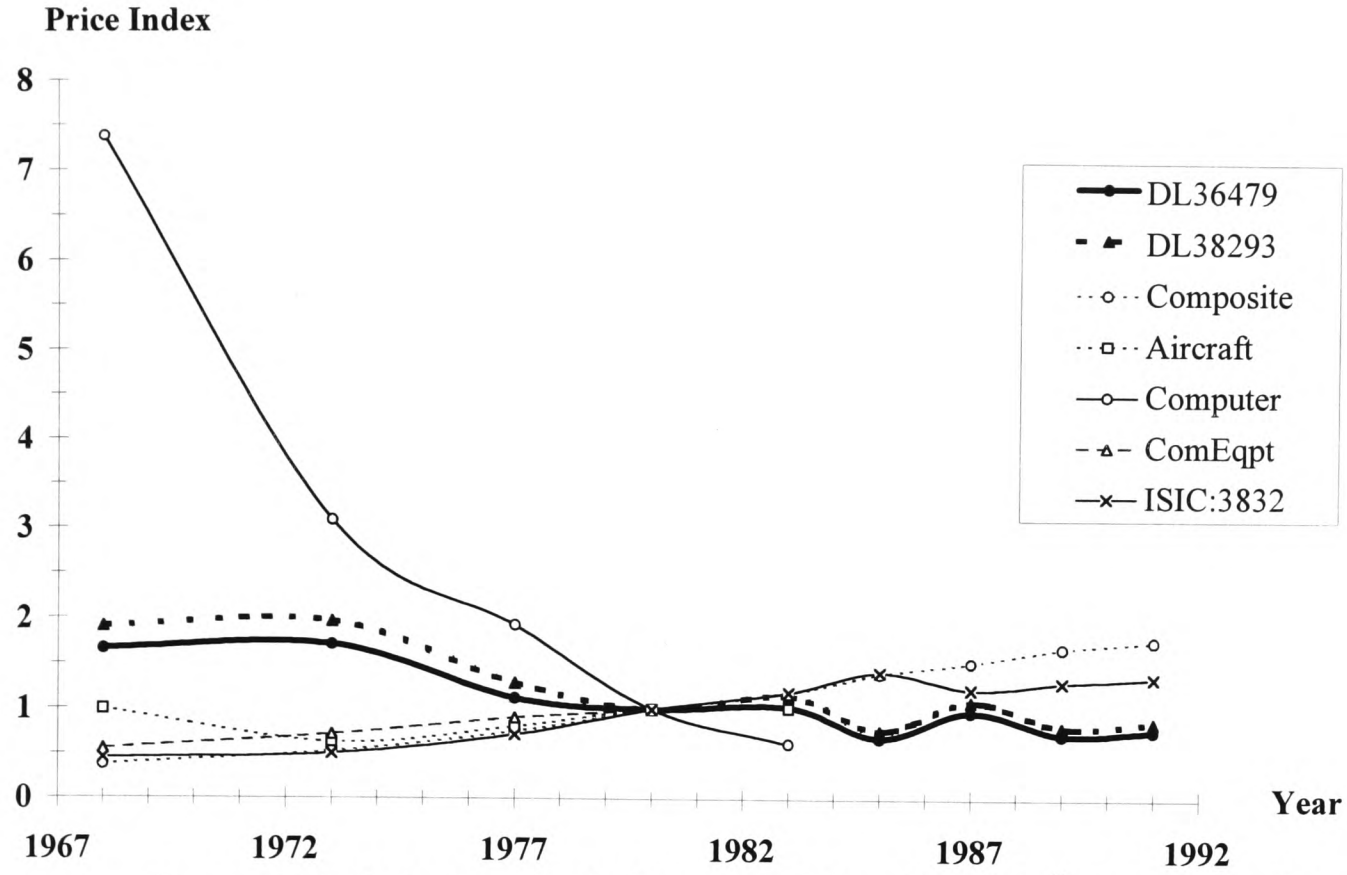


Figure 4.14: Hedonic price indices; model 3; split results[8]; compared with various price indices: Composite: general NASA price index[7], Aircraft, Computer and Communication Equipment: Gordon (1990) hedonic price indices, ISIC:3832: OECD price index for Radio, TV and telecommunication equipment.

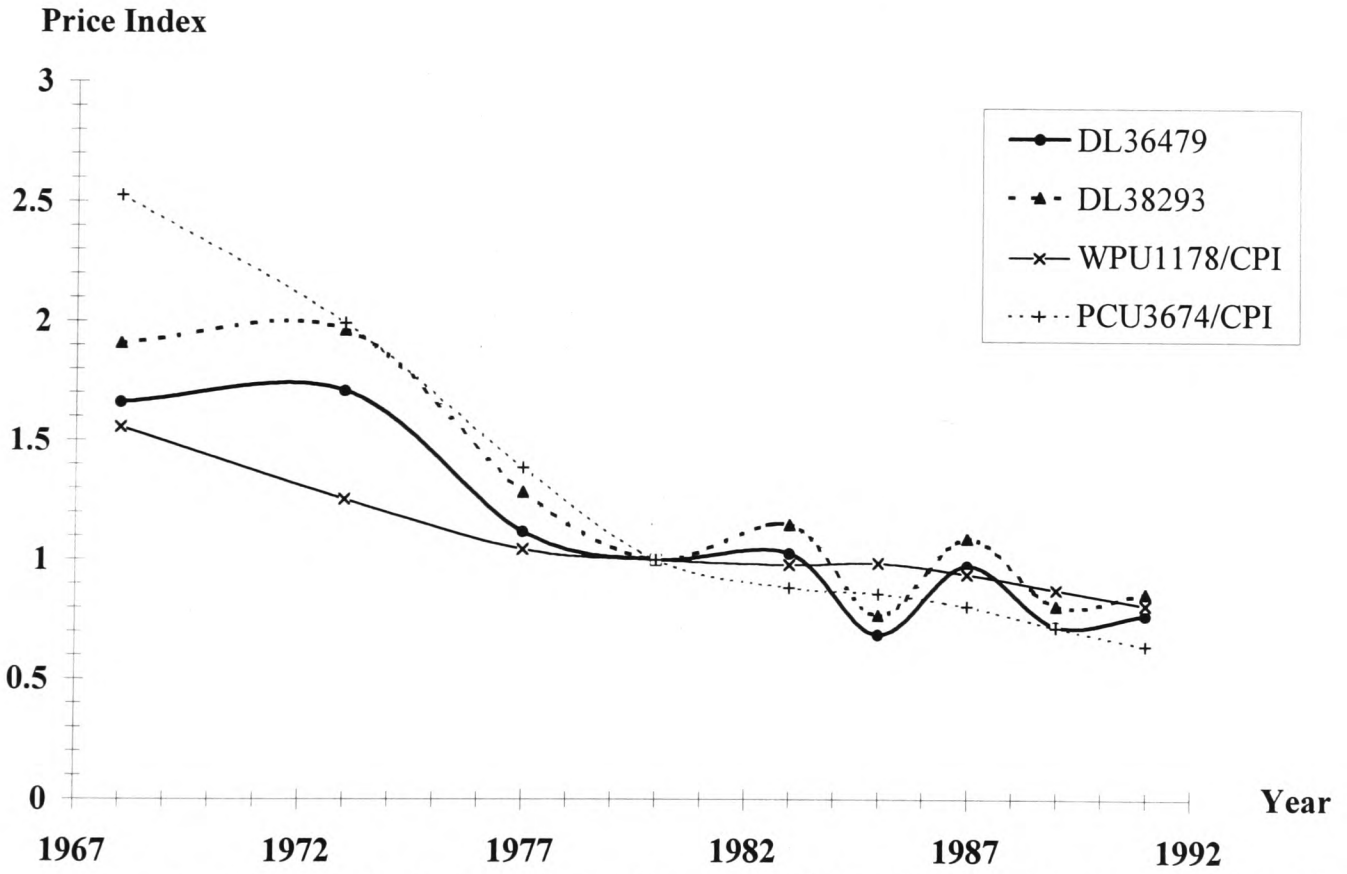


Figure 4.15: Hedonic price indices, model 3, split results; compared with deflated (by the CPI, 1980=1) price indices of electronic components: WPU1178: BLS price index for electronic components and accessories, and PCU3674: BLS hedonic price index for semiconductors and related devices.

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[8] DL36479 represents the price index calculated from the double-log regression of model 3 using the first sample period, 1964-79, as the base for the chained price index, and DL38293 is the equivalent index with the base being the last sample period, 1982-93.

While figure 4.14 compares our satellites with 'similar' high technology goods, or outputs, the next graph (figure 4.15) compares the quality-adjusted price index of commercial communication satellites, again calculated using the third model, with various measures of electronic components, the main constituents of most spacecraft. Two price indices, apart from our satellite price index, are considered in this graph, one of which is a hedonic price index of semiconductors and related devices (PCU3674) calculated by the Bureau of Labour Statistics (BLS). The other price index, for electronic components and accessories (WPU1178) is not adjusted for quality change, but is included for informative purposes.[9]

A significant difference between these two electronic component price indices can be observed in figure 4.15. Indeed, the non-quality adjusted price index of electronic components and accessories diminished at a slower pace than the quality-adjusted price index of semiconductors and similar devices. Moreover, quality-adjusted semiconductors' prices have decreased at approximately the same pace as a general price index[10] throughout the three decades under study, their prices falling further than that of satellites. Many plausible scenarios can be envisaged as to why this has been the case. First, it is possible that satellites only started to use semiconductors when the technology was well and truly tested, i.e. when it achieved the military standard, and beforehand, spacecraft technology consisted of a greater number of analogue devices such as travelling wave tubes[11]. These analogue devices may have been more expensive than semiconductors, and their price may not have declined so much because of their slow replacement by digital technology. As more semiconductors were introduced in satellite design, the price decline of both satellites and its constituents followed a similar path, but improvements in semiconductors' technology were soon to bypass that of satellites, hence the further diminution of semiconductors prices in the last part of the sample period. A second possible explanation is simply that satellites may have been more expensive in the first few years of their introduction because of their novelty, and consequently more experimental production process. As more satellites were ordered, and more manufacturers entered the market, the production process became more competitive and prices declined more rapidly to reach a lower level in the middle of the sample.

Since then, the price of satellites has continued to decrease but at a much slower pace. The price indices for the latest years of the sample appear to undulate, implying an unsettled price market for constant quality. But this may not be the case, as it may just be a result of the lack of precision of the time dummy variable's coefficients due to the small number of observations associated with each time period. Remember that in the third chapter, time dummy variables for the latter part of the period were not always significant, and their value was in consequence not significantly different from zero.

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[9] Both indices were extracted from the BLS web site on the Internet, the former belonging to the family of new producer price indices, and the latter being a 'commodity' price index.

[10] We have questioned the Producer Price Indices specialists of the Bureau of Labour Statistics concerning the apparent slow decline of the hedonic index for semiconductors and related devices compared with a general price index and were affirmed that it is truly a hedonic index. The reason it is not decreasing as sharply as expected, is that only DRAM devices have experienced such a rapid price decline for constant quality, but most other components of the index, such as transistors, have not. Consequently, since satellites consist of a wide variety of semiconductors amongst other things, this semiconductor price index is appropriate for our purposes.

[11] Travelling wage tubes are commonly used in satellites as signal amplifiers, see chapter 2 for more details.

So far, we have explored these quality-adjusted price indices distinguishing among satellites built by different manufacturers, or ordered by different customers. Yet some differences in the satellite characteristics produced by various manufacturers and bought by different countries were noted in the first three chapters of this thesis. In the next two sections, price indices for one producing regions, North America, and 4 customer groups, the US, Europe, international consortia and other countries, will be considered.

4.2.2 Different manufacturers

Of the types of graphs presented in the foregoing section, only the comparison with the component price indices will be shown here for the satellites built by North American manufacturers. As seen in the third chapter, models three and four offer very similar results, and as a contrast to the previous section, the fourth model will be used here to present the results. European satellite manufacturers will be ignored again because of the poor results obtained (section 3.4.2).

According to figure 4.16, the quality-adjusted price index of commercial communication satellites built in North America has decreased until 1980 and has stabilised thereafter, closely following the prices of its semiconductor components in the transitory period of the sample. This result is consistent with that of the previous section, which is understandable as satellites built in North America constitute the majority of the observations in this sample. Note that semiconductors are not the sole constituents of a spacecraft, a great number of other high technology components are required in its making, antennas, solar panels are just examples. Unfortunately, it has proved impossible to find a quality-adjusted price index for these components, so we are confined in comparing satellites with only part of the input in their fabrication, i.e. semiconductors.

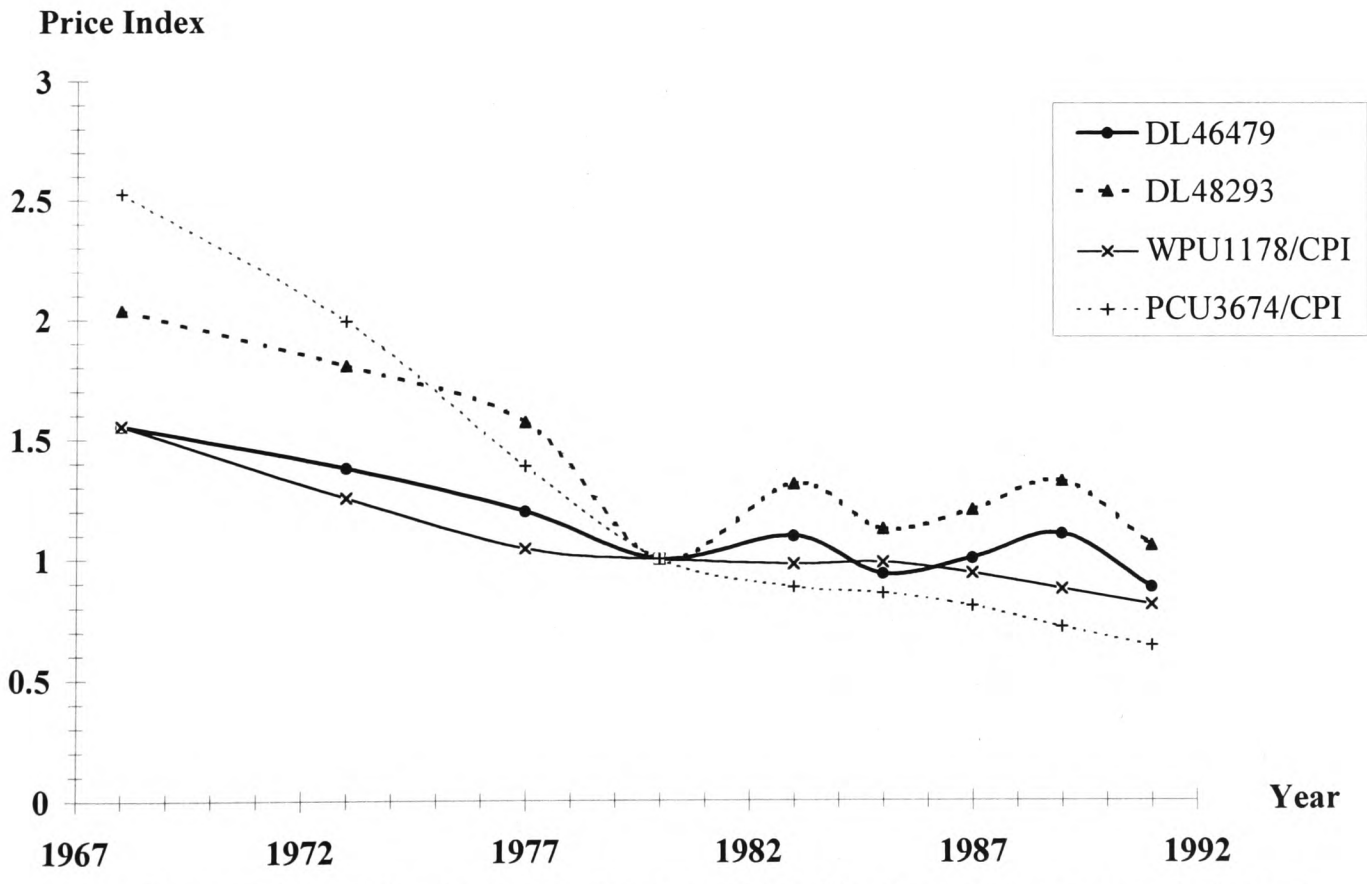


Figure 4.16: Hedonic price indices, model 4, North American manufacturers, split results; compared with deflated (by the CPI, 1980=1) price indices of electronic components: WPU1178: BLS price index for electronic components and accessories, and PCU3674: BLS hedonic price index for semiconductors and related devices.

4.2.3 Different customers

Once again, the European results are disappointing, nevertheless, the other three price indices can be presented. Because satellites owned by international organisations do not seem to be properly fitted using the third model, the fourth model will be considered in the following. Figure 4.17 illustrates the comparison of three price indices calculated from the fourth model, for the customers from the US, international organisations and other countries, compared with the usual two BLS price indices for electronic components and semiconductors.

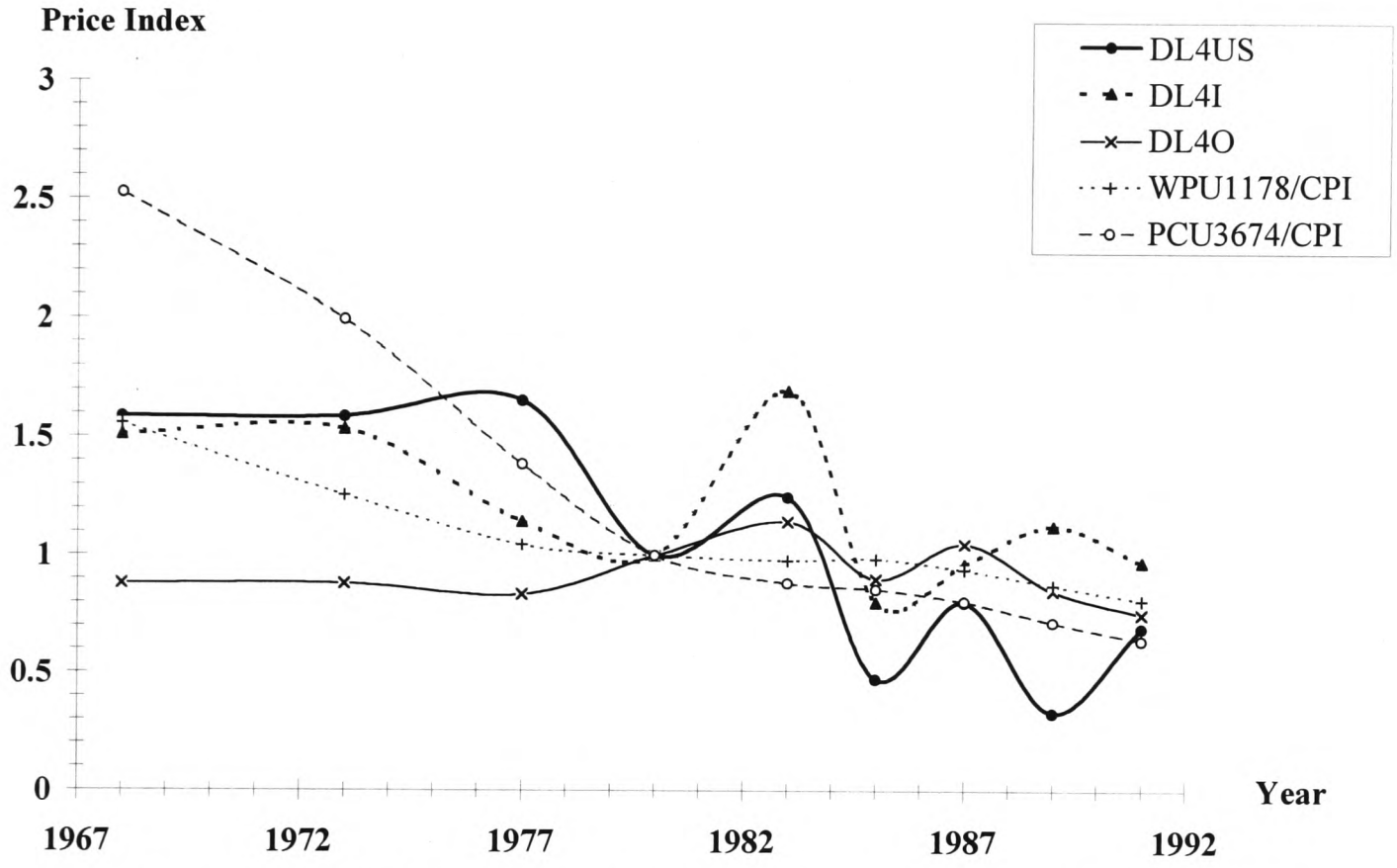


Figure 4.17: Hedonic price indices, model 4, US, international and other customers, pooled results; compared with deflated (by the CPI, 1980=1) price indices of electronic components: WPU1178: BLS price index for electronic components and accessories, and PCU3674: BLS hedonic price index for semiconductors & related devices.

A striking feature of figure 4.17 is the significant difference between on the one hand the price indices for the US and international organisations, and on the other hand the price index for other countries' satellite operators. The latter price index seems to follow more closely the price of semiconductors than the two former indices. One reason for this difference was postulated (see chapter 3) to be that other countries' satellites were strongly based on 'old technology' satellites that had previously been developed for more demanding customers such as US companies and Intelsat in particular. It is also possible that with the increase in popularity of communication satellites in the early 1980s, other countries' customers started to demand custom-made spacecraft, as opposed to the 'standard' satellite of the first generation, and this has increased the general price level for this category of customers. Furthermore, it may also be the case that European manufacturers sold satellites to other countries' customers at a higher price and this has contributed to the price increase in the first part of the 1980s. The next section will examine this last hypothesis in more details. We can say that, in general, the price of commercial communication satellites has not followed the price of some of its components, mainly electronics. It has also declined much more slowly than that of computers, but faster than that of aircraft and

communication equipment, which both have increased for a constant quality good (Gordon, 1990). So far, we have compared satellites built mainly within the North American manufacturing market. The next section examines characteristics and price differences between satellites built in North America and in Europe.

4.3 Buyer/seller price comparison between US and Europe

North American satellite producers provided approximately three quarters of the communication satellites included in this study, five of which were for the European market. Did Europe develop a different technology not wanted by US customers in order to protect European manufacturing from flooding by cheaper US-built communication satellites? The rationale behind this section is to determine the reason that prevented the US from supplying more European satellites than it did and vice versa. Table 4.2 summarises the number of satellites produced by each producing region for each ownership region. Predicted values for the price from both North American and European supply regressions were calculated for all four ownership regions. Table 4.3 summarises the results obtained from the price comparison of each satellite when built in one region or the other.

Table 4.2: Number of satellites produced per sub-period by each manufacturing region for each customer region.

Customer	US		Europe		Interna tional		Others		
Manufacturer	**NA**	**Europe**	**NA**	**Europe**	**NA**	**Europe**	**NA**	**Europe**	**Others**
1964-71					5		1		
1972-75	4		1		2	1			
1976-79	3		1		2		5		
1980-81	9		5		3			1	1
1982-84	2		2		1		3		
1985-86	2		1	3		1	7		2
1987-88	1		1	1	1	1	2		
1989-90	3	1	3	4	2		4	1	1
1991-93	1				3		5	1	
Total	25	1	5	17	19	3	27	3	4

Table 4.3: Price comparison between North American and European builders for the same satellites owned by various customers.[12]

Period	Manufacturer \ Customer	US	Europe	International	Others
1964-93	**North American**	US>E[*1]	US<E[*2]	US>E[*4]	US>E[*6]
	European	US~E	US<E[*3]	US>E[*5]	US<E
1982-93	**North American**	US>E[*7]	US>E[*8]	US>E	US~E
	European	US<E	US<E[*9]	US>E	US<E

[*1]: except G-Star, Msat(AMSC), Satcom-Ku1, SBS, TDRSS, Telstar-4
[*2]: except BSB
[*3]: except Eutelsat-II-F4, Hispasat-I
[*4]: except Inm-III, Int-K, Int-III
[*5]: except Marecs
[*6]: except Anik-E, Aussat-A, -B, BS-3N, JCSat, Msat, Superbird-A
[*7]: except PAS-1
[*8]: except BSB, Astra-1A
[*9]: except Hispasat-I

[12] Because European manufacturers started their operations in the 1980s, 1964-79 is not provided in this table.

From the 1964-93 comparison results, European customers would appear to have paid too much for their satellites regardless of the original manufacturing region. Similarly, during the same period, US customers would have paid less for their satellites if they had been built in Europe. The only difference in the later period of the sample, 1982-93, is that European satellites manufactured in the US would have been cheaper if they had been produced by European satellite designers. The only appropriate conclusion from this exercise, therefore, is that the obtained regressions for North American and European manufacturers do not apply to each other's satellites. In other words, the characteristics that the US customers value are valued less by European customers and vice versa. Consequently, the attributes of European and US satellites are different enough to support the idea of the development of a different type of European satellite to encourage the expansion of the European communication satellite producing industry.

Table 4.4: Regressions on North American manufacturers with European customer dummy variable and European, international and other countries' customers with North American producers dummy variable; model 3.

Variables	North American producers 1964-93	European customers 1964-93	International customers 1964-93	Other customers 1964-93
Intercept	2.318942 ***	7.387703 ***	0.822252	3.917468 ***
ln(number)		0.331769 **		-0.299530 **
mrdev	0.000384			-0.000470
meolpowe		0.000094 ***	8.53E-05 **	0.000015 ***
mlifetim		-0.022110 **	0.023437	
msumtr	0.002133 ***		-0.013140 **	
mtotbw			0.000088	
mhmpower			-0.012870 *	
mgmeirp	0.002591 ***	-0.012450 ***	-0.008490 *	
mD3a	0.017084	0.207341	-0.159720 ***	
mDtwt		-0.153270 ***		-0.030800 **
mservice	0.011794 **		0.063283	0.007548
mmtrp	-0.049898 *	-0.442500 **	0.691028 *	-0.044680
mctrp		-1.153820 ***	0.674578 **	-0.020850
mkutrp	-0.033309 *		1.418805 ***	
mDEc	-0.020825			
mDUm		0.123935 **		
D7275	0.224835			
D7679	0.201588	-0.149880		0.142875
D8081	-0.049912	1.696950 ***		0.472376 **
D8284	0.378002 *	1.315574 ***		0.304755
D8586	0.120606	0.086347		0.317783
D8788	0.336042	2.636291 **		0.285345
D8990	0.226427	0.299861		0.195139
D9193	0.129702			0.096927
n	76	22	22	34
R^2	0.7075	0.9884	0.9366	0.8166
F	8.92	34.13	13.44	6.04

Note: the prefix *m* represents ln(*gtomass*)*variable
***: significant at the 1 % level
**: significant at the 5 % level
*: significant at the 10 % level

The first footnote in table 4.3 lists the exceptions for which the comparison of the price of US-built satellites, with the price obtained if they had been produced in

Europe, yields a cheaper price for European manufacturers. A further examination of these satellites provides an interesting outcome: all of these satellites included transponders of frequency bands other than C-band. With the exception of Marisat and MSat, all of these satellites included Ku-band transponders, which was the norm in European telecommunication and broadcasting services. Moreover, the proportion of C-band transponders of all these satellites was less than 50 %. Unfortunately, such a pattern cannot be found for the predicted prices using the 1982-93 regression results, suggesting that by that time, the US may have caught up with the technology. Further, in the case of international customers, US-built satellites were more expensive than European-built satellites. Indeed, US manufacturers have produced all the very complex expensive Intelsat satellites, while Europe has manufactured the less expensive and less complicated Inmarsat satellites. The price discrepancy therefore encountered is entirely due to this separation in the customer/builder combination.

Table 4.5: Regressions on North American manufacturers with European customer dummy variable and European, international and other countries' customers with North American producers dummy variable; model 4.

Variables	North American producers 1964-93	European customers 1964-93	International customers 1964-93	Other customers 1964-93
Intercept	3.455462 ***	2.756337 **	3.061063 ***	4.816330 ***
ln(number)	-0.090200	0.827109 **		-0.335560 **
gtomass	0.000323 ***	0.001382 **	0.001158 ***	-0.000330
rdev		0.027008 **		
eolpower				0.000102
lifetime		-0.276100 **	0.341049 ***	0.037718
sumtr		0.123853 **	-0.129490 ***	0.035204
totbw		0.002157	0.000932 ***	-0.000500
hmpower		0.005751		
gmeirp			-0.093520 ***	
D3a			-0.276910 *	0.211347
Dtwt		-1.326590	1.030061 ***	-0.274460 **
service	0.137873 ***	-0.509130 **		0.098520
mtrp	-1.122460 ***			-1.653950 *
ctrp	-0.530120 **			-1.269730 *
kutrp	-0.731990 ***	1.018221		-1.024810
DEc	-0.203800			
DUm		2.492447 **		
D7275	0.246644			
D7679	0.397939 **	-1.606180 *		-0.052780
D8081	0.156405	-0.686490		0.127791
D8284	0.515335 ***	-0.463800		0.262971
D8586	0.331955 *	-0.686290		0.024470
D8788	0.376189 *	-0.476100		0.178205
D8990	0.372511 *	-0.519990		-0.031380
D9193	0.220172			-0.155030
n	76	22	22	34
R^2	0.7313	0.9889	0.93122	0.8535
F	10.89	21.03	27.08	4.29

***: significant at the 1 % level
**: significant at the 5 % level
*: significant at the 10 % level

Manufacturers and customers dummy variables have been introduced in the regression analysis in order to circumvent the ambiguity resulting from the direct

comparison of prices predicted from either manufacturing regressions. These regressions are presented in tables 4.4 and 4.5.

The coefficient of the dummy variable for North American-built satellites, *DUm*, introduced in the regression of European-owned satellites was positive for all models. This implies that European satellites manufactured in the US were more expensive than their European-built counterparts. This may be explained by the fact that the six (five contracts) European satellites produced by North American builders are the four Luxembourg Astra satellites and the two British BSB satellites, both of which were expensive private direct-to-home broadcasting satellites. In contrast, the coefficient of the European customer dummy, *DEc*, introduced in the regression of North American manufactured satellites was negative, implying that they have supplied satellites cheaper to Europe than they would have done in the US.

The size of the American market allows for the use of different satellites with different frequency bands, while in Europe, the smaller size of the market obliges manufacturers to mix frequency bands on the same hybrid satellite. As multi-bands satellites are generally more costly than single-bands spacecraft, this contributes to the high price of European satellites compared to their US counterparts. This may explain part of the difference in price between these two regions.

Because both US and European producers and customers are very different from one another, it is not possible at this stage to deduce whether the difference between these two regions is supply or demand driven, or whether this is true price discrimination on the manufacturers' side. Further investigation on the subject is needed at the firm level and goes beyond the scope of this thesis.

4.4 Productivity

In a previous section, the price indices obtained from the hedonic regressions of the third chapter were compared with that of the aircraft and computer industries. We now need to examine why the price of satellites, using similar components to the aircraft and computer industries, certainly in terms of electronics, has not evolved in a similar fashion. Economies of scale are undoubtedly a factor in the latter two as many more computers are produced than satellites, and aircraft production is an order of magnitude greater than that of satellites. Despite these discrepancies in production size, these three industries have all been subject to vast technological improvements since their introduction. The main question is whether productivity in the satellite manufacturing industry has increased because of components improvements, in particular because of a price decline for constant quality components, or is productivity growth intrinsic to the satellite producing sector. Although there is not enough output data, i.e. not enough satellites have been built to justify a firm-level analysis, productivity of the industry in general can still be assessed. No direct internal cost information could be obtained in the course of this study, and as a result, we have to rely on movements of weighted input and output prices.

4.4.1 Model and data

The satellite supply industry is more oligopolistic than competitive. In principle therefore, the use of price indices to calculate an exact productivity index, the so called 'dual' method proposed by Griliches and Jorgenson (1967), would not be strictly justifiable. The core problem here is that excess profits place a variable wedge

between unit cost and unit prices (see Diewert, 1974, for a comprehensive treatment). There is a further difficulty, due to the possibility that large fixed costs may give rise to economies of scale that would be confounded with an exact measure of total factor productivity change (see Diewert, 1992). Fortunately, in this case, these potential obstacles to measuring productivity change in the industry can be surmounted.

First, no strong indications of departures from constant returns have been found; indeed, in highly 'customised' manufacturing operations, it would be most unusual for strong increasing returns to appear. Second, the real problem posed by departures from pure competition lies in the possibility that the proportionate gap between revenues and costs may change. But, if the degree of monopoly affecting the mark-up on marginal costs is constant, the proportionate movements of the calculated index of total factor productivity would not be biased one way or the other.

A second problem with the use of price indices of components exists. Dulberger (1993) observes that the decline in computer components, such as semiconductors, calculated using hedonic price indices, is not consistent with the processor component of the NIPA deflator for office and computer equipment. The implications on productivity of such mistakes are important. Norsworthy and Jang (1993), utilise hedonic cost functions to argue that the effect of semiconductors on quality-adjusted price decline of computers and telecommunication equipment are understated. Their paper is of greater importance for productivity measures which will be calculated in the next paragraphs. We will therefore proceed with caution in calculating productivity measures using such price indices of components.

In section 4.1.1.2, it was seen that a stable relationship exists between the real unit prices of satellites and their 'complexity'; and that the short-run relationship between the two (as indicated by the slope of ln(*price*) against 'complexity') was essentially the same throughout the whole sample period. Our interpretation of this finding is that the logarithm of costs varied with 'complexity', as the engineering usage of the latter measures would suggest, so that a linear relationship was maintained between the logarithm of the price and the costs. In other words, the results may be read as supporting the maintenance of a constant proportionate mark-up pricing rule in the industry. Turning this around, we shall proceed on the supposition that the index of price per constant quality unit can be regarded as an index of unit costs, and the dual method may be reasonably applied in estimating the trend of multi-factor productivity.

To implement this we can use the cost-dual of the standard Cobb-Douglas production function. The total factor productivity index (TFPI) function obtained is given as follows[13]:

$$TFPI_{80}(t) = \frac{TFP^t}{TFP^{80}} = \left(\frac{w_L^t / w_L^{80}}{P_S^t / P_S^{80}} \right)^{\theta_L} \left(\frac{w_K^t / w_K^{80}}{P_S^t / P_S^{80}} \right)^{\theta_K} \left(\frac{w_M^t / w_M^{80}}{P_S^t / P_S^{80}} \right)^{\theta_M} \tag{4.3}$$

where K represents capital; L, labour; M, material, or electronics in this case; and S, satellites. The elasticities of capital, labour and material will be taken from

[13] The development of this equation is provided as a technical annex at the end of the chapter.

Naffrichoux (1993, p.114), as the average over the five years that she mentions: θ_L = 0.299, θ_K = 0.260, and θ_M = 0.441[14]. The labour price index was extracted from the Rusch (1992) database. The producer price index for semiconductors and related devices PCU3674 was chosen as the material price index because it is the closest quality-adjusted input price index that was available. Capital costs will be calculated using the Jorgenson user-cost formula (represented as an index here):

$$\frac{w_K^t}{w_K^{80}} = \left(\frac{r^t + \delta^t}{r^{80} + \delta^{80}} \right) \frac{P_I^t}{P_I^{80}} \tag{4.4}$$

where P_I represents some measure of the price of investment, r is the interest rate and δ is the depreciation rate. Interest rates for the US were extracted from the International Financial Statistics database produced by the IMF (1994)[15]. A constant value of $\delta = 0.08$ for depreciation rate was assumed throughout the sample. The price index was obtained from the Annual Report to the President (1994, p.288-289) as a ratio of current dollar to constant dollar non-residential private domestic investment.

A measure of total factor productivity constructed without allowing for quality increase in purchased components, risks confounding productivity growth in the electronics components industry with efficiency gains in the satellite building industry. Calculating total factor productivity growth (TFPG) using a non quality-adjusted price index would increase the slope of the TFPG measure, apparently exhibiting a higher productivity growth than in reality. Indeed, a productivity index calculated from indices of components that are not quality-adjusted risks picking up the decrease in price associated with the components' quality change rather than the productivity of the satellite producing industry. The price indices calculated by the Bureau of Labour Statistics (BLS) for some of the electronic components and accessories are quality adjusted because they are constructed using hedonic regressions. The commodity price index for electronic components and accessories used earlier is not quality-adjusted while that of semiconductors and related devices is a hedonic price index. Furthermore, although semiconductors are quality-adjusted, there are no provisions in the BLS calculations for the difference in quality between commercial and military components. In the satellite industry, most components must satisfy military specifications. Even if there is an increasing tendency to use a greater proportion of commercial parts in satellites nowadays, the majority of parts during the course of our sample still used a higher number of 'mil. specs.' components. The extensive testing required for the qualification of components for military specification would attenuate the decrease in the price index calculated by the BLS.

A further investigation of the BLS producer price indices for electrical goods discovered that price indices for antennas, transistors and other microwave components are available as a specialisation of electronic components and accessories. It is interesting to note that the price of antennas has decreased much faster than the price of transistors and that the price of other microwave components has increased. This may be because electronics increasingly replace some microwave devices, and that their usage and production decline thus pushing the price upwards. A more precise quality-adjusted index of components would be required in the case of

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[14] I surveyed a number of people in the industry, and they did not question these elasticities.

[15] This particular interest rate is what the IMF denotes lending rates, code 60P.

commercial communication satellites as antennas and photo-voltaic cells also enter the fabrication of spacecraft but such a composite hedonic price index does not exist, and we therefore must make do with the PCU3674 mentioned above.

4.4.2 Partial factor productivity

Before calculating total factor productivity as defined by equation (4.3), let us first examine each of the three input factors compared with the hedonic price index for North American-built commercial communication satellites in more details. Because of the difficulties encountered with the European-built satellites, only North American producers will be considered in this section, ignoring all other satellites. Because the manufacturers regressions were performed for North American producers, these include the Canadian spacecraft constructor Spar Aerospace. We will assume here that since Canada usually follows very closely its southern neighbour, capital and labour costs as well as the CPI and PPI for semiconductors are close enough to be treated as equal. In any case, the number of Canadian-built satellites is relatively small compared with that of the US.

Assuming the three conditions required for using the cost-dual to calculate the productivity index are satisfied, i.e. first degree homogeneity, constant degree of monopoly in the product market and constant degree of monopsony in the factor markets, indices of partial factor productivity[16] are given by equations (4.5):

$$LPI_{80}(t) = \frac{LP^t}{LP^{80}} = \frac{w_L^t \Big/ w_L^{80}}{P_S^t \Big/ P_S^{80}} \qquad KPI_{80}(t) = \frac{KP^t}{KP^{80}} = \frac{w_K^t \Big/ w_K^{80}}{P_S^t \Big/ P_S^{80}}$$

$$MPI_{80}(t) = \frac{MP^t}{MP^{80}} = \frac{w_M^t \Big/ w_M^{80}}{P_S^t \Big/ P_S^{80}} \qquad \textbf{(4.5)}$$

The three partial factor productivity indices presented in figure 4.18 are all composite indices calculated from a geometric average of the fourth model results in the first sample period, and the third functional form in the later half of the sample. This composite index is preferred to indices calculated from either functional forms (models 3 or 4), because in the first part of the sample, Intelsat spacecraft dominate the number of orders while they disappear in the mass of purchases in the second part of the sample period, and in the third chapter, the fourth functional form was found to fit better for the spacecraft purchased by international organisations.

Observing these partial factor productivity indices, we note that capital productivity has increased considerably in the first half of the sample to decrease equally rapidly in the second half. Comparing labour productivity with that of capital, however, we notice that the former appears relatively stable over time, suggesting that output prices and wages increase at the same rate. In contrast, the price of components[17] has had a relatively stable decline compared with the price of satellites.

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[16] The development of these equations is provided in the technical annex at the end of this chapter.

[17] Refer to footnote [10] on page 157 for a comment on the hedonic price index for semiconductors.

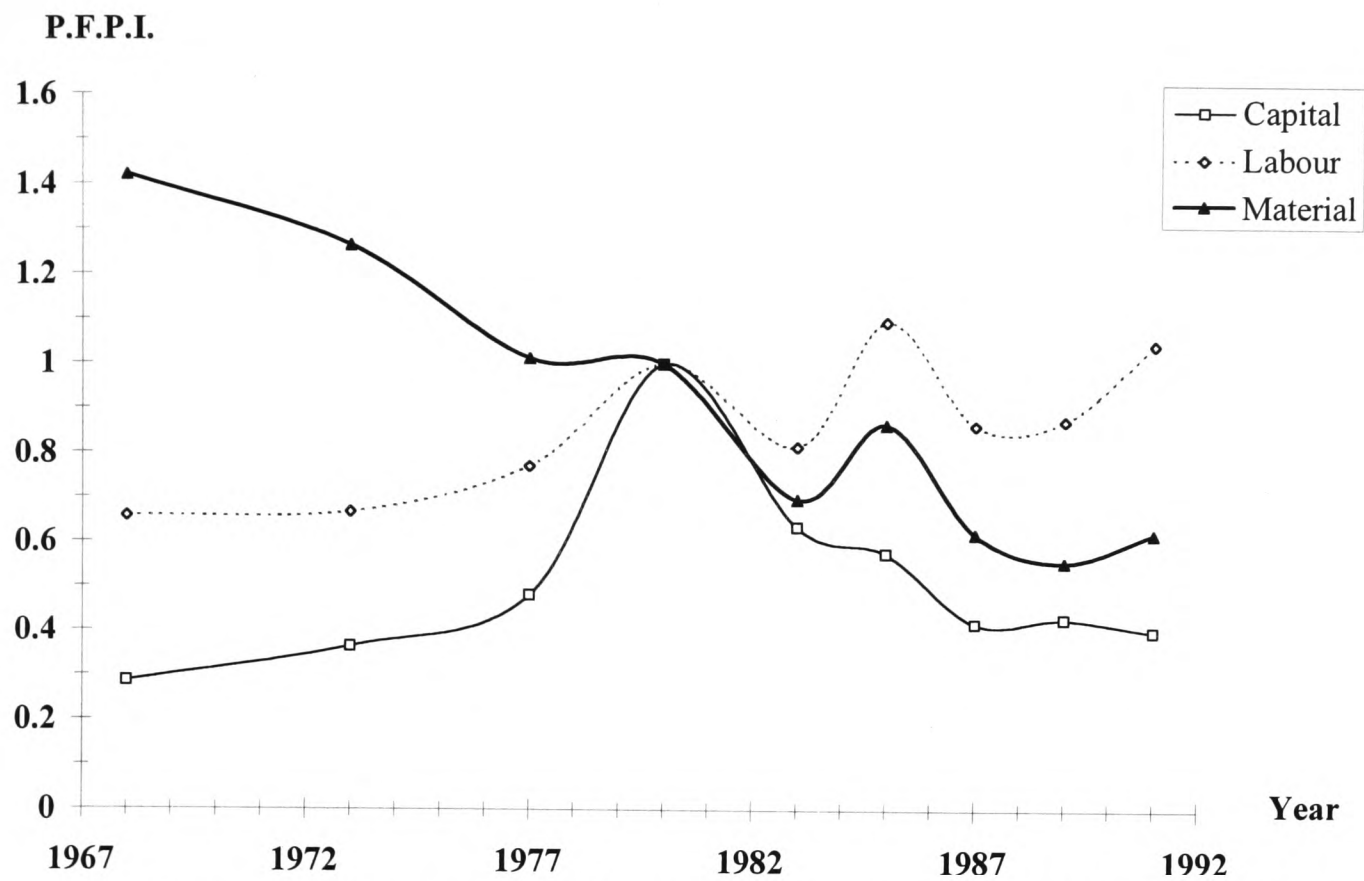


Figure 4.18: Composite[18] index of partial factor productivity for capital, labour and material; all input indices are deflated by the CPI.

4.4.3 Total factor productivity

In this section, the partial factor productivity measures calculated above will be elevated to the power of their elasticities and multiplied according to equation (4.3). Figure 4.19 presents the index of the total factor productivity of the US commercial communication satellite manufacturing industry.

Despite the oscillations previously observed, the general tendency of the TFPI is increasing pre-1980 and decreasing post-1980. Overall, though, TFPI has increased but very slightly. Before going further, we need to examine more carefully the industry. Since the satellite manufacturing industry is not competitive, but rather more oligopolistic with a tendency towards monopolistic competition (as first described by Chamberlin, 1960), the results depicted by the measure of total factor productivity growth are not entirely accurate. We have reasons to believe that satellite producers are a monopsony in the labour market. Even though there is more than one firm building satellites, they are not necessarily located in the same region, let alone the same country. As the skills required by workers, both technicians and engineers, are extremely sophisticated, the labour force has a good incentive to remain within the space sector. Furthermore, due to these skills, engineers trained in satellite design have a strong preference towards work on the development and production of spacecraft. Because of this, satellite builders have a strong bargaining power over their work force, and we suspect that the productivity measures obtained are lower than what they might be in a competitive environment. The problem with this is two-fold: first, the relative weight on labour and material is too small, and second, if the degree of monopsony changes over the years, there is a further bias on TFP.

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[18] Remember that the composite measure of productivity is calculated using the composite hedonic price index for communication satellites obtained in chapter 3, and is not related in any way to the NASA composite index used in section 4.2.

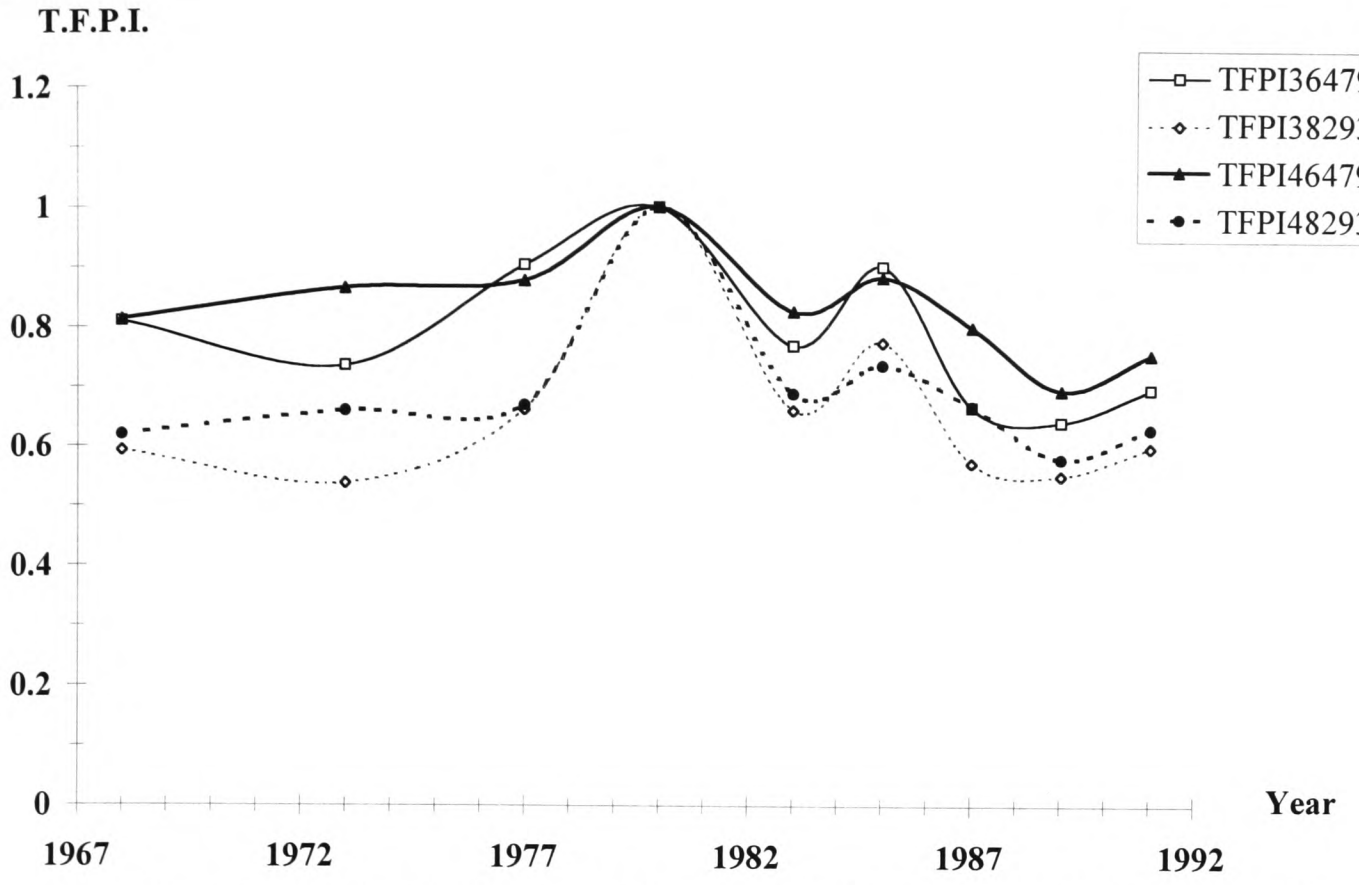


Figure 4.19: Total factor productivity index; models 3 and 4; US manufacturers; split regressions.

To calculate total factor productivity from the partial factor productivity measures, we need the further assumption that the right input share weights are employed. Assuming constant returns to scale, equation (4.3) can be expressed in terms of the partial factor productivity measures calculated earlier:

$$TFPI = \left(\frac{LPI}{KPI}\right)^{\theta_L} KPI^{1-\theta_M} MPI^{\theta_M} \tag{4.6}$$

In general, a monopsonist hires less employees than the competitive firm, and therefore the measure of the share of labour θ_L used here is too low. The effect of an underestimated labour share on the TFPI depends on the base year chosen and because of this ambiguity, will not be presented here. Indeed, taking 1980 as the base year would consistently underestimate TFPI, but would yield the opposite result if 1968 was chosen as the base year. This is not the case for TFPG. Calculating the total factor productivity growth[19] using the form of equation (4.6) yields:

$$TFPG = \theta_L\left(g_{w_L} - g_{w_K}\right) + \left(1-\theta_M\right)g_{w_K} + \theta_M g_{w_M} - g_{P_S} \tag{4.7}$$

where g is the growth rate representation. Because of the monopsony, the growth rate of TFP will be underestimated if the price of labour is growing faster than the rate of capital, but overestimated otherwise. We can only unambiguously comment on the growth of TFP, but not on its level. Because of this, we have experimented with various weights and examined the effect on TFP. Maintaining the weight on materials constant, and maintaining constant returns to scale, we have varied the elasticity with respect to labour. Weights of 0.15 and 0.20 have also been examined for the elasticity of output with respect to capital, hence weights of 0.359 and 0.409 for the elasticity of output with respect to labour. Figure 4.20 shows the composite (see section 4.4.2) measure of TFPG for three values of the weights on

[19] The development of this equation is provided in the annex to this chapter.

capital maintaining the weight on material constant and varying the weight on labour and capital accordingly to maintain constant economies of scale. The index of TFPG is in general lower as we increase the share in labour inputs prior to 1982 (approximately), but higher post-1982.

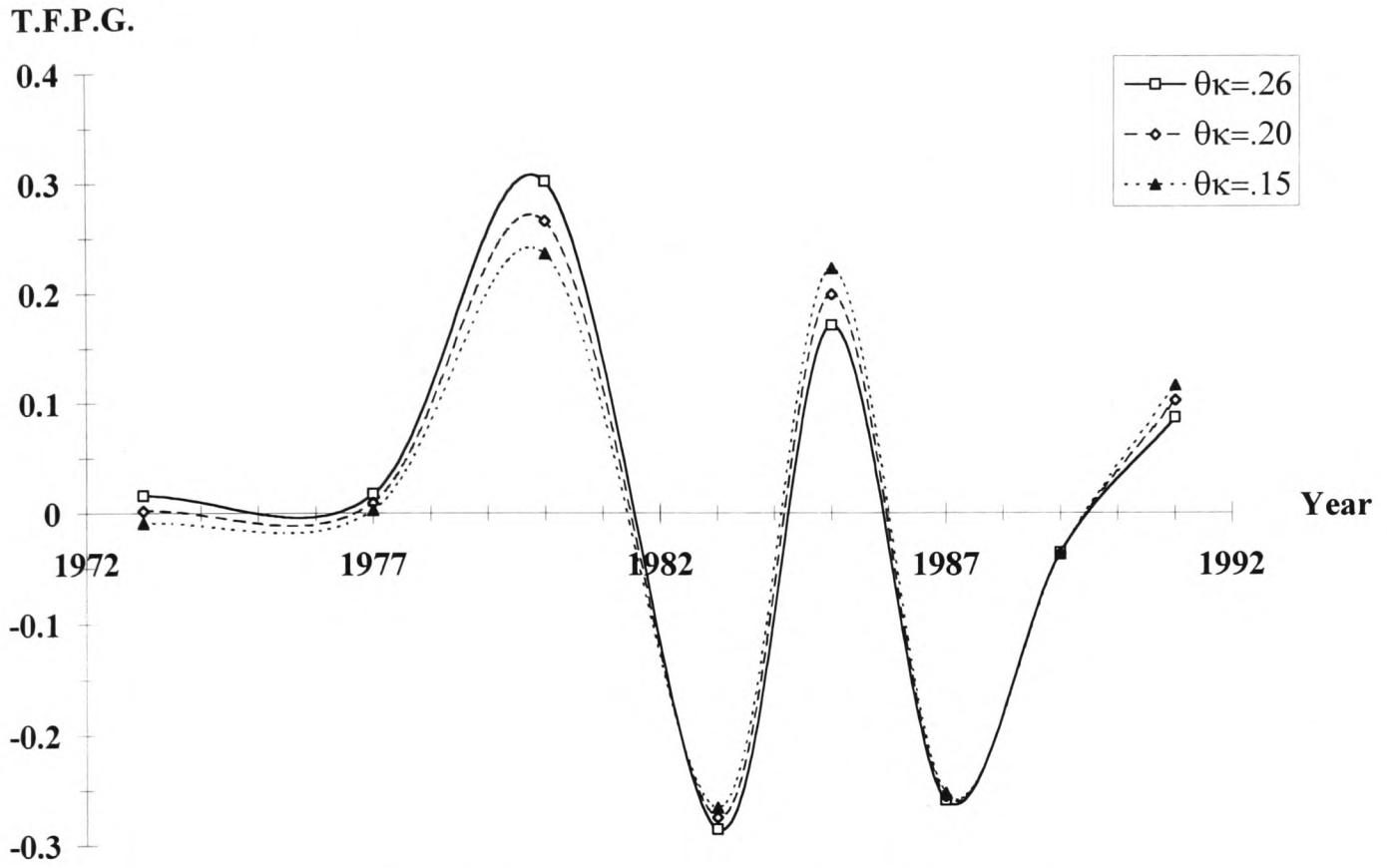


Figure 4.20: Composite total factor productivity growth with varying elasticity of output with respect to capital.

During the pre-1980 period, North American manufacturers produced 88 % of all commercial communication satellite families (see first chapter). Total factor productivity during this period appears to have increased, although not as rapidly as one would expect in a new technology environment. During the second part of the sample, however, we observe a diminution of the US stake on the world satellite production market to around 68 % accompanied by a decline in total factor productivity. In the first chapter, the degree of concentration of the manufacturing industry was examined through Lorenz curves and concentration ratios. From figure 1.7, we discovered that the degree of concentration of this industry has diminished over the years. Is this diminution in total factor productivity entirely attributable to this increase in competition? It is doubtful! Contrarily to what one would expect, the variation between the three measures of TFPG in figure 4.20 is quite minimal. We suspect that the elasticity of output with respect to capital has varied with the price of capital, augmenting in weight when the cost of capital declines. It is possible that the weights employed in the calculation of the TFPI are neither accurate for the US manufacturing industry, nor constant over time. However, because of the secrecy of the industry, it was impossible for the author to obtain a time series of the weights on inputs in the cost function. These total factor productivity measures must therefore be considered in consequence.

In section 4.4.2, material factor productivity was found to have decreased throughout the entire sample. This affects the value of gross total factor productivity growth. Assuming that the elasticity of gross output with respect to purchased components input was constant over the entire sample, the production function can be separated into a net output and a purchased input parts, with the overall learning

coefficient elevated to the power of the complement of the purchased input elasticity, as in the following equation:

$$Q_t = \left(A e^{\beta t} E^{\gamma} L_t^{\theta_L} K_t^{\theta_K} \right)^{1-\theta_M} M_t^{\theta_M} \qquad (4.8)$$

Calculating productivity net of purchased inputs yields a higher growth value in the early years of the sample (see figure 4.21). The development of the net output productivity growth corresponding to equation (4.8) is provided in a technical annex to this chapter. Figure 4.21 shows the comparison of the gross and net measures of productivity growth.

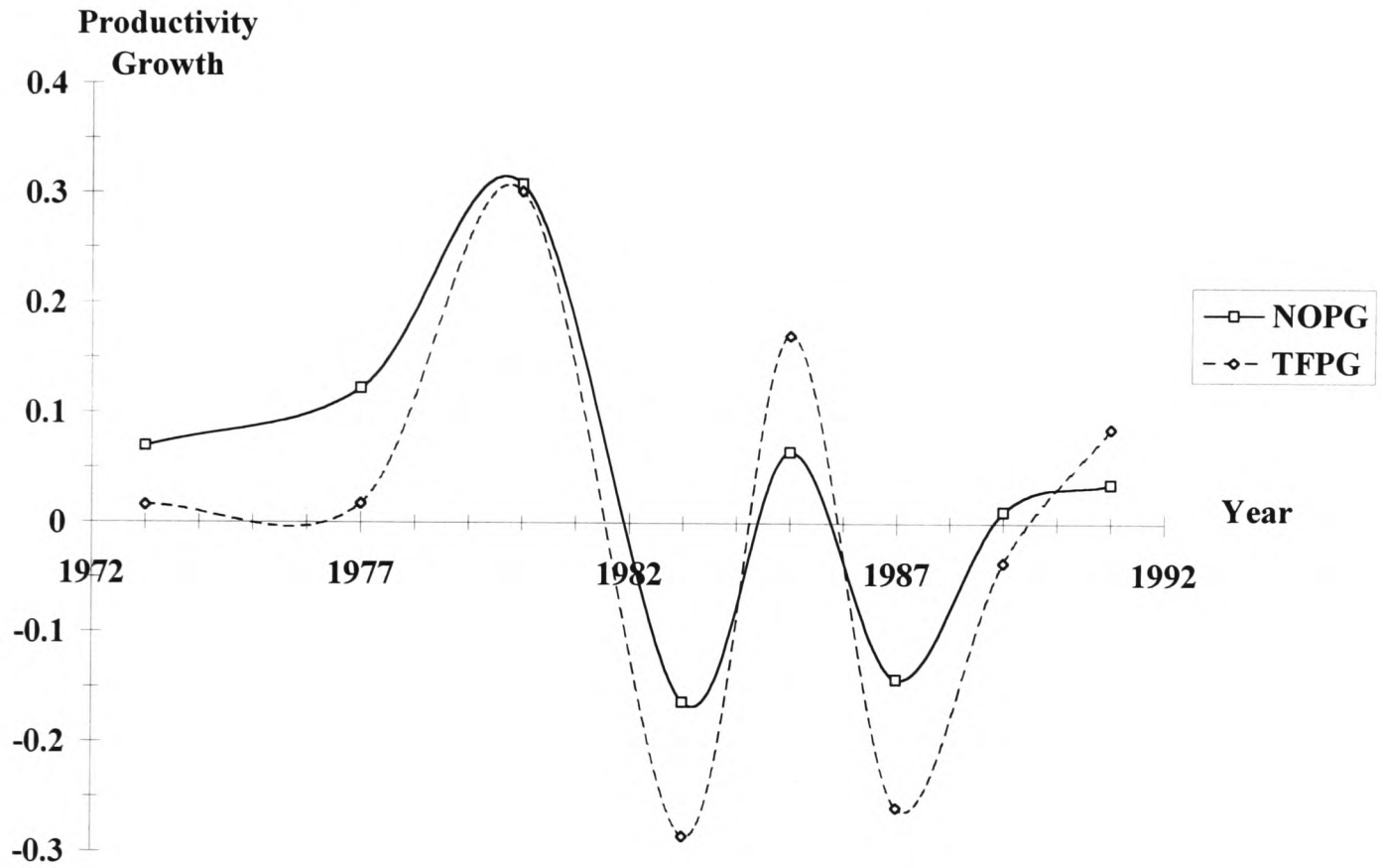


Figure 4.21: Gross composite total factor productivity growth (TFPG) and net output composite productivity growth (NOPG).

In the early part of the sample, net output productivity growth is almost constant and above its gross value. After 1980, TFPG oscillates but as reported previously, this is a consequence of the oscillating satellite price indices obtained from the hedonic regressions of the third chapter. The general trend however during the second half of the sample is a declining TFPG, but to a lesser degree for the net value. One interpretation of this discrepancy is that substitution of components for labour and capital along a pre-existing production function has raised their (joint) productivity. Another interpretation is that new technological knowledge was required in order to deduce how to use those new enhanced electronic components. A very similar decline in TFPG occurred during the same period in many other sectors in the United States and the communication satellite manufacturing industry is no exception.

4.5 Learning

4.5.1 Model

In previous studies (Hirsch, 1952, 1956; Rapping, 1965), labour requirements were explained by the cumulative measure of output. A common way to define the learning curve, therefore, is the following:

$$\ln(c_t) = \ln(a) + \alpha \ln(E_t) \tag{4.9}$$

where c_t is the cost, a is a constant, and E_t, a measure of cumulative experience. A widely used measure of experience is the cumulative output. On many occasions throughout this thesis have the potential problems with such a simple measure of output been mentioned. The main drawback, however, is the fact that satellite capacity has evolved over time, and so have the software signal compression techniques, hence reducing the need for satellites as such. A much preferred measure of experience, E_t, would be the satellite capacity or the equivalent number of channels that can be used on a satellite, but an even better measure is the complexity calculated in the first section of this chapter. Experience, therefore, can be calculated as:

$$E(t) = \sum_{\tau=1}^{t} number_i(\tau) \cdot Complexity_i(\tau) \tag{4.10}$$

where $number_i$ represents the number of satellites ordered in a particular contract i, and $Complexity_i$ is the measure of complexity developed in chapter 3. First, growth of the cumulative complexity measure utilised as a measure of experience is presented in figure 4.22. As expected, experience decreases rapidly in the early years of the sample to stabilise in the latter years.

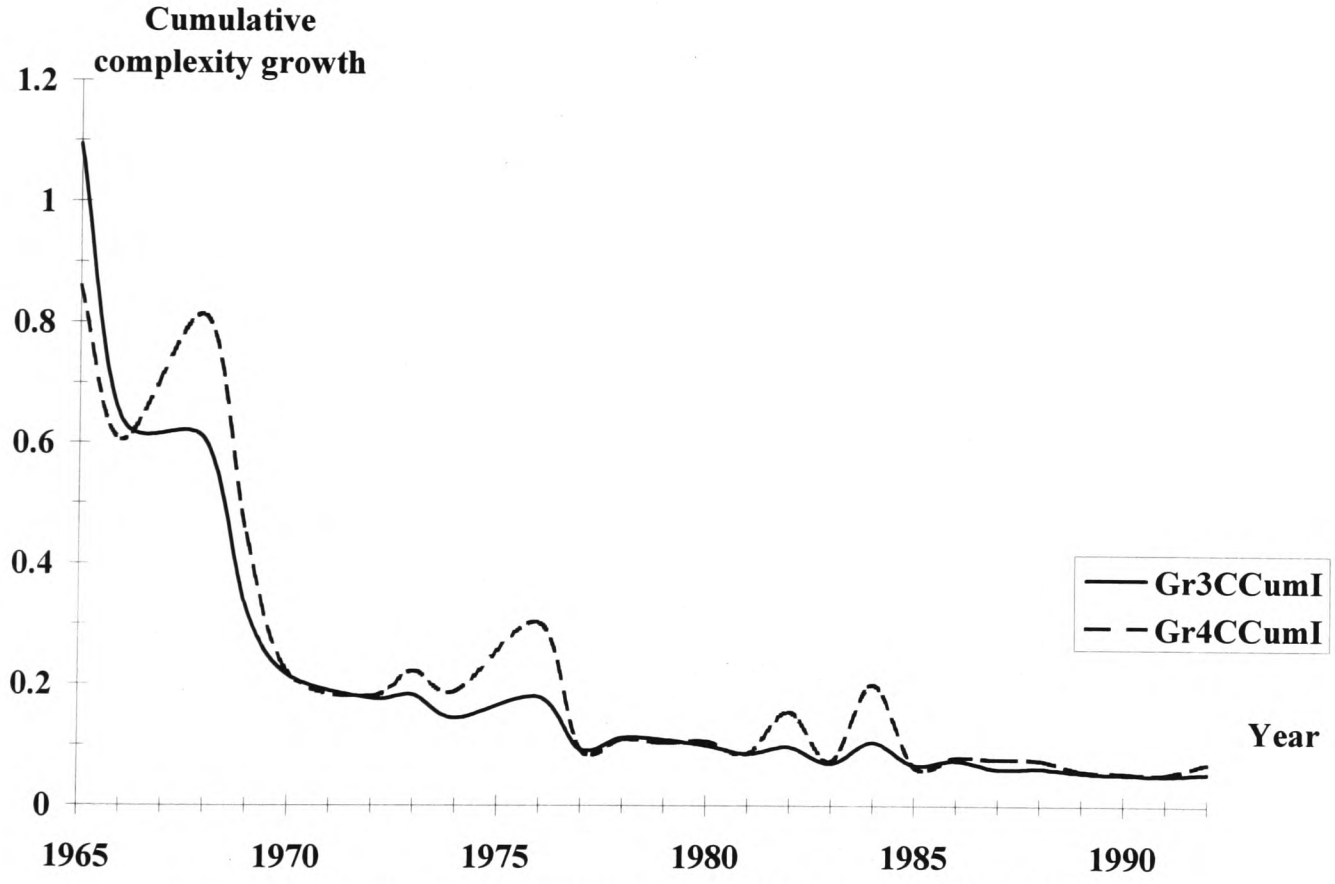


Figure 4.22: Cumulative complexity growth; models 3 and 4.

Using a standard definition (dating from the 1960s but still utilised nowadays, e.g. Berndt, 1991-chapter 3) of the state of knowledge as a measure of the experience, E, the measure of experience based upon satellite complexity used in equation (4.10) can be related to the total factor productivity measured in the previous section. The state of knowledge is a similar measure to our total factor productivity measure of the previous section (equation 4.3). Since costs were not available to the author at the time of this study, the price-dual will be used to estimate a learning curve. Using the growth transformation of equation (4.iv) in the annex, total factor productivity growth can be calculated as the next equation, and estimated using non-linear least-squares:

$$TFPG_t = e^{\beta}\left(\frac{E^t/E^{80}}{E^{t-1}/E^{80}}\right)^{\gamma} - 1 \qquad (4.11)$$

4.5.2 Results

Various combinations of total factor productivity measures and cumulative complexity were estimated and the results are summarised in tables 4.6 to 4.8. The best results of the learning regressions are provided in this chapter, for the regression results on the third model in particular, consult appendix J. Gross and net measures of productivity have been considered as a dependent variable for the learning curve model proposed in equation (4.11). In the latter, net output productivity (NOP), the learning effect applies solely to the net output, i.e. labour and capital.

Table 4.6: Learning curve estimates; dependent variable: gross total factor productivity growth, equation (4.8).

TFPG	θ_K	exp(β)	Std Err	EG	γ	Std Err	SSE	MSE	R^2
D4-8293	0.26	0.9848	0.0264	D4	0.1571	0.1386	0.1776	0.0081	0.0527
D4-8293	0.20	0.9865	0.0254	D4	0.1416	0.1333	0.1627	0.0074	0.0466
D4-8293	0.15	0.9879	0.0246	D4	0.1284	0.1295	0.1524	0.0069	0.0409
D4-6479	0.26	0.9866	0.0164	D4	0.0834	0.0877	0.0671	0.0031	0.0387
D4-6479	0.20	0.9885	0.0158	D4	0.0675	0.0844	0.0617	0.0028	0.0277
D4-6479	0.15	0.9902	0.0155	D4	0.0541	0.0830	0.0592	0.0027	0.0187
D43	0.26	0.9817	0.0251	D43	0.1491	0.1353	0.1702	0.0077	0.0502
D43	0.20	0.9835	0.0243	D43	0.1321	0.1314	0.1588	0.0072	0.0423
D43	0.15	0.9850	0.0238	D43	0.1179	0.1289	0.1513	0.0069	0.0354

Table 4.7: Learning curve estimates; dependent variable: net output productivity growth, version 1.

NOPG	θ_K	exp(β)	Std Err	EG	γ	Std Err	SSE	MSE	R^2
N4-8293	0.26	1.0277	0.0527	D4	0.2828	0.2563	0.7341	0.0334	0.0481
N4-8293	0.20	1.0301	0.0506	D4	0.2561	0.2471	0.6708	0.0305	0.0427
N4-8293	0.15	1.0324	0.0490	D4	0.2331	0.2405	0.6259	0.0285	0.0378
N4-6479	0.26	1.0263	0.0316	D4	0.1545	0.1591	0.2536	0.0115	0.0394
N4-6479	0.20	1.0295	0.0302	D4	0.1267	0.1525	0.2294	0.0104	0.0292
N4-6479	0.15	1.0323	0.0294	D4	0.1030	0.1492	0.2166	0.0098	0.0205
N43	0.26	1.0198	0.0473	D43	0.2784	0.2371	0.6289	0.0286	0.0545
N43	0.20	1.0226	0.0458	D43	0.2492	0.2305	0.5829	0.0265	0.0471
N43	0.15	1.0250	0.0447	D43	0.2249	0.2261	0.5518	0.0251	0.0403

Table 4.8: Learning curve estimates; dependent variable: net output productivity growth, version 2.

$NOPG^{(1-\theta_M)}$	θ_K	exp($\beta(1-\theta_M)$)	exp(β)	Std Err	EG	$\gamma(1-\theta_M)$	γ	Std Err	SSE	MSE	R^2
M4-8293	0.26	1.0114	1.0205	0.0288	D4	0.1628	0.2913	0.1467	0.2109	0.0096	0.0504
M4-8293	0.20	1.0131	1.0236	0.0276	D4	0.1475	0.2638	0.1410	0.1932	0.0088	0.0450
M4-8293	0.15	1.0146	1.0262	0.0267	D4	0.1344	0.2404	0.1369	0.1806	0.0082	0.0400
M4-6479	0.26	1.0130	1.0234	0.0175	D4	0.0893	0.1597	0.0907	0.0762	0.0035	0.0411
M4-6479	0.20	1.0149	1.0268	0.0166	D4	0.0736	0.1316	0.0865	0.0686	0.0031	0.0311
M4-6479	0.15	1.0165	1.0298	0.0162	D4	0.0603	0.1080	0.0842	0.0645	0.0029	0.0224
M43	0.26	1.0070	1.0125	0.0265	D43	0.1635	0.2925	0.1389	0.1910	0.0087	0.0567
M43	0.20	1.0088	1.0157	0.0256	D43	0.1468	0.2626	0.1346	0.1774	0.0081	0.0493
M43	0.15	1.0103	1.0185	0.0250	D43	0.1327	0.2374	0.1316	0.1681	0.0076	0.0426

The notation utilised in these tables is the following: D43 signifies that the composite measure of total factor productivity growth is the dependent variable; D4-8293 represents the TFPG calculated using the 1982-93 base for the chained price index of the fourth model; D4-6479 is the equivalent dependent variables using the 1964-79 base for the chained index. For the complexity measure, or independent variable, D3 is the complexity calculated from the third model, D4, from the fourth model, and D43 is the composite using the fourth model for the first half of the sample, and the third for the second half.

The first measure of net output productivity growth (table 4.7) is calculated using equation (4.xix) in the annex and uses a similar form to equation (4.11) for the TFPG. An alternative measure presented in table 4.8 is constructed using equation (4.xxi) in the annex. As expected, by dividing the coefficients of the experience growth (EG) obtained from the second version of net output productivity growth by ($1 - \theta_M$) yields very similar results to those obtained in the first estimation of the learning curve.

A first observation from these learning coefficient results is the consistently higher value of the learning coefficient when estimated using the net output productivity growth measure. The highest value obtained for the learning coefficient is 0.2828, very close but slightly lower than the value estimated by previous studies, Hirsch (1956) for instance states a progress elasticity for airframe of around 0.33. Such a difference between two products of the same greater aerospace industry[20] is surprising, but understandable due to the very nature of the product under study here: Commercial communication satellites are custom-made spacecraft, built in small quantities. In that sense, economies of scale are unlikely, and not present according to the results of the third chapter. Further, with the ever changing components' technology, learning over the construction of many similar satellites is difficult.

4.6 Conclusion

Probably the most intriguing finding of this chapter, is the discovery of a pricing rule based on engineering specifications. We interpret this pricing rule as a mark-up pricing rule, because 'complexity' is more closely related to total unit cost per satellite, than to some properties of the market demand curve that depend upon the technical characteristics of the satellites. In the next chapter, the fact that demand for satellite services is a decreasing function of capacity will be pointed out, so there are two steps to notice: (a) 'complexity' is not a good proxy for capacity; (b) if 'complexity' was a good proxy for capacity, then a relationship between price and capacity reflecting demand-side conditions would be expected rather than the complexity-price relationship found here on the basis of the hedonic regressions.

The complexity calculation of the communication satellites provided a direct relationship between complexity and the price, thus justifying the long-run 'engineering rule of thumb' that stipulates a price per mass for each satellite. The disappearance of the distinction between long run and short run in the fourth model as compared with the third model demonstrated the importance of the mass in the price determination. Furthermore, this striking result proves what we suspected in the introduction, i.e. that satellite building firms still utilise the pricing rules of the

[20] The 'greater' aerospace industry here is meant to include all 'flying' products.

military days, the cost plus a mark-up. It also shows that although the degree of concentration has changed over the years, the interaction between manufacturers and customers from Europe and North America has not decreased the degree of monopoly in either regions. The fact that the mark-up appears to be constant over the years simplifies the identification problem greatly, there is no supply curve and satellite manufacturers are choosing points on the demand curve for the price of their spacecraft. So although the industry is not competitive, hence causing difficulties with the identification problem, the apparent constancy of the mark-up, and thus the degree of monopoly, allows us to calculate productivity measures and learning coefficients using the dual.

The BLS producer price index for communication satellites is not quality-adjusted, and only exist for recent years. However, because they do not use time dummies to calculate the index but rather yearly regressions, we very much doubt that they will ever get enough observations to calculate a hedonic price index for the communication satellite industry according to their method of calculation. For semiconductors and another few commodities, however, they can calculate a hedonic price index. One minor difficulty with the use of this hedonic index for semiconductors is that they do not distinguish between electronic devices that satisfy military specifications and those that do not (the vast majority of components). In the early days of satellite design, a wide range of components of variable quality was available to satellite designers. Because of the almost impossible task of in-orbit maintenance, engineers had to utilise the 'best' components that had been extensively tested, in other words, 'military specified' devices. We suspect that because of the fixed costs encountered in such tests, the price of these components would have been different from that of commercial components. As the quality of ordinary electronic devices increases, however, more and more of these commercial components are put into satellites, so military specifications are bound to disappear eventually.

In the third part of the chapter, the price of European and US-owned and -built satellites was compared with the hypothetical price they would have paid if the other party had built them. The objective of this exercise was to discover whether there is a regional bias in the price of satellites, for example, to find out if European satellite operators are willing to pay more for satellites built in Europe in order to encourage their own industry. The truth is more complex, as it appears that Europe has developed a different type of satellite, focusing on the Ku-band as the main frequency for its transponders, in order to encourage the expansion of a European-based manufacturing industry. Simply predicting the price of satellites of the other region using the regression of one region did not yield the expected results, and consequently, we had to resort to regional dummy variables. On the one hand, a positive dummy variable for satellites produced in North America in the European regression implied that US-built satellites were more expensive to European customers than their own satellites. On the other hand, a negative dummy for European customers in the mirrored regression implied that US manufacturers have supplied satellites to Europe at a cheaper price than they would have done in their own country.

The last two parts of the chapter have examined productivity and learning in the industry. The productivity measure was found to increase in the first part of the sample period, but decrease slightly during the second half. Overall, however, a small augmentation in productivity has been measured. This productivity measure depends on the elasticities of output with respect to each of the inputs. We have assumed these

elasticities constant over the years, because of the lack of a relevant time series. It seems important to obtain such a time series in the future, because the cost of capital has changed dramatically during the 29 years of our sample, and as a consequence, the weights on input price indices must have varied accordingly. Furthermore, our measure of total factor productivity is calculated using general input price indices that may be too general for the specific industry under study. The cost of capital for example is the most general index, a measure of the price of expensive testing equipment such as soundproof chambers, white laboratories as well as micro-gravity and vacuum chambers would be more appropriate, but requires extensive investigation within the finances of satellite manufacturing firms. In addition, quality-adjusted price indices are still relatively rare and are only available for specific sectors, and generally relating to the computer industry. Most components used in the production of satellites have evolved considerably since the 1960s and quality-adjusted indices for antennas and solar cells are crucial for our productivity measure.

Various factors are also likely to affect our measure of total factor productivity growth. First, because of the very nature of the industry, we have reasons to believe that satellite producers are a monopsony on the labour market. Workers are highly skilled, there are few manufacturers for which to work for, and their highly specialised skills prevent them from easily working in other domains. To investigate the effect of the degree of monopsony on total factor productivity, the elasticity of output with respect to labour was varied, maintaining constant returns to scale and the weights on material constant. Total factor productivity growth increased as a consequence of an increasing the share of labour inputs post-1982, but decreased post-1982, and overall, the learning coefficient decreased as a consequence.

Further, because the productivity of purchased inputs has consistently decreased over time, it was decided to calculate productivity net of these purchased components. The intuition behind this was that new technological knowledge was required in order to understand how to use those new enhanced electronic components. The net measure of output productivity growth obtained was slightly less volatile than the gross measure and showed a higher value of productivity growth in general. Moreover, the learning coefficient estimated from the net values were significantly higher that those obtained from the gross TFPG measures.

Finally, the learning coefficients obtained were smaller than those obtained years ago for the airframe manufacturing industry. This result was to be expected because satellites are custom-made products, and as a consequence are less likely to generate economies of scale. Moreover, few satellites are built every year, and the ever improving components' technology forces satellite designers to constantly update their design with each new project. Learning on an aircraft production line is therefore expected to be higher than that of very short satellite production lines (on average less than 5 satellites in the early years, and less than 3 more recently).

Annex 4.1 Complexity measures for US and Europe manufacturers

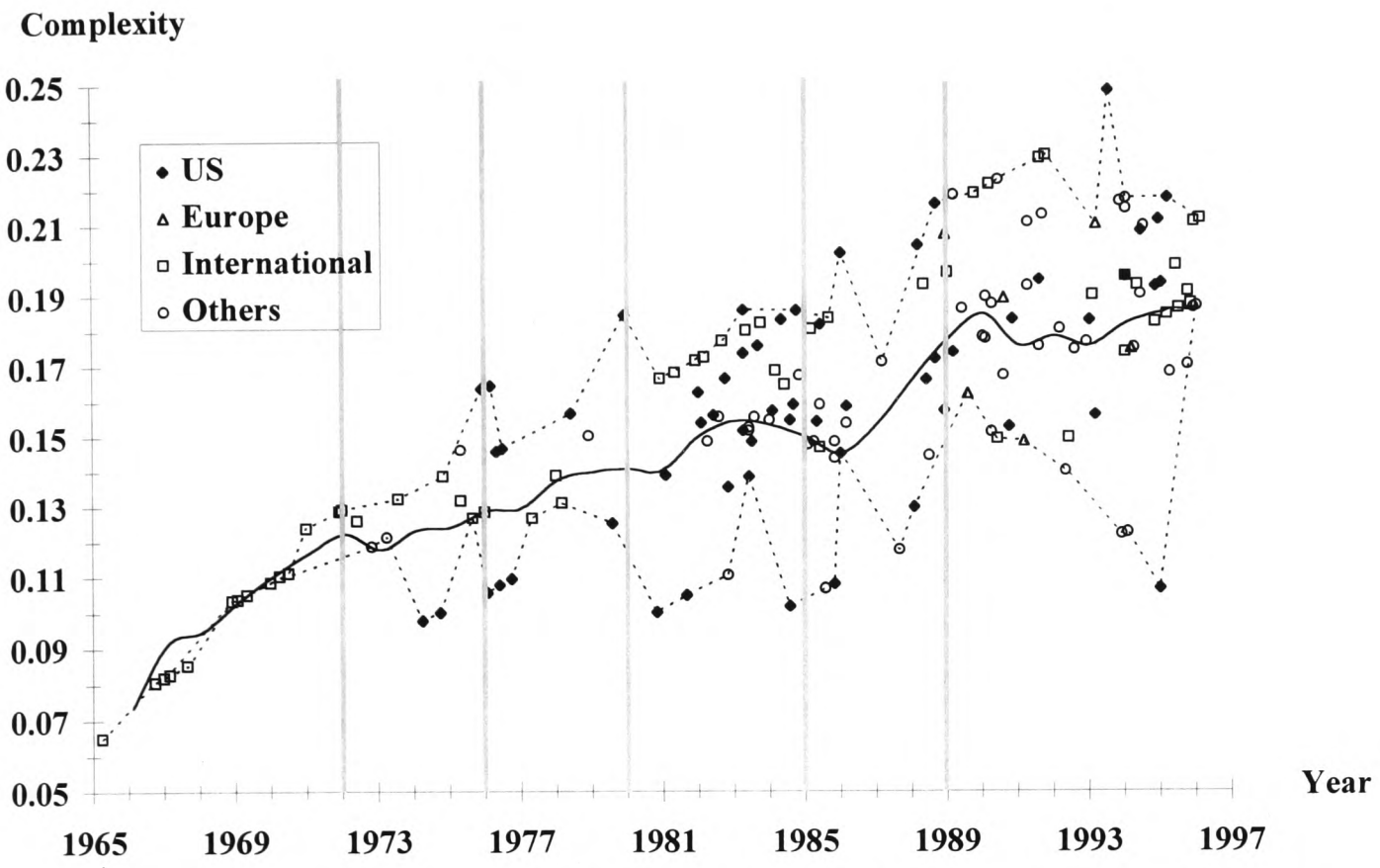


Figure 4.i: Temporal evolution of complexity; North American manufacturers; 1964-93; logs, pooled sample, model 3.

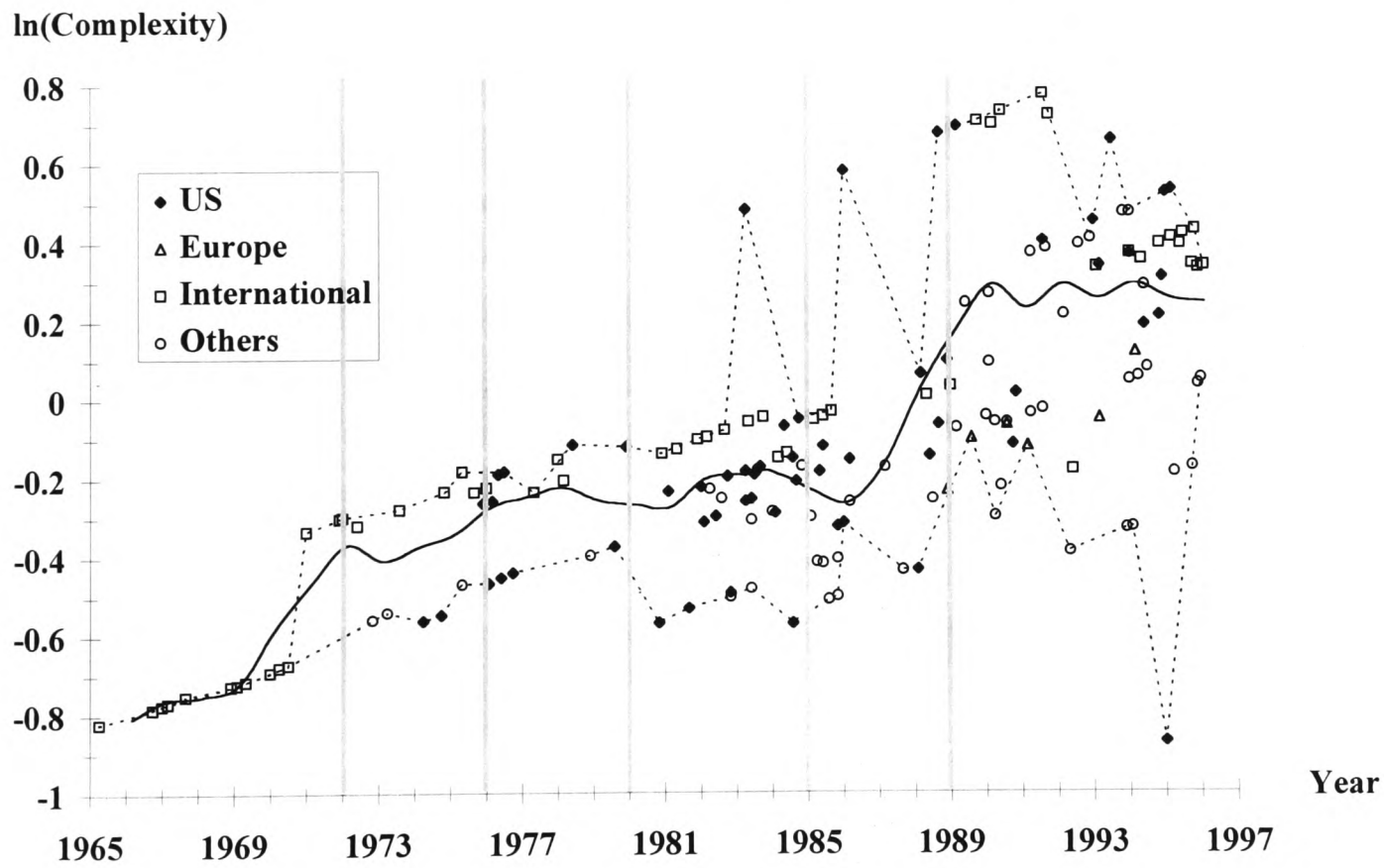


Figure 4.ii: Temporal evolution of complexity; North American manufacturers; 1964-93; logs, pooled sample, model 4.

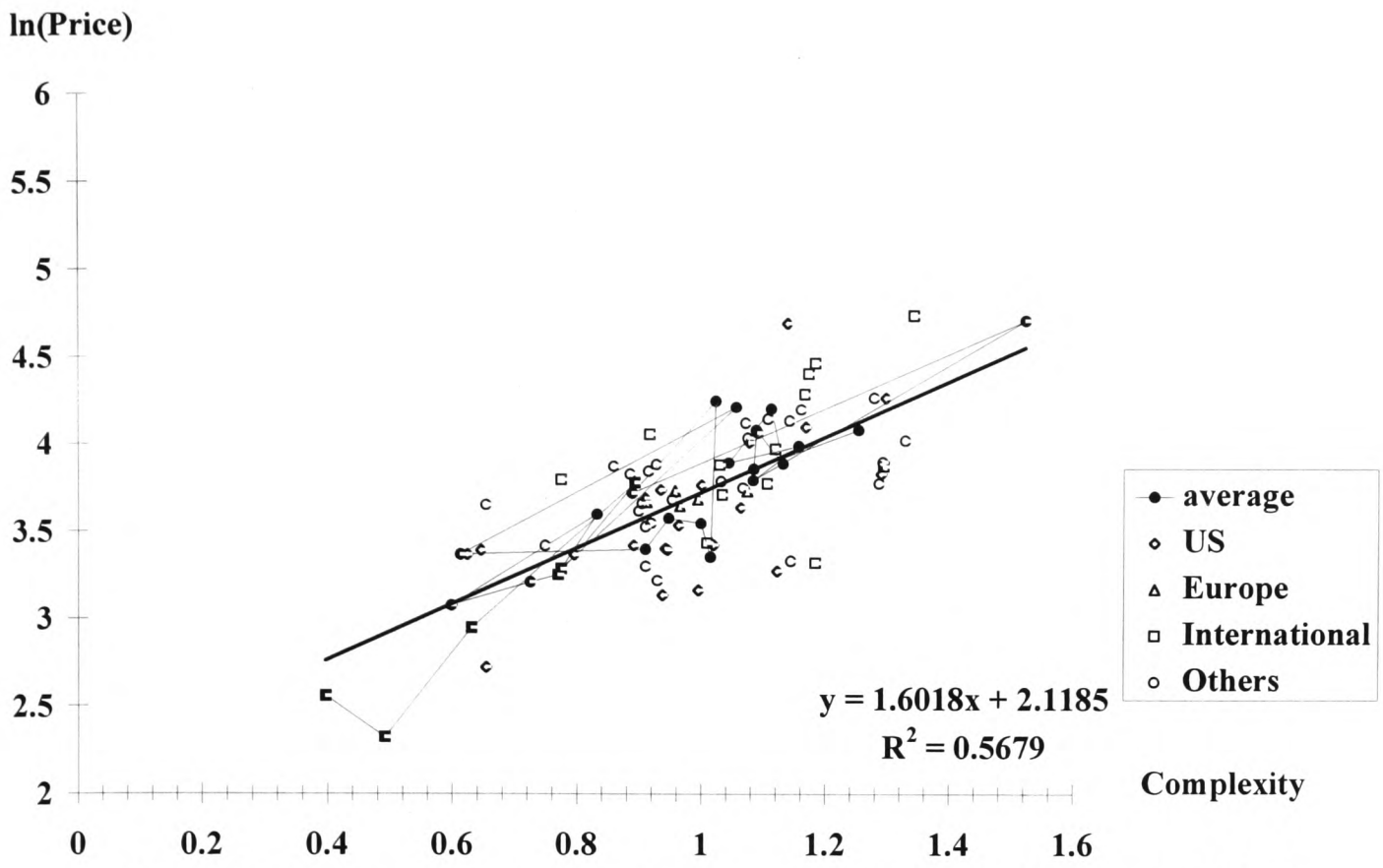


Figure 4.iii: Price versus normalised complexity (1980 = 0 for complexity); North American manufacturers; 1964-93; logs, pooled sample, model 3.

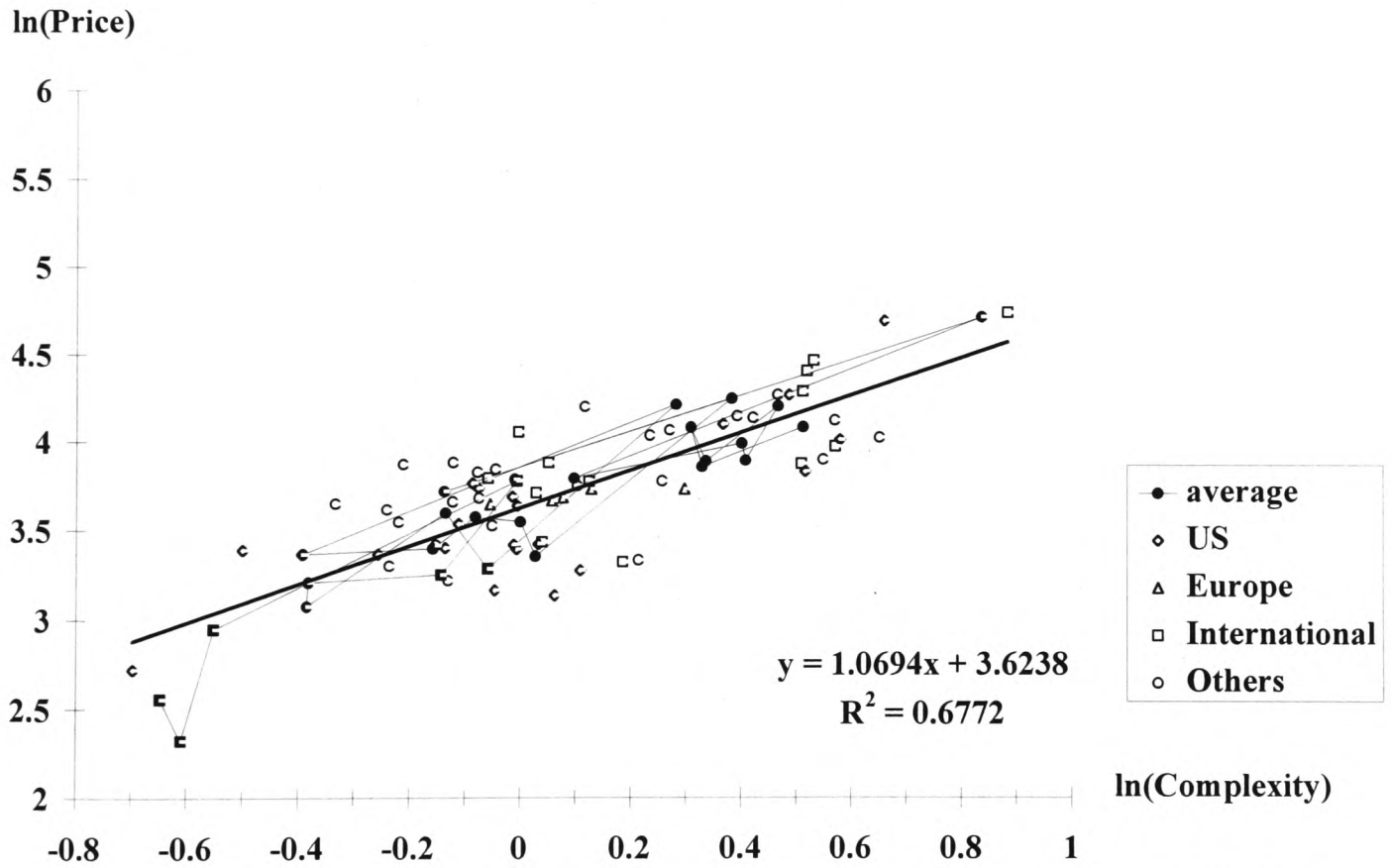


Figure 4.iv: Price versus normalised complexity (1980 = 0 for complexity); North American manufacturers; 1964-93; logs, pooled sample, model 4.

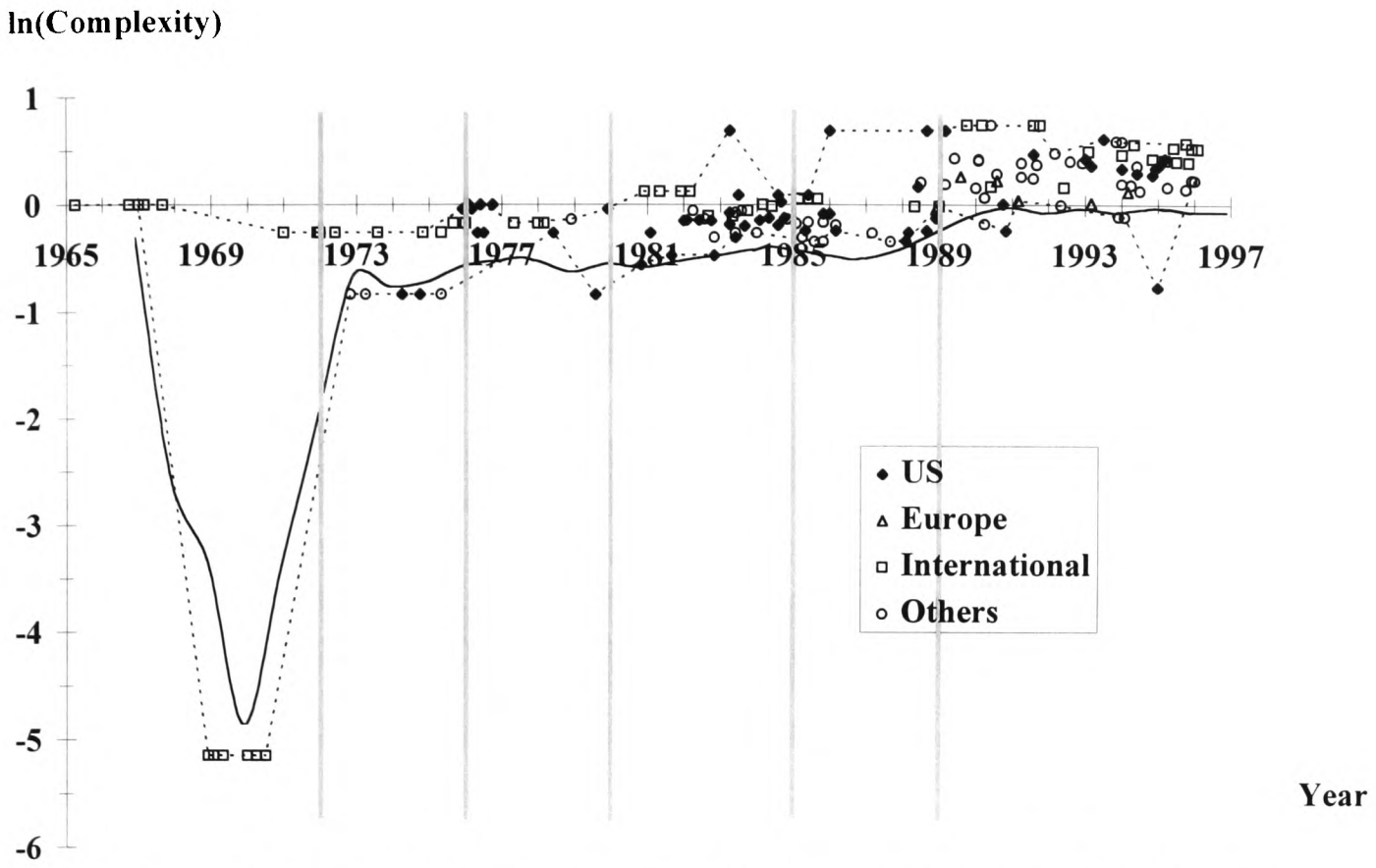


Figure 4.v: Temporal evolution of complexity; North American manufacturers; 1964-93; logs, split sample, model 4.

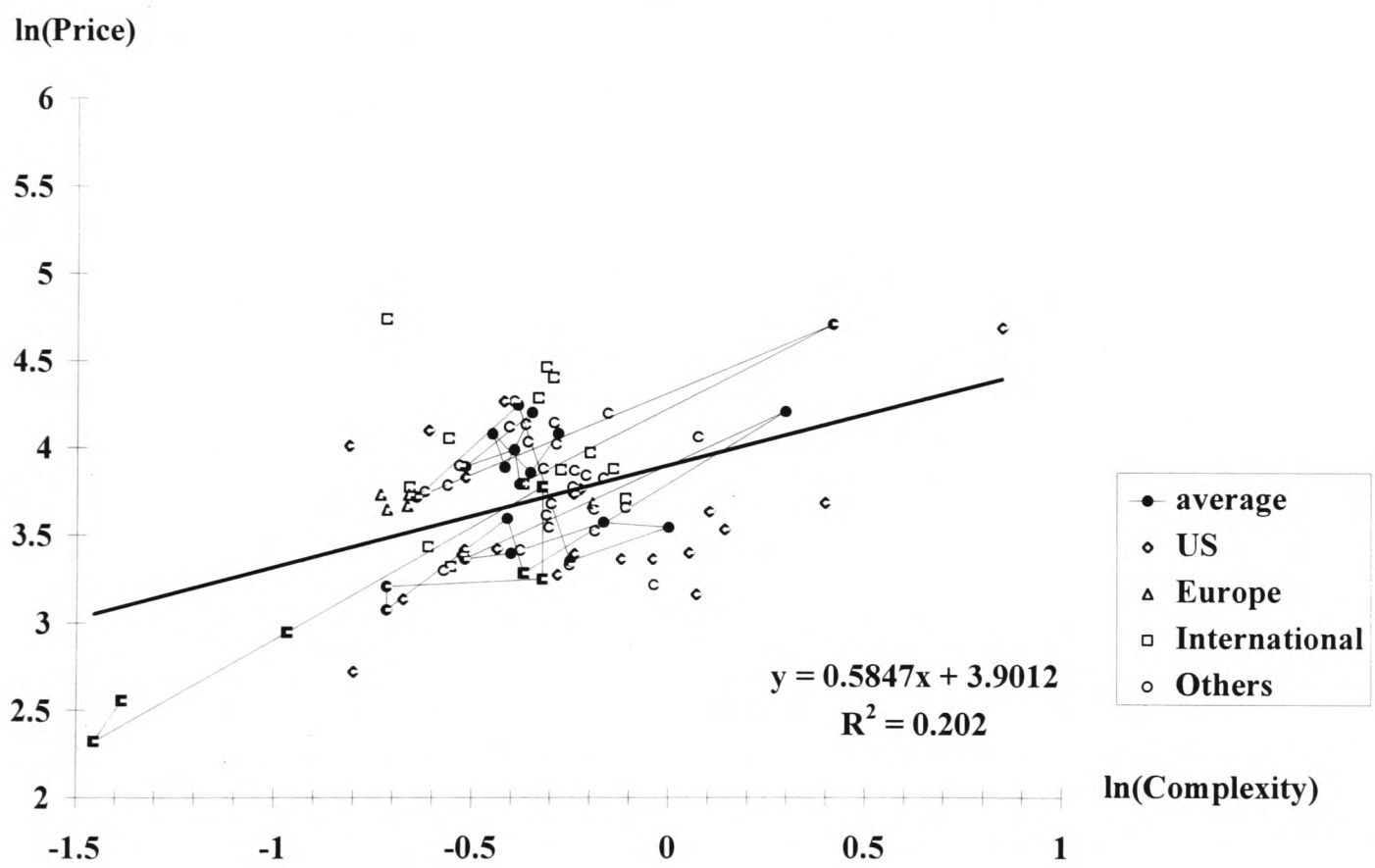


Figure 4.vi: Price versus normalised complexity (1980 = 0 for complexity); North American manufacturers; 1964-93; logs, split sample, model 4.

Annex 4.2 Development of the total factor productivity growth equation

Suppose a standard Cobb-Douglas production function:

$$Q_t = Ae^{\beta t} E_t^{\gamma} L_t^{\theta_L} K_t^{\theta_K} M_t^{\theta_M} \tag{4.i}$$

where E is technological experience; L, labour inputs; K, capital inputs; and M, material inputs. If the industry was competitive, the profits would be driven to zero. The assumptions required for using the cost dual to calculate the productivity index are: first degree homogeneity, constant degree of monopoly in the product market, constant degree of monopsony in the factor markets. Since the introduction of this chapter, we have found evidence that the industry has been subject to a constant mark-up throughout the years and therefore, the profit function for a joint monopolist can be written as:

$$\pi = pQ - \sum_i w_i x_i = \mu \sum_i w_i x_i \tag{4.ii}$$

where μ is the mark-up. Solving this equation for Q, we get:

$$Q = \frac{(1+\mu)\sum_i w_i x_i}{p} \tag{4.iii}$$

Replacing Q by the production function in the previous equation and solving for the technical change variables yields:

$$TFP_t = Ae^{\beta t} E_t^{\gamma} = \frac{Q_t}{L_t^{\theta_L} K_t^{\theta_K} M_t^{\theta_M}} = \frac{(1+\mu_t)\sum_i w_{it} x_{it}}{p_t L_t^{\theta_L} K_t^{\theta_K} M_t^{\theta_M}} \tag{4.iv}$$

Assuming that the elasticities add up to 1, i.e. the industry exhibits constant returns to scale. Recall that the coefficient of the variable number was not significantly different from 0 (in the logs) and therefore, no evidence of economies of scale were found. Using the Shephard's lemma, input quantities can be replaced by the partial derivative of the cost with respect to their input price. These transformations yield the subsequent measure of total factor productivity and its index, *TFPI*:

$$TFP_t = \frac{(1+\mu_t)}{\theta_L^{\theta_L} \theta_K^{\theta_K} \theta_M^{\theta_M}} \left(\frac{w_{Lt}}{p_t}\right)^{\theta_L} \left(\frac{w_{Kt}}{p_t}\right)^{\theta_K} \left(\frac{w_{Mt}}{p_t}\right)^{\theta_M} \tag{4.v}$$

$$TFPI_{80}(t) = \frac{TFP^t}{TFP^{80}} = \left(\frac{w_L^t / w_L^{80}}{p_S^t / p_S^{80}}\right)^{\theta_L} \left(\frac{w_K^t / w_K^{80}}{p_S^t / p_S^{80}}\right)^{\theta_K} \left(\frac{w_M^t / w_M^{80}}{p_S^t / p_S^{80}}\right)^{\theta_M} \tag{4.vi}$$

An alternative way to obtain the total factor productivity index is to first calculate partial factor productivity. Starting from profit maximisation of equation (4.ii), we get that the marginal revenue product is equal to the price of the factor x_i.

$$w_i = MRP_{x_i} = p\left(1 + \frac{1}{\varepsilon}\right) MP_{x_i} \tag{4.vii}$$

where ε is the price elasticity of demand. Rearranging this equation yields:

$$MP_{x_i} = \frac{w_i}{p\left(1+\frac{1}{\varepsilon}\right)} \qquad \textbf{(4.viii)}$$

Assuming a constant degree of monopoly in the product market, as deduced from the price complexity relationship, the index of the marginal product of factor i becomes:

$$\frac{MP^t_{x_i}}{MP^{80}_{x_i}} = \frac{w_i^t \Big/ w_i^{80}}{p^t \Big/ p^{80}} \qquad \textbf{(4.ix)}$$

Under first order homogeneity, the marginal value is equal to the average value and this index of marginal product can be transformed into an index of productivity of the factor i. Hence the three labour, capital and material productivity indices:

$$LPI_{80}(t) = \frac{LP^t}{LP^{80}} = \frac{w_L^t \Big/ w_L^{80}}{p_S^t \Big/ p_S^{80}} \qquad KPI_{80}(t) = \frac{KP^t}{KP^{80}} = \frac{w_K^t \Big/ w_K^{80}}{p_S^t \Big/ p_S^{80}}$$

$$MPI_{80}(t) = \frac{MP^t}{MP^{80}} = \frac{w_M^t \Big/ w_M^{80}}{p_S^t \Big/ p_S^{80}} \qquad \textbf{(4.x)}$$

Assuming that the input share weights are accurate, the index of total factor productivity can be calculated by elevating each partial factor productivity index to the power of its input share weight, which is the equivalent of equation (4.vi):

$$TFPI = LPI^{\theta_L} KPI^{\theta_K} MPI^{\theta_M} \qquad \textbf{(4.xi)}$$

Growth rates can be approximated from discrete yearly variables, using the following simple calculation:

$$TFPG_t = \frac{TFP^t - TFP^{t-1}}{TFP^{t-1}} = \frac{TFP^t \Big/ TFP^{80} - TFP^{t-1} \Big/ TFP^{80}}{TFP^{t-1} \Big/ TFP^{80}} \qquad \textbf{(4.xii)}$$

Although growth rates will be approximated using the previous formulation, they can also be approximated using the following. Taking the logarithm of a slightly modified equation (4.vi), yields:

$$\ln TFPG_{80}(t) = \theta_L \left[\ln\left(\frac{w_L^t}{w_L^{80}}\right) - \ln\left(\frac{w_K^t}{w_K^{80}}\right) \right] + \left(1-\theta_M\right) \ln\left(\frac{w_K^t}{w_K^{80}}\right) + \theta_M \ln\left(\frac{w_M^t}{w_M^{80}}\right) - \ln\left(\frac{P_S^t}{P_S^{80}}\right) \qquad \textbf{(4.xiii)}$$

Calculating the yearly difference, we obtain the following equation:

$$\Delta \ln TFPG(t) = \theta_L \left[\ln\left(\frac{w_L^t}{w_L^{t-1}}\right) - \ln\left(\frac{w_K^t}{w_K^{t-1}}\right) \right] + \left(1-\theta_M\right) \ln\left(\frac{w_K^t}{w_K^{t-1}}\right) + \theta_M \ln\left(\frac{w_M^t}{w_M^{t-1}}\right) - \ln\left(\frac{P_S^t}{P_S^{t-1}}\right) \quad \textbf{(4.xiv)}$$

Using the log approximation and the growth rate representation, yields:

$$TFPG = \theta_L \left(g_{w_L} - g_{w_K}\right) + \left(1-\theta_M\right) g_{w_K} + \theta_M g_{w_M} - g_{P_S} \quad \textbf{(4.xv)}$$

The learning curve can therefore be estimated using the subsequent equation:

$$TFPG_t = e^{\beta} \left(\frac{E^t / E^{80}}{E^{t-1} / E^{80}} \right)^{\gamma} - 1 \quad \textbf{(4.xvi)}$$

From the modified production function defined in equation (4.8) in the text, the following measure of net total factor productivity can be obtained:

$$\left(NOP_t\right)^{1-\theta_M} = \left(Ae^{\beta t} E_t^{\gamma}\right)^{1-\theta_M} = \frac{Q_t}{L_t^{\theta_L} K_t^{\theta_K}} = \frac{\left(1+\mu_t\right)\sum_i w_{it} x_{it}}{p_t L_t^{\theta_L} K_t^{\theta_K}} \quad \textbf{(4.xvii)}$$

The net output productivity index can be calculated in the subsequent fashion:

$$NOPI_{80}(t) = \frac{NOP^t}{NOP^{80}} = \left(\frac{w_L^t / w_L^{80}}{p_S^t / p_S^{80}} \right)^{\theta_L / 1-\theta_M} \left(\frac{w_K^t / w_K^{80}}{p_S^t / p_S^{80}} \right)^{\theta_K / 1-\theta_M} \quad \textbf{(4.xviii)}$$

The net output productivity growth can be calculated using the same formula as in equation (4.xvi) and the corresponding learning curve is therefore:

$$NOPG_t = e^{\beta} \left(\frac{E^t / E^{80}}{E^{t-1} / E^{80}} \right)^{\gamma} - 1 \quad \textbf{(4.xix)}$$

And this equation can be estimated by non-linear least squares. An alternative way to estimate the learning curve would be to calculate *NOPI* as:

$$\left(NOPI_{80}(t)\right)^{1-\theta_M} = \left(\frac{NOP^t}{NOP^{80}} \right)^{1-\theta_M} = \left(\frac{w_L^t / w_L^{80}}{p_S^t / p_S^{80}} \right)^{\theta_L} \left(\frac{w_K^t / w_K^{80}}{p_S^t / p_S^{80}} \right)^{\theta_K} \quad \textbf{(4.xx)}$$

and to estimate the learning curve as:

$$\left(NOPG_t\right)^{1-\theta_M} = e^{\beta(1-\theta_M)} \left(\frac{E^t / E^{80}}{E^{t-1} / E^{80}} \right)^{\gamma(1-\theta_M)} - 1 \quad \textbf{(4.xxi)}$$

Both methods will be used but understandably give very similar results.

Chapter 5

Demand for communication satellites

5.1 MODEL OF DEMAND FOR COMMUNICATION SATELLITE CAPACITY 184
5.1.1 Desired capital stock 186
5.1.2 Stock adjustment model 189
5.2 DATA 191
5.2.1 Variables 192
5.2.1.1 Endogenous stock 192
5.2.1.2 Factors affecting regional demand for communication capacity 193
5.2.1.3 Factors affecting demand shifts 196
5.2.1.4 Factors affecting the proportion of communication capacity supplied by satellite ... 196
5.2.2 Evolution of stock and orders 196
5.3 INSTRUMENTS FOR DEMAND SHIFTERS 202
5.3.1 Principal component analysis 202
5.3.2 Traffic demand regression 213
5.3.3 Desired satellites stock 216
5.4 STOCK ADJUSTMENT MODEL 220
5.4.1 Fixed stock adjustment 220
5.4.2 Time varying stock adjustment 227
5.4.3 Comments on the results 235
5.5 CONCLUSIONS 236
ANNEX 5.1 239

5. Demand for communication satellites

The role of demand shifts will be examined in this last chapter, because the fall in 'quality-corrected' prices is not big enough to support the interpretation that the expansion of satellite service capacity seen in chapter 1 was due to supply shifts along a stationary market demand schedule. Given the expansion in satellite capacity, one of two things is possible: either the demand is extremely elastic, i.e. we are observing shifts in supply due to the forces identified in chapter 4 along this schedule; or more plausibly, the demand schedule is less price elastic. This chapter undertakes to examine the question. Econometric theory would dictate a joint estimation of the supply and demand schedules for satellites of given (bandwidth) capacity to solve the identification problem first mentioned in the introduction to this thesis. In chapter 4, the discovery of a strong relationship between price and complexity supports the hypothesis of oligopoly on the supply-side with a simple mark-up pricing mechanism. The conclusion that the supply-side of the industry is characterised by price leadership (in chapter 4), with a mark-up pricing rule suggests that the econometrics of the demand schedule are greatly simplified, simultaneous equations are not required. The industry supply schedule is simply to set prices by picking points off the demand schedule. The econometrics analysis of the supply and demand schedule in a competitive industry would need the joint estimation of supply and demand, but consistent with the mark-up pricing behaviour (chapter 4), we believe that vendors are price setters, and we can directly identify the demand schedule.

The focus of the chapter is the growth of demand for services provided by satellites. Therefore, the relationship of the development of satellite service capacity to total communication capacity is what we are interested in. In this chapter, we will undertake to explain the growth of the stock of satellite capacity in response to the desired stock. This will require to look at factors which shift demand for satellite capacity in each of the regions of the world or countries that are ordering satellites in this period. The chapter is therefore going to develop both measures of the stock of service capacity for each of the relevant satellite service markets and the factors which were responsible for the growth of demand in those several respective markets. It will be seen that the factors driving demand led to a faster rate of expansion outside the original western world during the period (total demand for communication capacity), but in the second half of the period, the ability to use new software technologies such as data compression moderated the rate of growth derived for new satellites.

By relating the growth rate of the stock of satellite capacity to the growth rate of demand for satellite services as part of the demand for communication services in general, we can explain investment in, or launches of, satellites as a reflection of the adjustment of the stock of satellite capacity. Consequently, an issue with which we are concerned is the extent to which actual stock is adjusted to the change in desired stock (or the speed of adjustment). The speed at which countries adjust their stock depends on some of the characteristics of these countries. Consequently, we also want to test the view that there are systematic differences between regions arising from their relative size and characteristics.

The chapter is organised as follows: the first section sets out the model with a commentary relating to the relevant literature; section 2 describes the variables utilised in this demand-side analysis and studies the evolution of satellite capacity stocks and orders; section 3 calculates the factors affecting shifts in demand; section 4

presents the results of the stock adjustment estimation in two different sub-sections: fixed and varying stock adjustment; finally, the last section concludes.

5.1 Model of demand for communication satellite capacity

Many stages are involved in the international transmission of signals, as figure 5.1 demonstrates. Two determinants contribute to this stock of communication capacity: first, the part of the network that generates messages, i.e. the capacity of the local network and the number of international circuits; and second, the stock of alternative capacity to carry signals to their destination, that is fibre optics and cable networks as well as other countries' satellites. The particular aspect of the transmission that is of interest here is the demand for the stock of own satellite capacity, $S_{it}(t)$, and how countries adjust their stock of capacity over time.

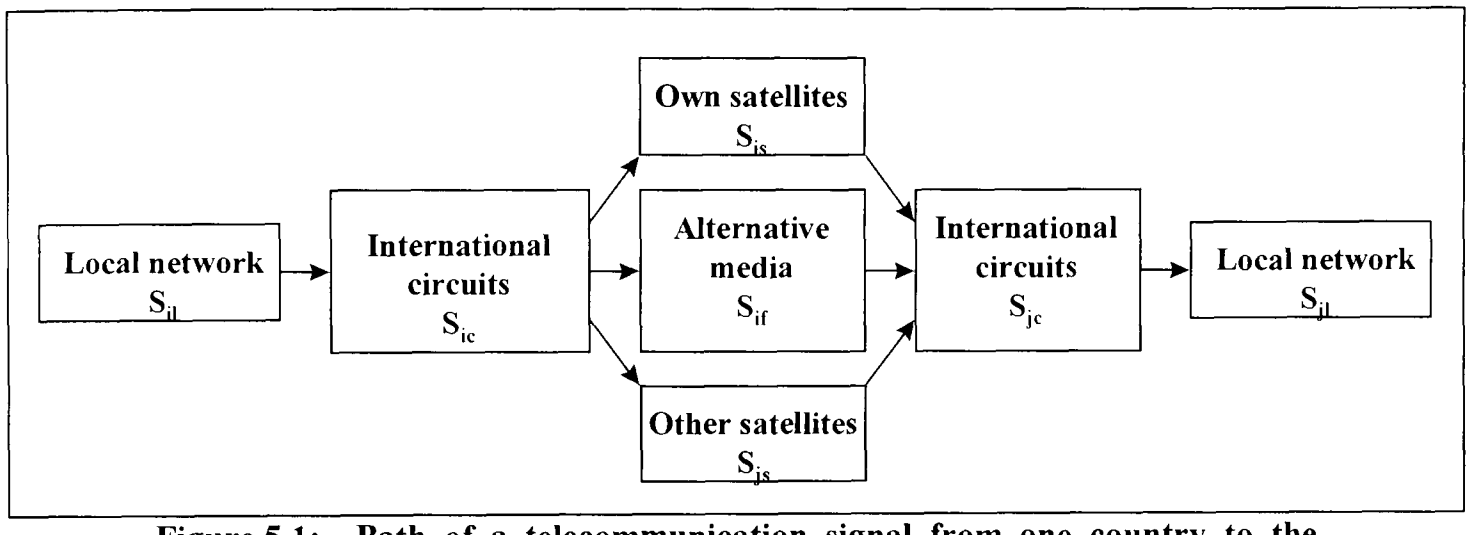


Figure 5.1: Path of a telecommunication signal from one country to the global region covered by the satellite; own country *i*, all countries *j*.

The adjustment model used for this purpose is based upon the classic Koyck (1954) partial adjustment mechanism (short run adjustment):

$$\ln(y_t) - \ln(y_{t-1}) = \lambda\left[\ln(y_t^*) - \ln(y_{t-1})\right] \tag{5.1}$$

where a firm's target is to adjust to the desired stock level. Jorgenson (1963) described this formulation as representing the backlog of uncompleted projects by the difference between desired stock and actual capital stock. As noted by Nickell (1978), the main problem of this model is that all the exogenous variables are expected to remain constant after a certain time $t + m$. This entirely static formulation assumes that a firm will only want to adjust to the desired stock level as soon as possible while in reality, it may not want to adjust just yet. Furthermore, the timing of the purchase of satellites is slightly more complex, because of several factors: time-to-build, delivery lags, potential constrained supply if all customers order at the same time, etc. Unfortunately, we are lacking most of the variables necessary to implement any of Nickell's more sophisticated models: no information concerning the world-wide satellite owners was available at the time, and it would take a considerable amount of time to construct such an international company database for a significant time series.

In most investment models, investment is defined as depending on the level of stock and a standard depreciation of past stock. In the case of satellites, this depreciation term is likely to vary with time and across satellites, as they possess various design lifetimes, and these can be shortened or lengthened according the orbital environment satellites encounter. Engineers cannot protect their spacecraft entirely against potential damage created by space debris and magnetic storms, to

name only a few. Moreover, a satellite at the end of its planned lifetime may still have some value to whomever can refuel it somehow! In the present case, we will assume that satellites remain fully operational until the end of their planned design lifetime.

Kydland and Prescott (1982) suggest that neither the neo-classical nor the adjustment cost models of investment are adequate. Indeed, using a standard investment demand function does not appear to fulfil the necessities for the present purposes. In the standard neo-classical investment model, the stock of capital adjusts immediately after the investment is done (in the same time period that is). In the case of satellites, as it was explained in the first chapter, it takes about three to five years to develop and produce a satellite. First introduced in the literature by Kalecki (1935), Kydland and Prescott (1982) implement the notion of time-to-build by including in the model a delayed capital stock expenditure that took a certain time to build. The investment corresponding to the yearly capital stock expenditure is divided in equal amounts over the years of construction of the capital good produced. And only at the end of the last payment does the capital good become 'operational' to its investors. This equality of payments does not strictly apply to the satellite industry, which has a rather more complicated payment framework than that. Indeed, it is a common practice in the industry to provide part payment for the good after the preliminary design reviews and critical design reviews, once the potential performance of the satellite is closer to reality than just a concept on paper. Moreover, performance payments are a common practice in the space industry, allowing the manufacturer to share a proportion of the risks involved in dealing with goods that cannot be repaired or with great difficulty and expense. Because of the potential serial correlation of this model, and because it does not strictly apply to the satellite industry, it would then be helpful to have a rather more flexible investment plan. Park (1984) has proposed an adaptation of the time-to-build model with fixed investment plan by introducing a variation term to the 'yearly' investment. This theoretical flexible investment plan models the advent of investments being downgraded and even abandoned in the course of their development or production. Even if this solves the serial correlation problem, this is not enough for this case, because as much as 10 % of the price of a satellite can only be guaranteed once the satellite is operational in orbit. Some customers also ensure that the manufacturer is paid a yearly amount for the proportion of the spacecraft that is fully operational per year of planned service[1]. In a sense, this is stretching the performance payment over a number of years of operational service.

Another concept described by Peeters (1996), are delivery lags as an alternative to time-to-build. In this model, investment is done in one go, in contrast with time-to-build models, but the delivery of the good occurs some periods after the initial investment. This concept is also relevant to the satellite industry because most customers order more than one satellite in a given contract and also because all satellites cannot be launched in the same go[2]. The time between the first launch (which in our case is the measure of delivery) and the launch of the subsequent satellites can be considered as a delivery lag. A model that incorporates both the time-to-build framework with a more flexible investment plan as well as the delivery lag model is therefore required. Peeters (1996) suggests that equipment is probably subject to delivery lags rather than construction lags, but this is certainly not the case for satellites and most of the custom built equipment.

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[1] Consult chapter 1 for a description of the various types of performance payments.

[2] They could on certain launch vehicles but they don't because of the non-negligible probability of launch failure.

The satellite industry is not the only one which encounters delivery lags as well as time-to-build, Abel and Blanchard (1988) calculate construction lags of 9 to 15 months for industrial structures, 9 to 18 months for commercial structures and 12 to 24 months for other structures. The pre-construction period prior to the time-to-build period, mentioned by them, would correspond, in the satellite industry, to the request for proposal period that pre-empt the contract signature. It would be possible to calculate this period by calculating the time difference between the first notification of the need for a frequency and orbit allotment to the ITU[3].

In this thesis, the existence of time-to-build and delivery lags is not at stake. Their existence is known and so is their length. In this case, the time delay between investment and operation stock is first ignored, but then implemented as a time adjustment coefficient depending on the growth rate of orders.

Last but not least, satellite operators occasionally make forecasting errors, as it was the case in the 1980s, when many satellites were sold on the 'second-hand' market, because of over capacity above some regions. As mentioned in the first chapter, competition from alternative technologies such as cable and fibre optics, as well as significant improvement in software compression techniques, greatly reduced the need for physical bandwidth in space, and created this wave of cheap sell off of capacity[4]. This kind of sell off of the capacity, once it is ordered, could potentially be implemented in the model by adding a term in the net stock equation that could reduce the stock of satellites in the case of it being sold off to a different region. The US market and its numerous mergers and take-overs that resulted in the restructuring of the owned stock of satellites will not, in this thesis, be examined in enough details to be able to assess properly this second-hand market. In any case, there are relatively few of these 'second-hand' sales and modelling them properly, would require a much greater sample size, and in the case of satellites, the data included in this thesis represents roughly 90 % of the total capacity. Furthermore, the second-hand sale of these satellites was excluded from the calculation of the hedonic price indices.

To calculate the speed at which countries adjust their stock of satellite capacity, an idea of the stock demand is required, and this part of the model will first be presented. The calculation of the desired stock necessary to the stock adjustment model will be separated into two parts: factors affecting demand and stock demand. Then, the backbone of the model, a classic stock adjustment framework, will be described and adapted to the satellite services context.

5.1.1 Desired capital stock

Substantial part of the literature on stock adjustment models treats expected sales as a measure of desired capacity. The analogue of expected sales volume in this industry is the telecommunication traffic volume carried by satellites. Such a measure would have to be available for each region being served by the satellites held by one owner. But this sort of information is not available. Why not? Satellites handle traffic not only arising in their owners' country, but in neighbouring regions as well. We need to examine growth of traffic originating in the entire region served by the satellites of each owner. Unfortunately, we have no concrete information on the

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[3] Recall that all satellites have to be registered with the ITU, the regulatory body, in order to prevent harmful electromagnetic interference.

[4] For example, Satcom Ku3 and Ku4, were both sold respectively to SES (renamed Astra 1A), and to Intelsat (renamed Intelsat k). Consult chapter 1 for a more detailed description of the whereabouts of these satellites.

degree of use of these satellites from neighbouring countries, or the degree of capacity usage. A way to counteract this lack of data would be to assume that these customers have their own interests at heart when they order communication capacity, and whatever they can sell to other adjacent countries is a supplement. This, however, is not sufficient and highly implausible for regional and international satellites. More appropriately, we can use proxy variables for the growth of traffic in the demand for satellite communication function. Traffic is therefore a function of two types of variables: alternative means for handling traffic; and capacity of satellite technology to handle traffic. We can define the desired stock of satellite services of a particular country, i, at time t, as[5]:

$$S_i^*(t) = S_{is}^*(t) + S_{js}(t) + S_{if}(t) \tag{5.2}$$

where $S_{is}^*(t)$ is the desired stock of satellites owned by country i, at time t; $S_{js}(t)$ is stock of foreign satellites that could potentially service country i, at time t; and $S_{if}(t)$ represents the stock of alternative technologies, such as fibre optic cables, belonging to either countries that can carry international transmissions. Isolating the stock of satellites of country i, equation (5.2) becomes:

$$S_{is}^*(t) = S_i^*(t) - S_{js}(t) - S_{if}(t) \tag{5.3}$$

We will treat these three types of communication capacity as substitutes. Because accurate and complete data on inter-country alternative transmission methods, such as the fibre optic capacity, could not be found, the last two terms of the equation were approximated by a quadratic in time[6]. This logit approximation allows to isolate the stock of satellite capacity.

$$\ln\left(S_{ist}^*\right) = \ln\left(S_{it}^*\right) + \varphi t + \psi t^2 \tag{5.4}$$

In general, telecommunication traffic originating from country i, at time t will be a function of the quantity of reception and transmission equipment available in the country. Traffic will also depend on the introduction and growth of new satellite services. In addition, traffic will also depend on a number of country characteristics. Country financial indicators will also provide information regarding the use of telecommunications generated by international trade for instance. All these variables are likely to affect the growth of telecommunication traffic.

---

[5] Because of the substitutability between fibre optics, cables, own domestic satellites and other spacecraft, a pure Cobb-Douglas formulation does not satisfy the transmission model presented in figure 5.1. Assuming constant elasticity of substitution between all international media, a general formulation of the model for the capital needed would be:

$$S_i = S_{il}^{\alpha_1} S_{ic}^{\alpha_2} \left(S_{is}^{-\sigma} + aS_{if}^{-\sigma} + bS_{js}^{-\sigma}\right)^{-1/\sigma} S_{jc}^{\beta_2} S_{jl}^{\beta_1}$$

where the last two measures of capital stock imply location of another country's telecommunication facilities. Typically, the stock of capacity dedicated to international transmission can thus be defined as:

$$S_i = \left(S_{is}^{-\sigma} + aS_{if}^{-\sigma} + bS_{js}^{-\sigma}\right)^{-1/\sigma}$$

Furthermore, some countries do not own satellites and some other solely use their own domestic satellites. This implies that the elasticity of substitution between own and other country satellites is ∞ and equation (5.11) can be simplified greatly to:

$$S_i = S_{is} + aS_{if} + bS_{js}$$

[6] For the development of this equation, please consult the technical annex at the end of this chapter.

$$Q_{it} = f\begin{pmatrix} reception\,equipment, transmission\,equipment, new \\ services, country\,characteristics, country\,financials \end{pmatrix} \tag{5.5}$$

Because of the great number of variables collected, principal components will be extracted in order to reduce the number of instrument variables in the stock demand equation. The factors affecting demand shifts will therefore be calculated in the following manner:

$$\ln\left(Q_{it}^{1}\right) = \prod_{n=1}^{4} \theta_{in} \ln\left(PComp_{\text{int}}\right) + d_i D_{8593} \tag{5.6}$$

where $Pcomp_{int}$ represent the first four principal components among the set of communication demand variables, and θ_{in} the elasticity of demand of each principal component. An alternative to this calculation is to assume a distinction between variables present in the entire sample versus variables representing new technology introduced in the latter part of the sample.

$$\ln\left(Q_{it}^{2}\right) = \prod_{n=1}^{4} \left[\theta_{in}^{'} \ln\left(PComp_{\text{int}}^{'}\right) + \left(\theta_{in}^{''} \ln\left(PComp_{\text{int}}^{''}\right) D_{8593}^{''}\right)\right] \tag{5.7}$$

where $Pcomp'_{int}$ corresponds to the first four principal components among the long-lasting variables, and $Pcomp''_{int}$ represents the first four principal components among the new technology variables introduced in, and calculated for, the last part of the sample, 1985-93; D''_{8593} equals 1 for the period 1985-93, and 0 otherwise. The predicted values of these two traffic demand measures will both be used in the subsequent analysis but for simplicity, the superscripts will be omitted.

Regarding the desired stock equation, our model follows Jorgenson's (1963) capital stock measured by the following equation:

$$K^{*} = \frac{\gamma\, pQ}{c} \tag{5.8}$$

In the present case, the price of output, outgoing international telephone traffic, is not known, and the cost c will be replaced by the satellite unit price index calculated in the third chapter. Because of the mark-up pricing evidence of the previous chapter, this price index is a good approximation of the cost, and the mark-up should be absorbed into γ. Therefore, this equation can be modified into equation (5.9). The desired stock of communication bandwidth capacity can therefore be calculated using the very simple equation:

$$S_{it}^{*} = \alpha \frac{\hat{Q}_{it}^{\beta}}{p_t^{\varepsilon}} \xi_t^{\gamma} \tag{5.9}$$

where $\xi_t = \dfrac{Bandwith_t}{Voice_t}$ is a bandwidth efficiency measure.

S_{it}^{*} represents the desired stock as directly proportional to the predicted demand shift in terms of some measure of traffic $\hat{Q}_{it}$, and indirectly proportional to the price of a unit of satellite 'capacity' p_t. The reason to introduce a bandwidth efficiency measure affecting the proportionality factor in the stock demand equation, is that a conversion is needed between the capacity measured in terms of bandwidth

(i.e. the left-hand side variable), and the equivalent number of voice channels as a measure of traffic (a multiplier of the telecommunication traffic measured in minutes). Even though equation (5.9) represents general demand for communication, relating the stock to the satellite bandwidth efficiency and the satellite prices allows the comparison of all communication media. In other words, this equation represents the bandwidth capacity that would be needed if all signals were transmitted via satellite. In natural logarithm format, this equation becomes:

$$\ln\left(S_{it}^{*}\right) = \alpha' + \beta \ln\left(\hat{Q}_{it}\right) + \gamma \ln\left(\xi_{t}\right) - \varepsilon \ln\left(p_{t}\right) \tag{5.10}$$

but S_{it}^{*} here, is the desired stock of service capacity that would satisfy a country's demand, and not the demand for owned satellites.[7] Using the substitution between the desired stock of telecommunication capacity and the desired stock of satellite capacity developed in equation (5.4), the stock demand equation becomes (this equation will be needed in the stock adjustment model defined below):

$$\ln\left(S_{ist}^{*}\right) = \alpha + \beta \ln\left(\hat{Q}_{t}\right) + \gamma \ln\left(\xi_{t}\right) - \varepsilon \ln\left(p_{t}\right) - \varphi t - \psi t^{2} \tag{5.11}$$

5.1.2 Stock adjustment model

We will apply a model based upon standard stock adjustment models to study the demand for communication satellites. In contrast with traditional models of stock adjustment, investment does not immediately materialise into an operational satellite. Remember from the first chapter that the delay between the request for proposal and the operation of the satellite in space involves a lot of time and effort. Customers must first forecast their demand for telecommunication and broadcasting services for the next five to ten years, because once the need for satellites is identified, it may take three to five years before the ordered satellites are operational.

In a traditional time-to-build model, the stock of capital is generally auto-regressive. This assumption will be maintained because the stock of satellites in this period is equal to the stock of satellites of the previous period minus the satellites that have reached their 'end-of-life' in the previous period plus the orders that have been launched in the last period and are operational in this period (see equation (5.13) below). Because it generally takes three months after the launch date for the satellite to be fully tested and operational, we have standardised the operational stock of satellites to be usable in the period following their launch. Modifying the standard Koyck (1954) lag adjustment stock model equation (5.1), we get following:

$$\frac{S_{is}(t)}{S_{is}(t-B)} = \left(\frac{S_{is}^{*}(t)}{S_{is}(t-B)}\right)^{\lambda} \tag{5.12}$$

---

[7] The demand shift calculated as in equation (5.7) could have been separated into two different equations, one for Q_1 representing long-lasting demand variables and the second for Q_2 characterising new technology. These two predicted traffic demand variables could then have been implemented in equation (5.10) as two separate entities, with the new technology traffic demand multiplied by a time dummy variables representing the last generation of satellites. As the time series is relatively short, 29 years maximum, and much less in the case of countries without domestic satellites who joined Intelsat later than 1965, adding variables in equation (5.10) affected the fit of the regression. It was therefore preferred to calculate the predicted traffic demand as in equation (5.7) and then include this variable in the stock demand equation (5.10).

where $S_{is}(t)$ is the net stock of satellites for country i at time t, and $S^{*}_{is}(t)$ represents the desired stock of satellite at time t; B is the average time between the contracted date and the delivery date, and corresponds to the variable *rdev* utilised in the third chapter. B varies with each satellite and as a consequence, an average value will be assumed to be able to run this auto-regressive stock adjustment model. Theoretically, countries have a slow adjustment process because of the time-to-build framework. The greater the value of the lag utilised in this model, the larger will the adjustment coefficient be, as user-countries never quite adjust to the desired stock. As a consequence, since countries still take decisions yearly, using $B = 1$, gives equally good results as a larger lag. Moreover, the development time is known and is not to be estimated.

The stock of satellites here is measured in satellite capacity units (bandwidth, to be precise) rather than in the cumulative value of depreciated investments. Satellites theoretically remain fully operational until they drift out of orbit after fuel depletion and therefore are assumed not to lose bandwidth until termination of their planned service life. This framework allows us to model the net stock of satellites as the following:

$$S_{is}(t) = S_{is}(t-1) - D_{is}(t-1) + K_{is}(t) \tag{5.13}$$

where $S_{is}(t - 1)$ is the stock of satellite capacity inherited from the previous period, $D_{is}(t - 1)$ denotes the satellite capacity that was planned to die in the previous period, and $K_{is}(t)$ represents the flow of newly launched operational satellite capacity that was ordered approximately at time $t - B$. Appendix F presents averages of development times for various manufacturers.[8] Incorporating equation (5.11) into the stock adjustment model, equation (5.12) can be rewritten as:

$$\Delta \ln(S_{ist}) = a_0 + a_1 \ln\left(\hat{Q}_t\right) + a_2 \ln(\xi_t) + a_3 \ln(p_t) + a_4 t + a_5 t^2 + a_6 \ln S_{ist-1} \tag{5.14}$$

where $a_0 = \alpha\lambda$; $a_1 = \beta\lambda$; $a_2 = \gamma\lambda$; $a_3 = \varepsilon\lambda$; $a_4 = \varphi\lambda$; $a_5 = \psi\lambda$; $a_6 = -\lambda$.

Many models in the investment literature follow the convention of having a fixed adjustment speed. But, here, we regard it as relevant to allow for variation in adjustment speed as a function of the rates of change in length of order books. The speed of adjustment is assumed to depend on the stock of orders from other countries. The variable λ can therefore be specified as a function of other countries' orders, assuming that a fixed country effect is separable from the time effect in the adjustment coefficient.

$$\lambda_{it} = \lambda_i \left(\frac{O_{jt}}{O_{jt-1}}\right)^{\omega_i} \tag{5.15}$$

where O_{jt} is the list of orders of all other countries, j, at time t and accounts for the country-specific response to the volatility in the order books generated by other countries, ω_i is the variable adjustment parameter which reflects the year to year variation in orders of communication satellites, and λ_i is the fixed adjustment

[8] A more sophisticated and accurate model could be developed if economic obsolescence could be measured, i.e. if the satellite's resale value after a number of years of service could be estimated[8], or better, was known for all cases.

parameter specific to each country. This specification is meant to allow for the effects of responses to perceived manufacturing constraints and information about the length of vendors' order books; Different countries are differentially responsive to changes in order books. The motivation here, is that as order books lengthen, purchasers bring forward their desired order dates so as to obtain a place in the queue. It may be the case that the adjustment coefficient is constant over time, but varies across countries. But if the speed of adjustment varies with time as well as across countries, then incorporating λ_{it} according to equation (5.15) is appropriate. It is also possible that the country effect is similar across a group of countries, in which case, we can modify equation (5.15) to take into consideration a separation into two groups:

$$\lambda_{it} = \lambda_i \left(\frac{O_{jt}}{O_{jt-1}} \right)^{\omega_1 D_1 + \omega_2 D_2} \tag{5.16}$$

where D_1 and D_2 are two dummy variables separating countries into two groups, and ω_1 and ω_2, the elasticities that correspond to those two groups. One can think of many ways to separate these countries: frequent versus occasional purchasers of satellites, big and small owners of communication satellites, owners of domestic versus non-owners, and so forth. The last method will be favoured in what follows. Implementing both time varying stock adjustment measures into the stock adjustment model specified in equation (5.143), yields:

$$\Delta \ln\left(S_{ist}\right) = \left(\frac{O_{Tt}}{O_{Tt-1}} \right)^{\omega} \left[\begin{array}{l} a_0 + a_1 \ln\left(\hat{Q}_t\right) + a_2 \ln\left(\xi_t\right) + \\ a_3 \ln\left(p_t\right) + a_4 t + a_5 t^2 + a_6 \ln S_{ist-1} \end{array} \right] \tag{5.17}$$

$$\Delta \ln\left(S_{ist}\right) = \left(\frac{O_{Tt}}{O_{Tt-1}} \right)^{\omega_1 D_1 + \omega_2 D_2} \left[\begin{array}{l} a_0 + a_1 \ln\left(\hat{Q}_t\right) + a_2 \ln\left(\xi_t\right) + \\ a_3 \ln\left(p_t\right) + a_4 t + a_5 t^2 + a_6 \ln S_{ist-1} \end{array} \right] \tag{5.18}$$

The existence of Intelsat, however, means that some portion of orders will not behave in that way. Satellite purchases by this organisation represent new capacity shared amongst the member states of Intelsat. If only countries owning domestic satellites were considered, and Intelsat was completely left out of the analysis, the separation of orders in own versus other countries would be meaningful. However, Intelsat represents approximately a quarter of all orders. There are two ways to treat Intelsat in this study. The first method aggregates the regions covered by Intelsat satellite footprints. In doing so, the telecommunication indicators and other variables relevant to our study are aggregated as well. In contrast, the second method disaggregates Intelsat capacity by member states. This second method of dealing with Intelsat by assigning each country its share of the organisation satellite capacity is preferred to the first method as it is based on the understanding that each country has a decision on how much to invest in the international organisation, because it represents their usage of the capacity.

5.2 Data

Several databases were combined to obtain the necessary variables for this part of the study. The International Telecommunication Union (ITU) provided telecommunication data from their World Telecommunication Indicators database, as

well as satellite coverage and services from their Space Radiocommunication Stations[9] database. The World Fact Book published by the Central Intelligence Agency (CIA) was used to extract information on the type of terrain as well as country dimensions. For the financial aspect of countries, the International Monetary Fund (IMF) databases provided data such as GDP, exports/imports, total assets and liabilities to foreign banks and non-banks. Intelsat, Eutelsat and Inmarsat kindly supplied information on the date at which each country joined their organisation as well as their investment share. World population statistics were provided from the United Nations database. The variables extracted from these various databases are for most, except the terrain which rarely fluctuates yearly, in a panel data format. In what follows, each variable utilised in this study of the demand side of satellite communication will be described thoroughly.

5.2.1 Variables

The subsequent variables were calculated using the satellite manufacturing database[10] used in chapters 3 and 4, as well as the ITU Space Radiocommunication Stations database to calculate and divide the footprint attributed to each spacecraft. All these variables represent the flow and stock of satellites for the owners and potential users of these orbit transmitters. Two concepts need to be introduced at this point: first, the *country* concept, which is calculated to represent the potential use of satellite by all the countries covered by the satellite footprint; second, the *owner* concept, which is calculated to determine the proportion of the footprint that can be attributed to each owner, and how this varies over the years[11]. The stock variables are measured in terms of satellite capacity above them. All the calculations in this chapter will utilise satellite capacity measured in terms of bandwidth, as it is the most comparable measure across time and media. Four types of variables will be considered: endogenous stock, capacity, shifts, and transmission method determinants.

5.2.1.1 Endogenous stock

The first category, endogenous stock capacity, can be characterised by the following variables:

- *Own country stock* (MHz, continuous): Variable representing the proportion of a satellite footprint that covers a given country. This variable was calculated using the ITU Space Radiocommunication Stations database, which lists all satellites, their respective beams' characteristics including their footprint. Using the footprint information, each country was attributed a proportion of satellite footprint in terms of the percentage of ground coverage

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[9] The ITU Space Radiocommunication Stations database provides far too much details, for instance, for a single Intelsat satellite, up 1024 different beams were listed. With each beam comes a different set of frequency channels, with various powers, bandwidth, etc. Each satellite entry had to be simplified to provide one 'aggregated footprint' per satellite. The use of this database was primarily intended to assess the use of satellites according to their services. Unfortunately, the majority of satellite records do not discriminate between the services but rather list a category including all types of services: voice, sound and video broadcasting, data, etc.

[10] The number of satellites ordered and launched, their planned lifetime, capacity and equivalent number of voice channels measures were used to calculate the stock of satellites.

[11] In the case of international and regional organisations such as Intelsat, Inmarsat or Eutelsat, each member state owns part of satellite. It is common for the investment share in the organisation to correspond to satellite utilisation. For this reason, in the case of these international organisations, the ownership of a spacecraft was calculated using the investment share of each country.

that the country represents in the total area covered by the satellite[12]. Then, only the proportion of the footprint belonging to a given country was counted. For domestic satellites, a sole owner will characterise this variable, while in the case of Intelsat, all member states covered by the footprint will be counted.

- *Own country dead* (MHz, continuous): This variable measures the flow of satellites that are planned to die each year and the proportion of this satellite footprint capacity measure that will disappear above each country as a consequence.
- *Own country's orders* (MHz, continuous): This variable represents the yearly addition of orders to the future stock of satellites from the point of view of owners only. In the subsequent analysis, *other countries' orders* will be used, and calculated as *total world orders - own country's orders*.

In order to model the decision of a country to launch a satellite, the actual stock of satellites in place, what will die in the near future, and what will be launched by this particular owner or by neighbours which could potentially be used by this country will affect the decision of whether to acquire or update its fleet of spacecraft.

Own country stock will also be used to estimate the adjustment parameter λ that measures how fast the countries adjust their stock of satellite relative to one another. As mentioned previously, equations (5.17) and (5.18) take into consideration, the possibility that manufacturers have a maximum production capacity, and that by putting an order early, customers will 'beat the crowd'.

5.2.1.2 Factors affecting regional demand for communication capacity

A greater number of variables of different types was available for the right-hand side of the model; they can be divided into 4 categories: reception equipment, modern services, general country characteristics and financial information. In a first instance, the reception apparatus is divided into two groups: telecommunication and broadcasting reception equipment.[13]

- *Number of telephone main lines* (units, continuous): Provided by the ITU database, this variable is a measure of the telecommunication capacity of a country. The ITU specifies categories of main lines: automatic, digital, urban, residential and those equipped for international dialling. Only the percentage of residential main lines provides enough country data for the purposes for this study. Other categories are generally available for recent years. The number of main lines is preferred to the number of telephone sets because the latter is more associated with individuals' wealth within a country rather than the telecommunication potential. Even if a residence is layered with telephone sets in every room, if a single main line deserves this house, only one communication signal can be received at a time. And this is true for services such as call waiting. Teleconference calls are starting to appear, but these require special switches and equipment and do not form the majority of main lines.

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[12] We are well aware that this division of the satellite footprint is rather crude and non realistic but without precise information on each country's use of a particular satellite, this is a good proxy.

[13] The ITU separates telecommunication from broadcasting services. All the figures they list exclude the latter, fortunately, they list a few useful statistics concerning the broadcasting aspect of communications in general.

- *Waiting lists* (units of main lines, continuous): Variable measuring the potentially unfulfilled demand for basic telecommunications.
- *International outgoing telephone traffic* (minutes, continuous): Variable measuring international voice traffic. Whether a communication signal originates from one country or the other is not the issue here, it still occupies bandwidth on a satellite or another media. In this case, only outgoing traffic will be considered for a particular country in order to avoid double counting of transmissions. Obviously international traffic will use other media to reach their destinations, but using equation (5.9) can remedy this problem.
- *Television receivers* (units, continuous): The number of television receivers. In contrast with the number of telephone sets, this variable is an accurate measure of the use of broadcasting services[14]. The difference is that telecommunications are a point-to-point service, while broadcasting is a point-to-multipoint service. There are therefore no such limitations on the number of users receiving audio and video broadcasts that exist for the number of channels used for voice and data communications. The number of television channels is therefore the only way to determine the actual use of satellites for broadcasting purposes, but this variable does not exist in the data that was available at the time of the study.
- *Cable television subscribers* (units, continuous): In few countries, especially in North America, cable services started in the 1970s. In the rest of the world however, the cable phenomenon is relatively recent. Cable transmission is in direct competition to direct-to-home (DTH) satellite services and therefore is an important variable in this study.
- *Estimated satellite DTH subscribers* (units, continuous): In the 1980s, satellite dishes were a rare site in the landscape, but since the beginning of the 1990s, they have literally mushroomed in some western countries. Many satellites were launched in Europe, for the sole purpose of providing direct-to-home television broadcasting.

Telecommunication and broadcasting systems are increasingly growing closer together, as telecommunication service providers allow video transmission along their fibre optic cables, and cable television companies offer telephone services on their media. Satellite may not therefore remain sole providers of some trunk routes in the near future.

The ITU lists a considerable number of other variables such as residential and business telephone connection charges, monthly subscription and cost of a three minutes phone call. They also provide the same kind of information for analogue and digital mobile communication systems. Because at the time of data collection for this study, no truly international mobile telecommunication system existed (the likes of Motorola Iridium, Qualcom Globalstart and Teledesic were still on the design table at the time). Any fully international mobile telecommunication had to be relayed via the ground infrastructure before being transmitted to other countries, the number of international circuits being the constraint in this case (refer to figure 5.1 for details on the transmission path through these media). Data on the transmission equipment of the ground infrastructure have only recently been incorporated in the data collected by the ITU in the World Telecommunication Indicators database. As a consequence,

[14] It could be argued that televisions need to be switched on to justify 'usage' but the possession of a set is sufficient to measure potential usage.

essential variables such as the *Capacity of local exchanges*, the *total km of fibre optics* and the number of *international telephone circuits*, are only available for a few recent years. Including these variables in the study would bias the results as they do not fall into the category of recent new technology data because they did exist before they were collected.

In contrast, many communication services are fairly recent, and the following variables should not be discarded for their missing values in earlier years, but rather added to the model once these services started to appear on the markets:

- *Fax machines* (units, continuous): Estimated number of facsimile machines.
- *Videotex subscribers* (units, continuous): Number of television owners who subscribe to a teletex service providing general information and news via the broadcasting network.
- *Mobile phone subscribers* (units, continuous): Number of cellular, analogue and digital, mobile phone subscribers.
- *ISDN subscribers* (units, continuous): Integrated Services Digital Network subscribers.
- *PDN subscribers* (units, continuous): Number of Public Data Network subscribers.
- *Modems* (units, continuous): Estimated number of modems in use.
- *PCs* (units, continuous): Number of personal computers.

On a more general level, country characteristics such as population and standard economic indicators both affect the country's need for telecommunication and its capacity to afford the heavy infrastructure implied.

- *Population* (# inhabitants, continuous): This variable will mainly be used for country comparison purposes. Population may be redundant as a measure of potential market in rich countries, but this is not the case in poorer countries, where it represents potential future demand.
- *GDP* (US$, at 1980 prices, continuous): The Gross Domestic Product is an obvious measure of the wealth of each country. In conjunction with population, this variable allows to evaluate whether a country can afford a more sophisticated telecommunication system.
- *Import* (US$, at 1980 prices, continuous)
- *Exports* (US$, at 1980 prices, continuous): These last two variables are included purely for the telecommunication usage that they generate in organising international trade.

The main purpose of financial data is to assess the effect of a strong financial market requiring a substantial number of international communications on the decision to launch a domestic satellite. Inclusion of these variables was triggered by the sudden proliferation of South East Asian domestic satellites in the early to mid-1990s (Measat, Asiasat, Thaicom, and Koreasat further north).

- *Total foreign liabilities* (US$, at 1980 prices, continuous): Sum of the total liabilities to foreign banks and non-banks.
- *Total foreign assets* (US$, at 1980 prices, continuous): Sum of the total foreign assets held from foreign banks and non-banks. As a counterpart to the balance of trade, these two variables consider the effect of international monetary markets on the need for telecommunications.

5.2.1.3 Factors affecting demand shifts

One of the main factor affecting demand shifts is the technology involved in the transmission of communication signals. One such variable is the following:

- *Bandwidth efficiency*: (units/GHz, continuous) This variable measures the inverse of the number of equivalent voice channels per unit of bandwidth. The calculation of this variable is provided in appendix G.

Unfortunately, no other variable relating to the ground infrastructure technology was available for enough countries and years in the databases used at the time of the study.

5.2.1.4 Factors affecting the proportion of communication capacity supplied by satellite

Whether a country chooses to implement a network of fibre optic cables or scatter satellite receiving ground stations all depends upon the geography of the country. The next variable with thus represent the physical necessity for one type of system or another.

- *Terrain* (categorical): Dummy variable taking the value 0, if a country consists of relatively accessible flat terrain, 1, if a great part of the landscape is mountainous terrain, and 2 if the country is composed of a great number of islands. For example, for the Philippines, the dummy variable would take the value 2, and for Nepal, 1. These values have been attributed in terms of the increasing difficulty to implement ground transmission equipment such as fibre optics and coaxial cable and it is an increasing advantage to implement satellite technology. We therefore expect this variable to have a positive impact on the desired stock of satellites: the less accessible the terrain, the higher value of the dummy and the more likely it is to make use of a satellite. (This dummy enters additively in the logs in equations 5.6 and 5.7).

Country density was judged misleading in some cases like Australia and Canada where the population is relatively dense in urban areas but almost non-existent elsewhere.

5.2.2 Evolution of stock and orders

In the first chapter, the rate of change of owner net stock of satellites was calculated for the periods 1975-85 and 1985-95 (see tables 1.11 and 1.12). Orders and stocks of commercial communication satellite capacity will be studied in more details, in this chapter. Before estimating the model defined in section 5.1, the left-hand side variable, i.e. the stock of satellite capacity, will be examined. With the introduction of a time varying aspect of the stock adjustment in the model, the evolution of world and other countries' orders will also be studied before the regression. First recall the categorisation of countries into 10 groups from the first chapter (see table 1.2).

The next two graphs show the world partition of satellite bandwidth capacity stock, in 1980 (see figure 5.2) and 1990 (see figure 5.3). Prior to the 1980s, only Canada and the US possessed domestic satellites, the rest of the capacity being spread over the world via Intelsat spacecraft. In 1980, therefore, these two pioneers appear to possess almost three quarters of the world satellite bandwidth capacity. Note that the North American bandwidth figures also include a negligible proportion of Intelsat capacity. A decade later, however, with domestic satellites more widespread

throughout the globe, North America possesses a smaller share of the world's satellite capacity, but even in 1990, Canada and the US still own about half of the world communication satellite capacity.

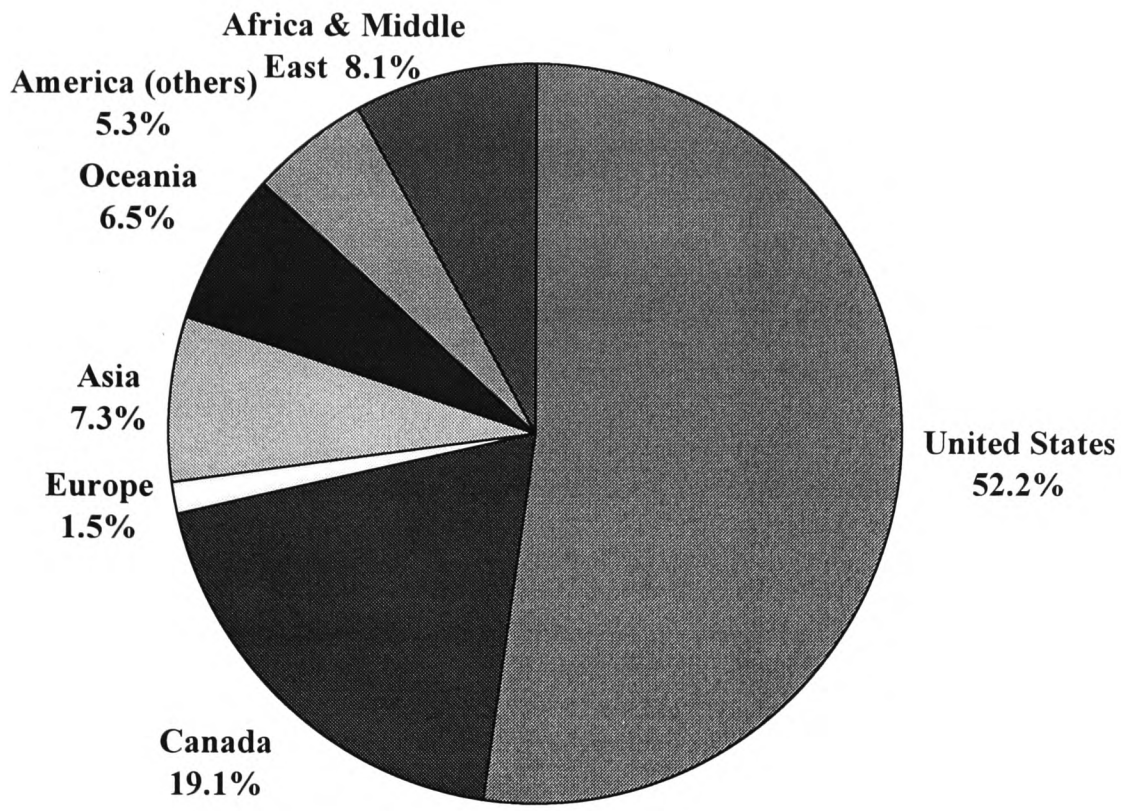


Figure 5.2: Own country stock; 1980.

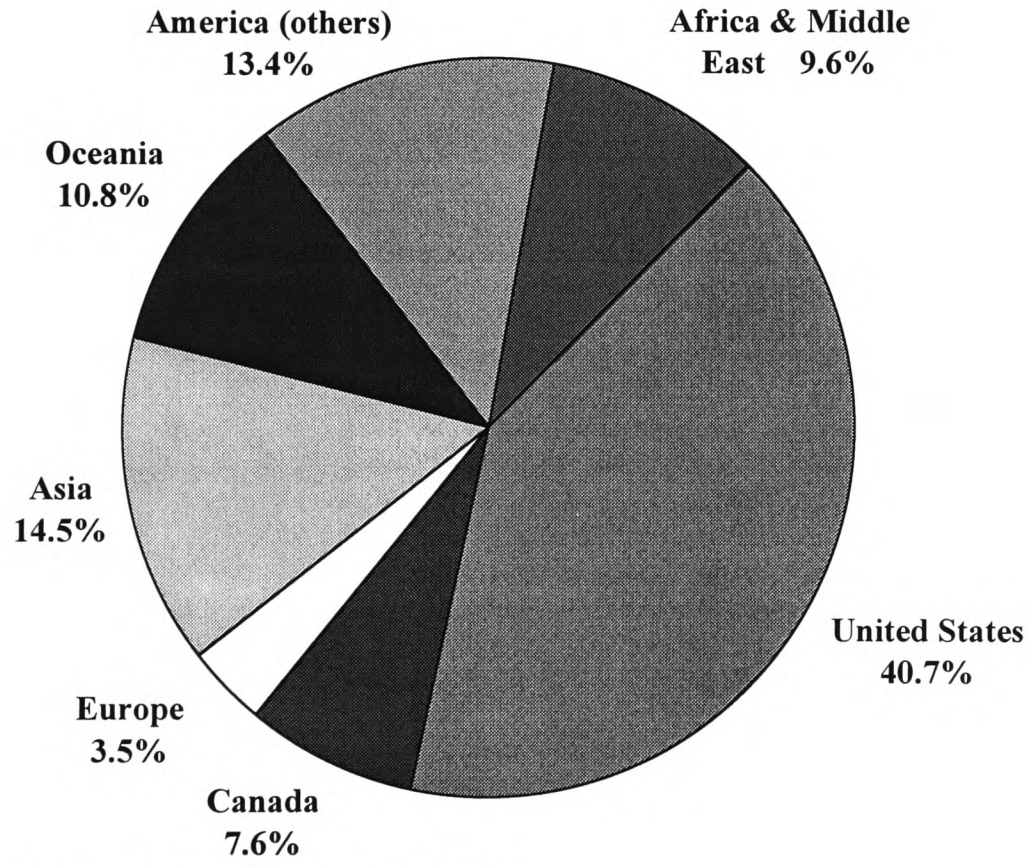


Figure 5.3: Own country stock; 1990.

The two previous pie charts summarise the capacity share for vast regions. It is also useful to examine the capacity share from a different angle, from the footprint point of view. The subsequent two maps (see figures 5.4 and 5.5) show the partition of satellite bandwidth throughout the world, and more particularly, for the countries included in our database. In these maps, countries in white are not included in this study mainly because of incomplete data.

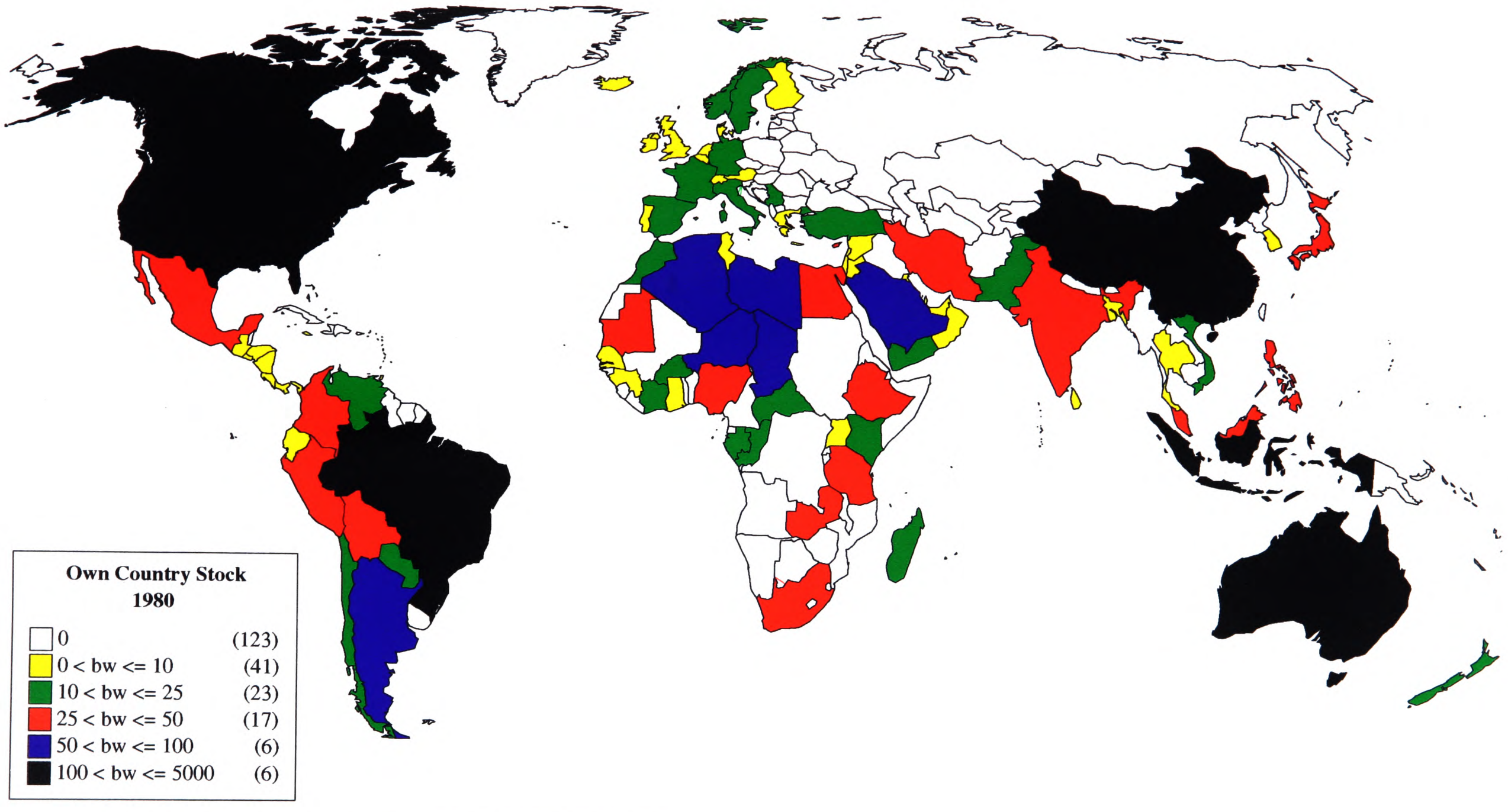


Figure 5.4: Own country stock (bandwidth in MHz); 1980.

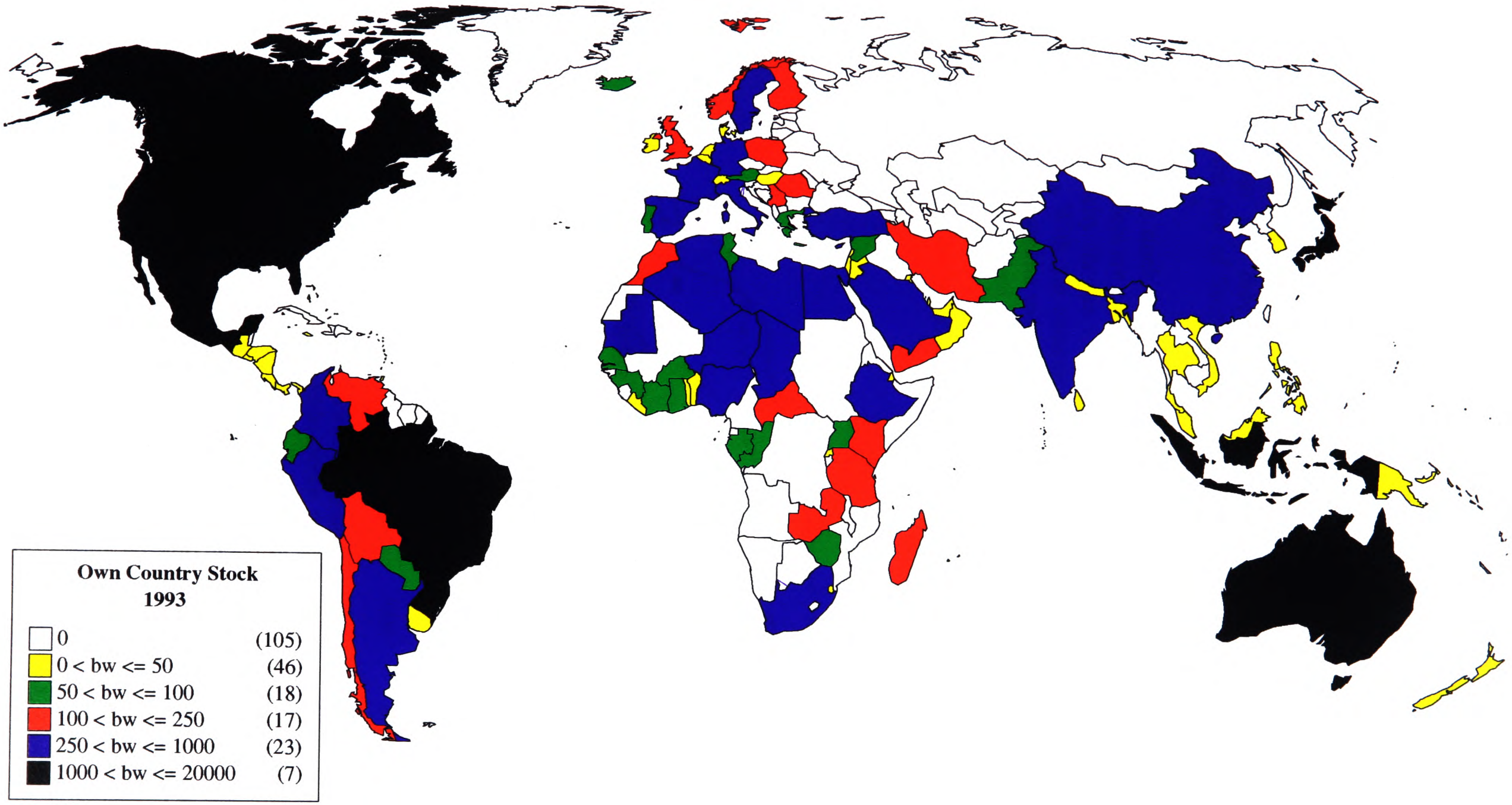


Figure 5.5: **Own country stock (bandwidth in MHz); 1993.**

An obvious observation from these maps is the importance of the country size in terms of its attributed bandwidth capacity. As discussed in the previous section, size is not a problem for the attribution of domestic satellites, but is important for regional and international organisations' satellites. Despite this strong correlation between country size and its attributed share of Intelsat capacity, comparing the two maps separated by slightly more than a decade shows an increase in the capacity of France, Italy, Spain and Germany in Europe as well as India and Mexico. Because the database available for this study stopped recording orders in 1992, mapping the stock of capacity after this date will provide increasingly inaccurate results. As consequence, the rise of South East Asia in the domestic satellite market does not appear in figure 5.5.

Prior to the stock adjustment models of section 5.4, graphs of the evolution of the stock and orders are plotted next. Figure 5.6 presents the temporal evolution of the stock of capacity for the 11 countries constituting the first group of domestic satellite owners. With the exception of a small period in the early 1970s, where Canada possesses a greater stock, the US appears at the top of the league throughout. Japan follows the European countries in this group up to 1990 and then increases its stock to the same level as Canada[15]. Note that Luxembourg appears in this group as the smallest owner of capacity, and this is due entirely to the very small size of the country.

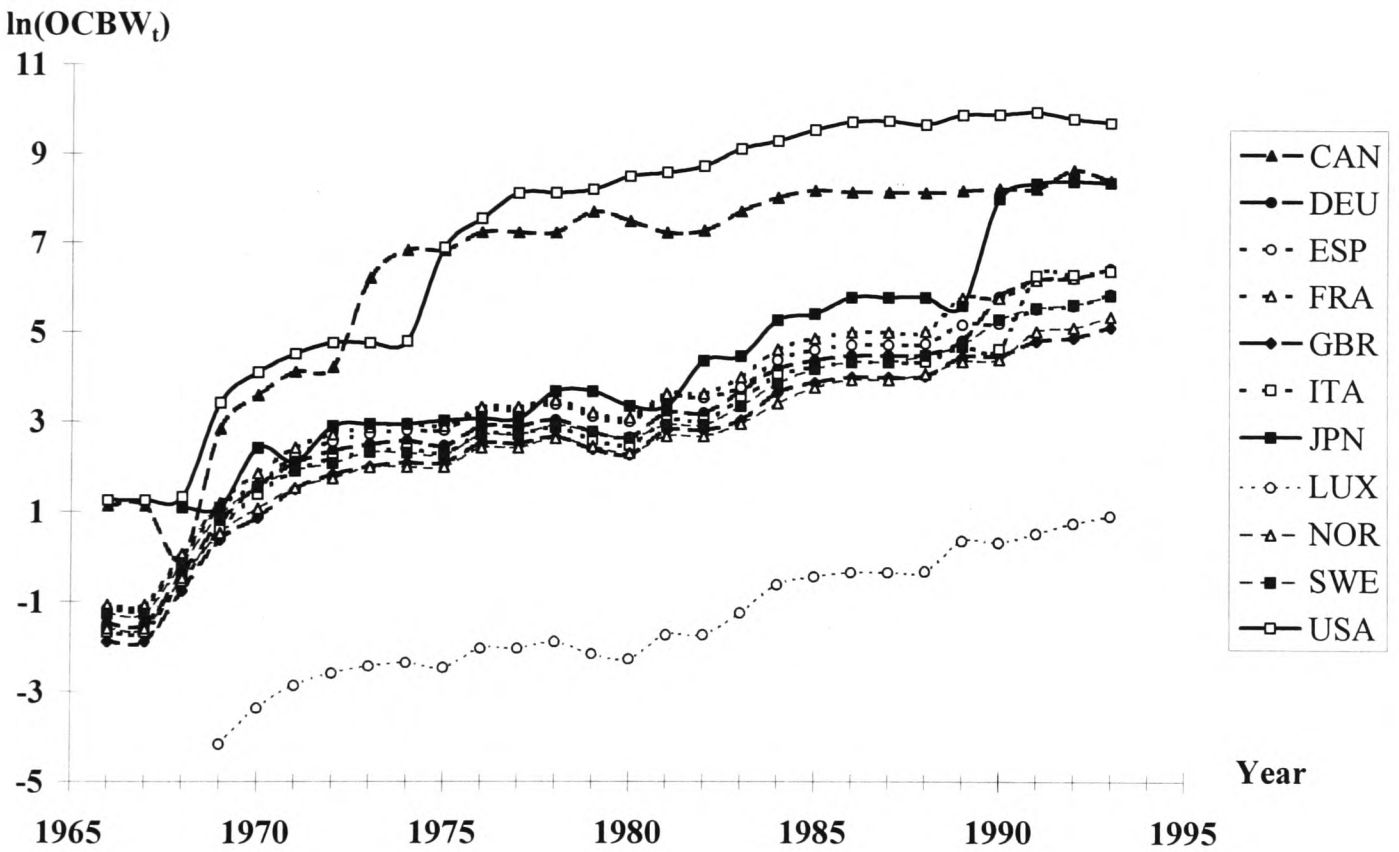


Figure 5.6: Evolution of the bandwidth capacity stock (in logs); Western World domestic satellite owners (Group 1).

Bandwidth capacity in itself allows country comparisons, but for the stock adjustment mechanism, the change in stock is what matters here. Figure 5.7 shows the change in satellite capacity over the sample years. When the value is negative, for instance, this implies that satellites have 'died' and have not been replaced in time. Because Canada and the US have the most important fleet of satellites, their change in stock is more considerable than that of other countries with more modest fleets.

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[15] Note that not all Japanese satellites are included in this study because of the lack of information concerning their characteristics. Consequently, prior to 1990, Japan may be closer to Canada than appears on the graph.

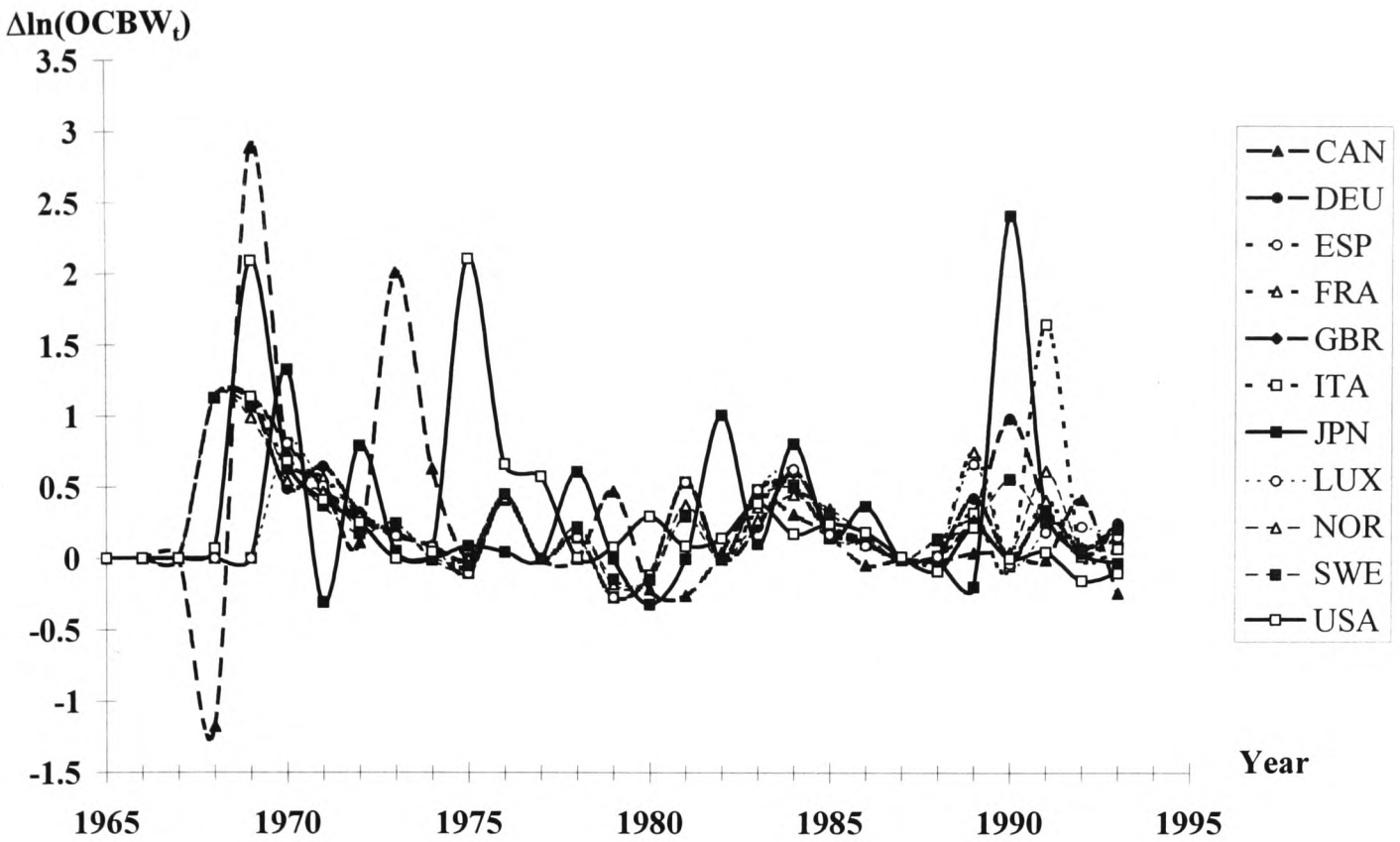


Figure 5.7: Evolution of the change in bandwidth capacity stock (in logs); Western world domestic satellite owners (Group 1).

An important measure which will not enter as such in the regression analyses, is the own orders of a country (see figure 5.8). As mentioned before, it will enter indirectly in the time varying stock adjustment model as *other countries' orders* (*total world orders* minus *own country's orders*). Before showing the time varying measure of the model, note that on three occasions, 1972, 1977 and 1984, yearly world orders consist solely of US satellite orders. This will decrease the number of observations for the time varying stock adjustment model in consequence for the US (division by zero problems). It is also worth noting that Canada and the US contribute the majority of world orders, certainly around 50 % as seen in the previous pie charts.

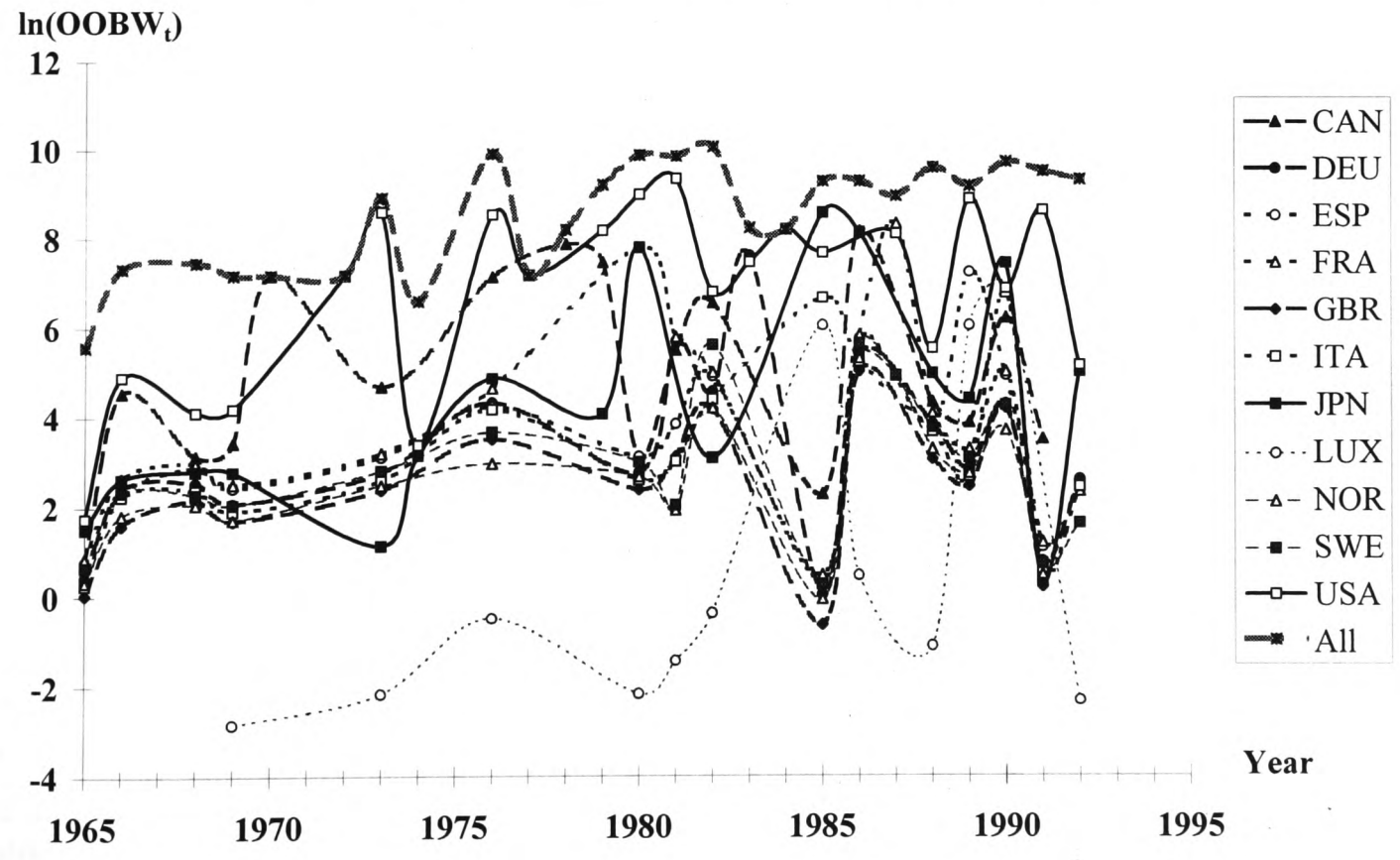


Figure 5.8: Evolution of the bandwidth capacity orders (in logs); Western World domestic satellite owners (Group 1).

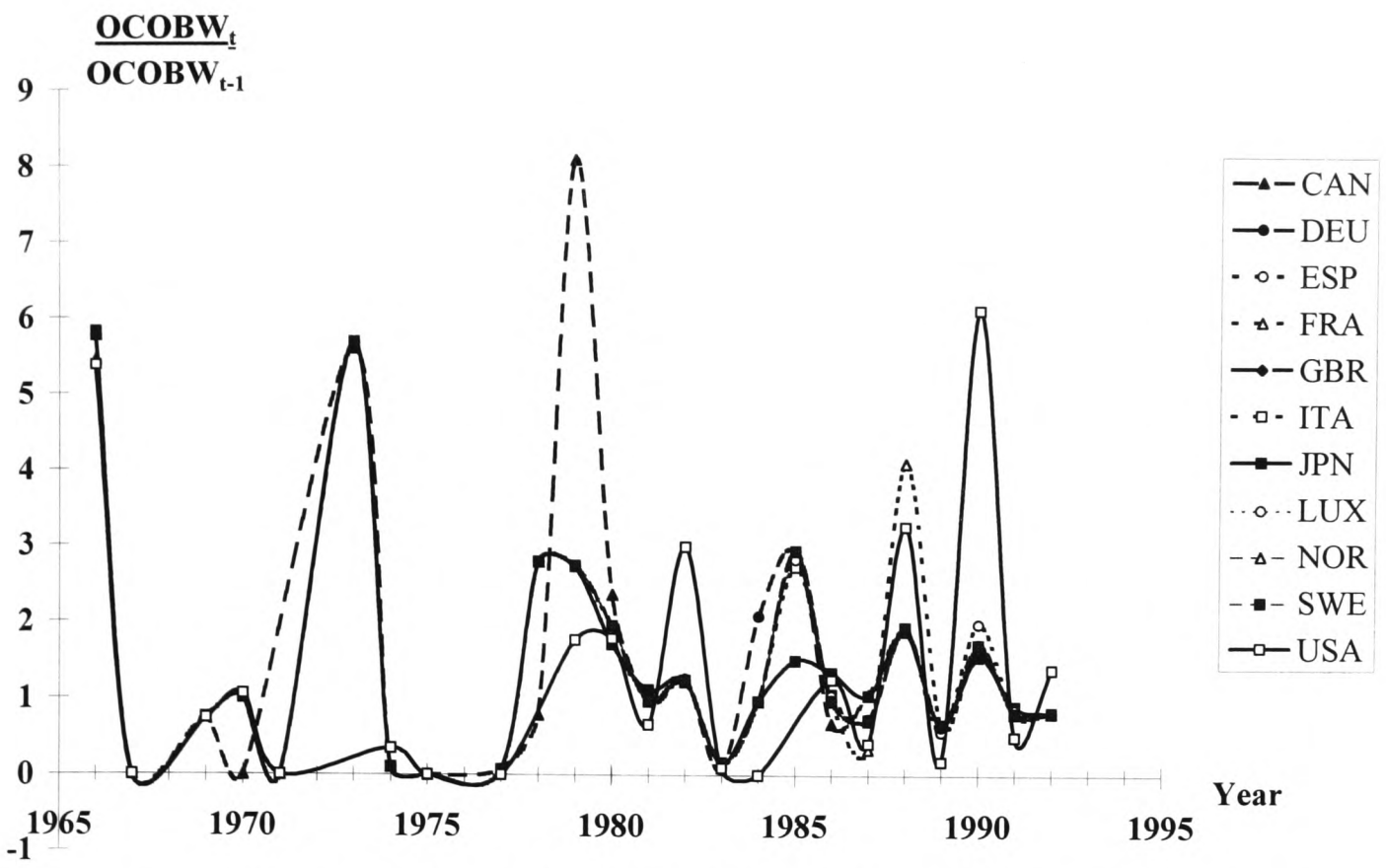


Figure 5.9: Evolution of the change in bandwidth capacity orders of other countries; Western World domestic satellite owners (Group 1).

Figure 5.9 presents the evolution of the change in other countries' orders over the years, i.e. the time varying parameter of the stock adjustment model. These Charts will be useful in the evaluation of the stock adjustment results of section 5.4 and should be kept in mind.

5.3 Instruments for demand shifters

The analysis of the role of factors affecting the demand-side of the satellites market proceeds in three stages: First, we reduce the data on shift variables by extracting the principal components. These are instruments used to identify the long-run demand function. Then, the predicted traffic demand will be calculated by regressing the international outgoing telephone traffic on these principal components. Finally, the stock demand for telecommunication satellites will be evaluated, yielding the desired stock as the predicted values of this stock demand.

The initial method of analysis will use a pseudo two-stage-least-squares technique where the predicted value of the traffic demand (demand-shift factor), calculated from a linear regression on the principal components, is introduced in the stock demand equation. Ordinary least squares are then applied to the stock demand equation.

5.3.1 Principal component analysis

Data reduction is required in the form of extracted principal components for the numerous demand variables described above. Principal components for the right-hand side variables of the demand equation were calculated using the variables listed below (table 5.1). In the left column are listed the variables for which data was available for the entire sample period, 1965-93, while in the right column are included the variables representing new technology or variables for which data started to be collected only recently. For example, cable television was introduced far before it appears in this database, but was relatively scarce in most countries before 1985.

Table 5.1: Variables included in the principal component analysis.

'Old' variables	Recent variables
Main lines	Fax machines
Waiting lists	Videotex subscribers
TV receivers	Mobile phone subscribers
Population	ISDN subscribers
GDP	PDN subscribers
Foreign liabilities	Modems
Foreign assets	PCs
Exports	Cable TV subscribers
Imports	Satellite TV receivers
Terrain	

Principal components were calculated for 7 groups of countries for the three satellite generations. The sub-groups of countries are slightly modified from that of the first chapter, the former 10 groups (groups A), have been reduced to 7, groups B, by aggregating some regions. Table 5.2 lists the new categories in relation with the previous groups used in the first chapter.

Table 5.2: Aggregation of countries for the principal component analysis.

Groups B	Name of country group	Groups A
1	Western world owners of domestic satellites	1
2	Other owners of domestic satellites	2
3	Africa	3
4	Middle East	4
5	Asia and Oceania	5 and 6
6	Europe	7 and 8
7	Central and South America	9 and 10

Because some new technology services did not exist at the beginning of the sample, principal components were calculated in three parts to avoid having to incorporate 'pre-innovation' zeros that would affect the results. Further, principal components were calculated in log format to facilitate the analysis of the subsequent traffic demand regression. As described in section 5.1.1, principal components are calculated using two methods. First, the sample was separated into three sub-periods, and principal components were calculated separately for each 7 sub-groups of countries and each of the three generations. Second, the principal component extraction was separated into two analyses. In a first instance, principal components were extracted for the entire sample, 1965-93, only including the variables that are present throughout this period, i.e., ignoring any new technology demand variable listed in the right column of table 5.1, leaving the variables in the left column. In a second part, principal components were extracted from the recent variables only, for the last generation of satellites corresponding to 1985-93. In other words, the first calculation incorporates all variables in the last sub-period, while the second separates on-going technology from recent technology in two distinct analyses. Table 5.3 summarises the variables used in each sub-period for each analysis.

Table 5.3: Summary of the principal component method; method 1 corresponds to equation (5.6), while method 2 uses equation (5.7).

		1964-75	1976-84	1985-93
Method 1		all	all	all
Method 2	Part 1	old		
	Part 2			recent

Listing the principal components obtained for each country under study would take considerable space and is of little interest. Tables 5.4 to 5.12 present the weights, attributed to each variable for the first four principal components of these demand variables for the three periods chosen. A time series of these principal components was then built to serve as regressors in the traffic demand equation.

Table 5.4: Eigenvectors of the first four principal components per satellite generation; Western World domestic satellite owners (Group 1).

Group 1 Variables	65-75	75-84	85-93	65-75	75-84	85-93	65-75	75-84	85-93	65-75	75-84	85-93
		Prin1			Prin2			Prin3			Prin4	
Main lines	0.467	0.426	0.345	-0.063	-0.133	0.147	-0.130	-0.093	-0.117	-0.085	-0.035	-0.203
Wait. lists	0.153	0.042	-0.199	-0.162	-0.264	0.419	0.675	-0.244	-0.113	0.202	0.329	-0.088
Fax		0.133	0.310		0.504	0.025		-0.267	-0.243		0.048	0.199
Videotex		0.109	-0.002		0.153	0.342		-0.032	-0.162		0.388	0.211
Cellphones		0.128	0.296		0.443	-0.134		-0.022	-0.168		-0.418	0.170
ISDN			0.283			-0.132			0.067			-0.014
PDN		0.030	-0.083		0.373	0.495		-0.426	-0.166		0.225	0.260
Modems		-0.051	0.009		0.038	0.316		0.170	-0.110		-0.087	-0.120
PCs		0.202	0.258		0.109	-0.074		0.256	-0.152		-0.384	-0.049
Population	0.462	0.412	0.331	-0.143	-0.199	0.191	0.005	-0.150	-0.123	-0.077	-0.004	-0.220
GDP	0.474	0.423	0.227	-0.046	-0.170	0.173	-0.076	-0.088	-0.002	-0.061	-0.023	-0.271
Exports	0.141	0.134	0.118	0.138	-0.201	0.217	-0.146	0.243	0.336	0.006	0.057	0.435
Imports	0.097	0.173	0.149	0.005	0.131	0.254	-0.428	0.232	0.343	0.867	0.211	0.240
Frgn assets	0.100	0.183	0.176	0.588	0.189	0.045	0.245	0.363	0.481	0.149	0.320	-0.135
Frgn liab.	0.081	0.130	0.167	0.603	0.222	0.070	0.155	0.489	0.517	0.121	0.294	-0.094
TV sets	0.471	0.424	0.340	-0.096	-0.161	0.177	-0.052	-0.111	-0.118	-0.050	-0.021	-0.210
Cable TV	0.226	0.301	0.280	0.321	0.144	-0.275	0.100	0.082	-0.136	-0.115	-0.185	0.213
Sat TV		0.061	0.219		0.133	-0.012		-0.127	0.072		0.264	0.186
Terrain	0.038	0.067	0.078	-0.326	0.104	-0.082	0.470	-0.182	-0.105	0.370	-0.127	0.484

Table 5.5: Eigenvectors of the first four principal components per satellite generation; Other domestic satellite owners (Group 2).

Group 2 Variables	65-75	75-84	85-93	65-75	75-84	85-93	65-75	75-84	85-93	65-75	75-84	85-93
		Prin1			Prin2			Prin3			Prin4	
Main lines	0.362	0.434	0.264	0.199	0.276	0.288	0.032	-0.055	0.311	-0.355	-0.052	0.210
Wait. lists	0.434	0.365	-0.313	-0.264	-0.160	0.267	0.311	0.427	-0.049	0.154	-0.128	0.180
Fax		-0.098	0.274		0.308	0.080		0.256	-0.070		0.429	-0.159
Videotex			0.265			0.138			0.074			-0.198
Cellphones		-0.010	0.320		0.179	-0.126		0.271	-0.169		0.569	-0.109
ISDN			0.353			-0.063			0.159			-0.257
PDN		0.052	0.305		0.387	-0.140		0.102	-0.015		0.297	0.227
Modems		0.101	0.140		0.204	0.322		-0.217	-0.306		-0.190	0.150
PCs			0.282			0.068			0.232			-0.195
Population	0.260	0.295	-0.227	0.245	-0.320	0.430	0.433	0.147	0.201	0.013	0.083	0.013
GDP	0.400	0.387	-0.090	0.185	0.000	-0.230	-0.187	-0.364	0.518	-0.521	0.154	-0.041
Exports	0.295	0.234	0.128	-0.393	0.286	0.171	0.066	0.179	0.192	0.413	-0.310	0.127
Imports	0.385	0.142	0.158	-0.066	0.128	0.065	0.328	0.522	0.045	0.069	-0.309	0.157
Frgn assets	0.278	-0.308	0.089	0.352	0.285	-0.161	-0.381	-0.074	-0.041	0.332	-0.227	0.440
Frgn liab.	0.315	-0.233	0.109	0.109	0.359	-0.167	-0.546	0.162	-0.004	0.346	-0.264	0.505
TV sets	0.204	0.422	-0.037	-0.416	0.144	0.452	-0.258	-0.111	0.293	-0.408	0.061	0.130
Cable TV			0.325			0.257			-0.067			-0.061
Sat TV			0.135			0.211			-0.433			0.146
Terrain	-0.002	-0.130	-0.151	0.573	-0.385	0.182	0.242	0.341	-0.250	0.083	0.029	-0.369

For country comparison purposes, the first two obtained principal components were plotted for the first two groups of domestic satellite owners (see figures 5.10 to 5.13). As was to be expected, Canada and the US dominate the first

principal component which consists of basic indicators as seen above. For the second group of domestic satellite owners, the first principal component is less clearly divided, but South East Asia is the fastest growing region in the 1990s. For this group, the second principal component which offers the greatest stability over time.

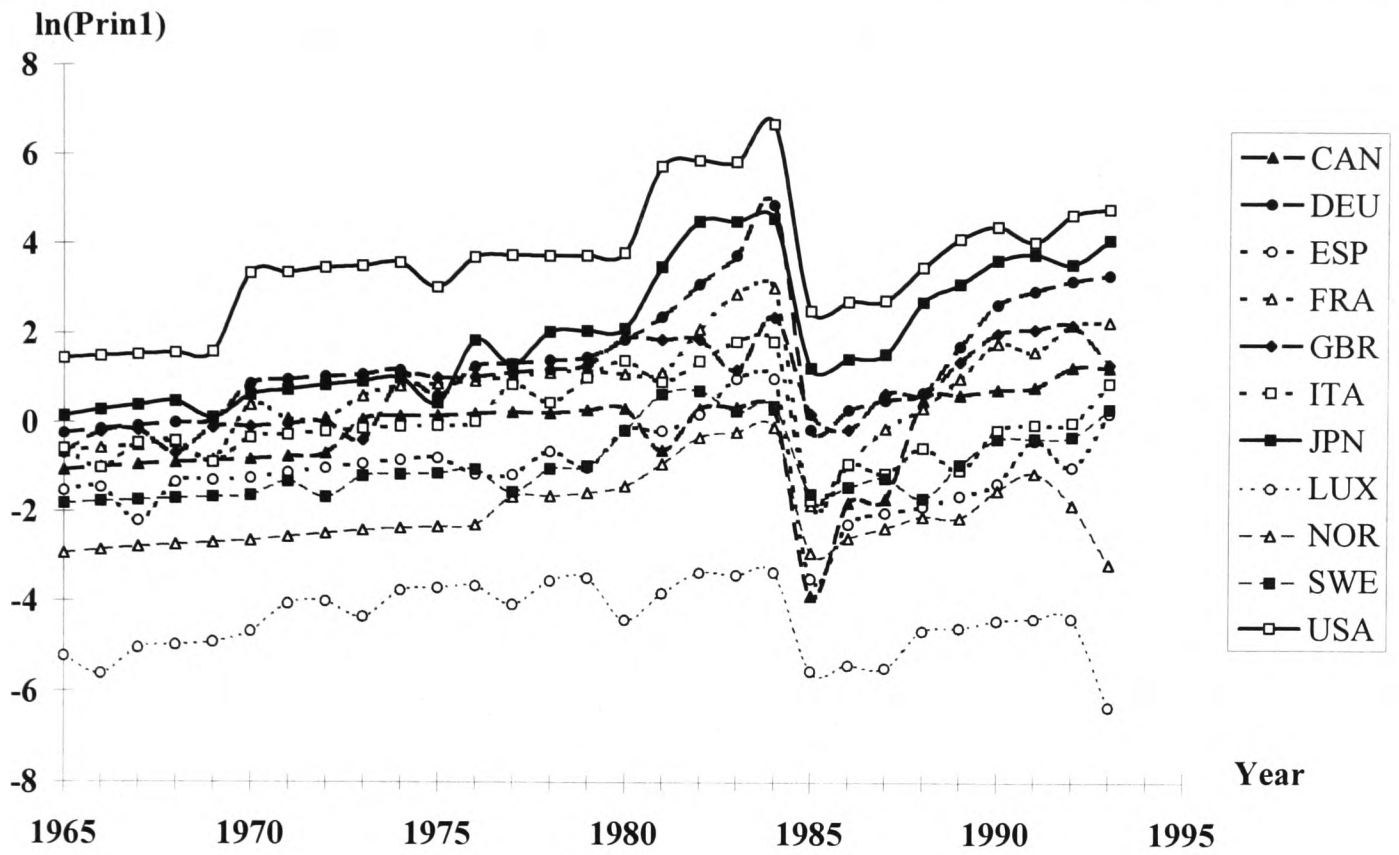


Figure 5.10: First principal component; Group 1.

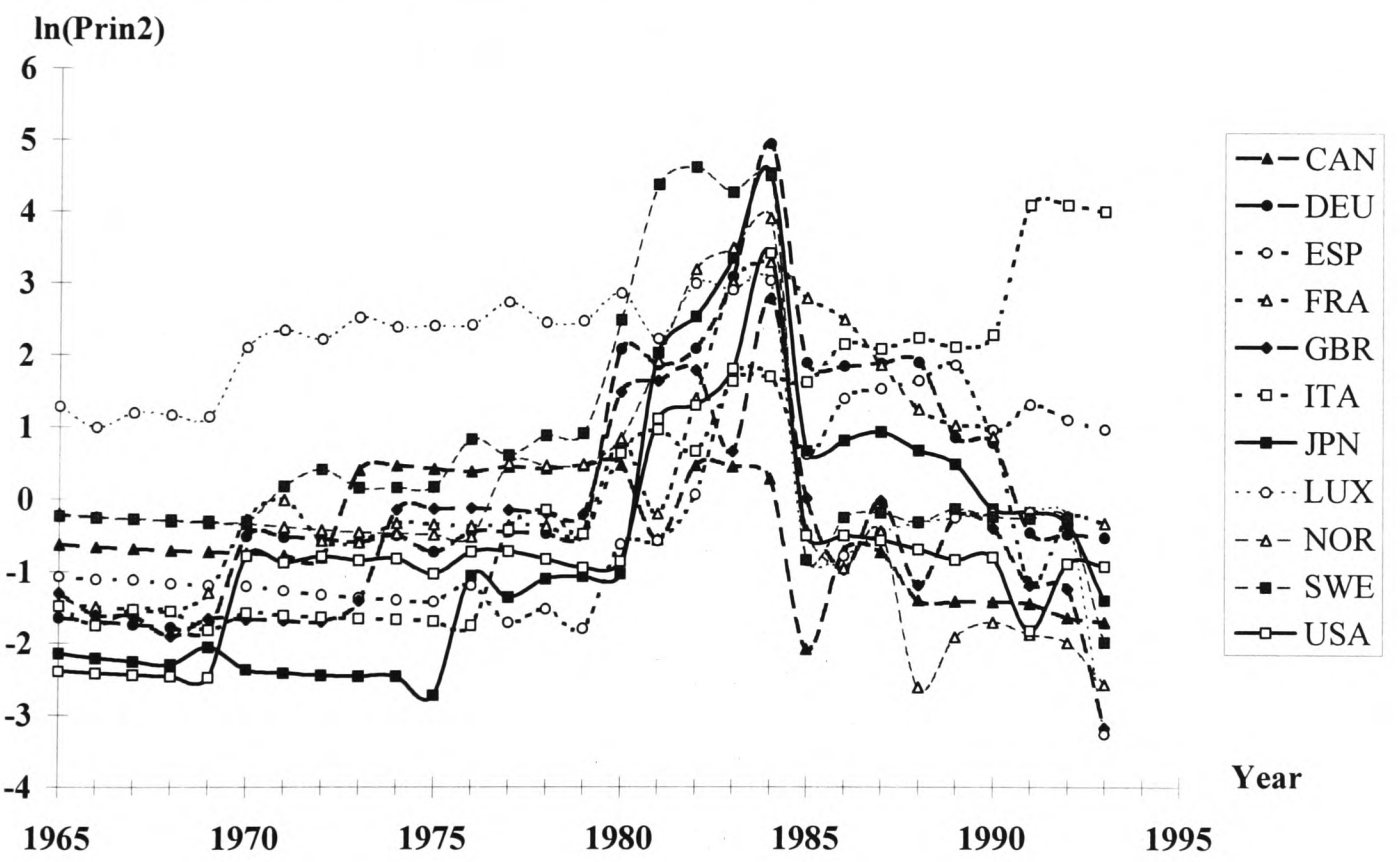


Figure 5.11: Second principal component; Group 1.

Population, GDP, number of television receivers and main lines are the first four major constituents of the first principal component, for group 1, 7-8 and 9-10, i.e. the western world regardless of ownership of domestic satellites, as well as the rest of the American continent with the exception of Mexico which belongs to the second group. In Africa, the Middle East and Central America, the length of the waiting list for telephone main lines, occupies a middle rank in the variable weights, but is in the

top four variables for group 2. Waiting lists have no particular importance in the western world owners of domestic satellites, Europe, Oceania and Asia.

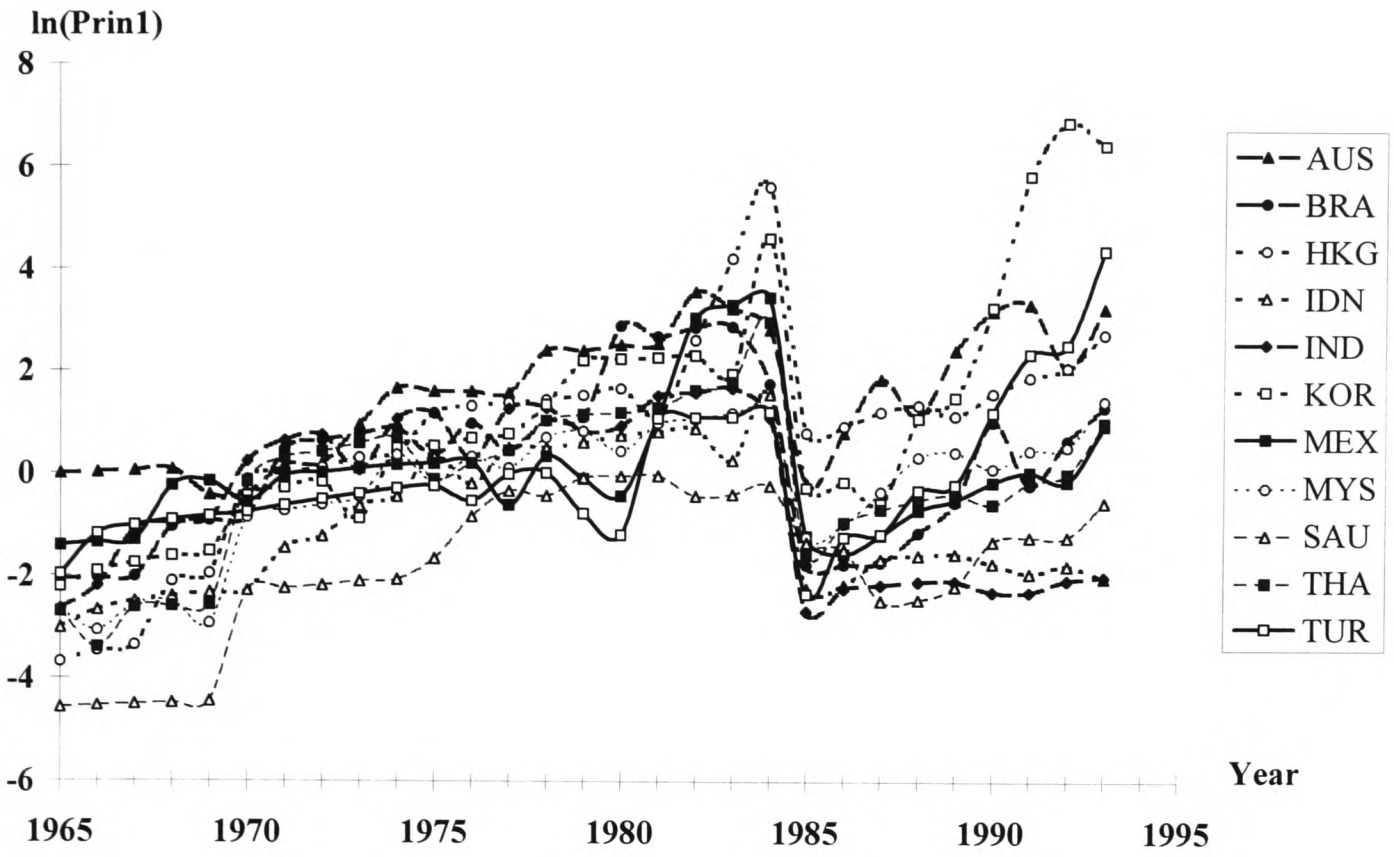


Figure 5.12: First principal component; Group 2.

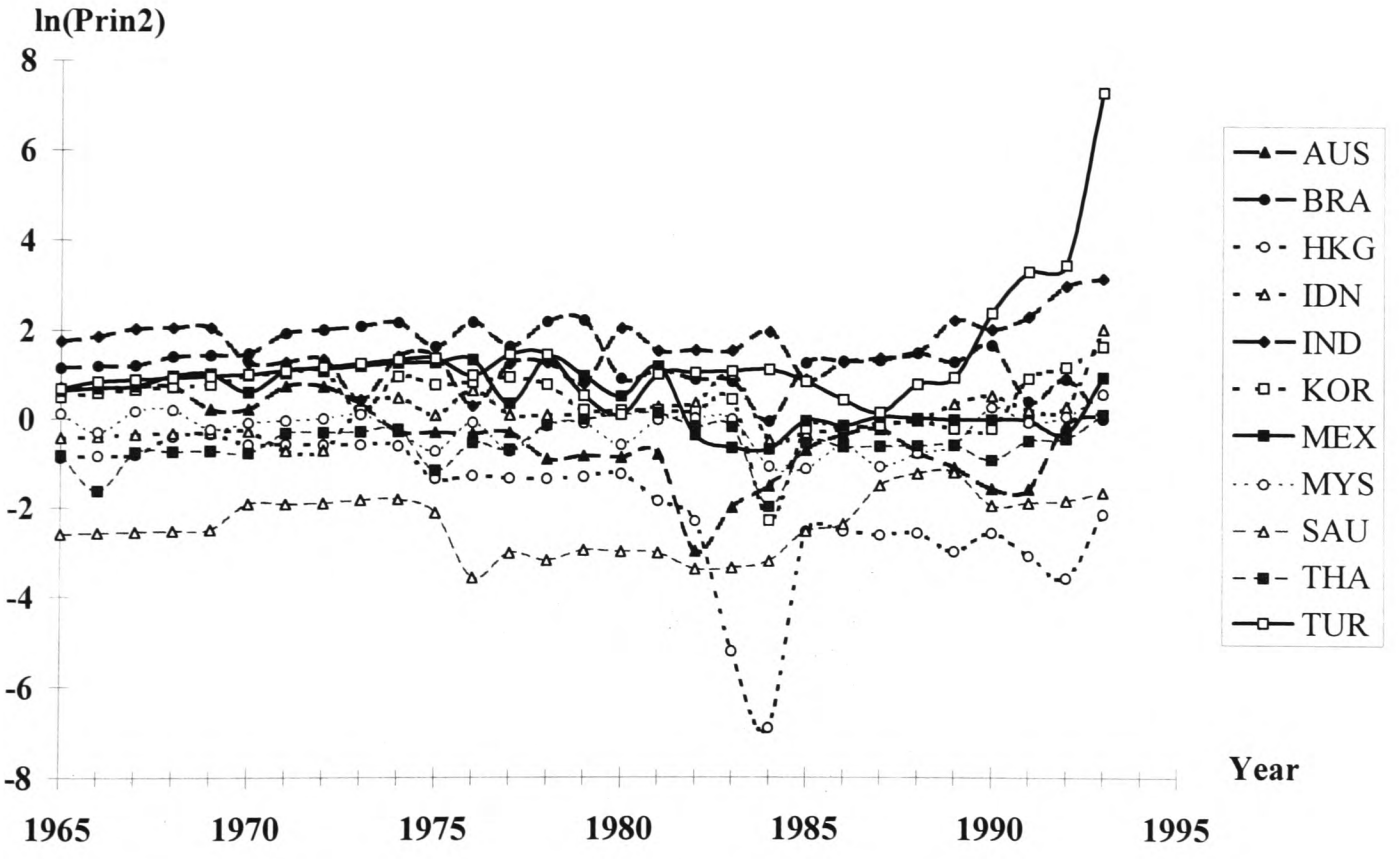


Figure 5.13: Second principal component; Group 2.

In Asia, the financial markets of Singapore push the foreign assets and liabilities variables in position two and three of the top mean weights from 1976 onwards. This supports the hypothesis of an important financial market that potentially drives the need for telecommunications in South East Asia. In table 5.5, we observe that these two variables have a high negative weight on the first principal component for group 2, which includes countries such as Hong Kong and Malaysia, which both have strong financial markets. This does not prove the hypothesis that a strong financial market pushes the need for communication satellites because of the

necessity to communicate internationally, but this is as close as we can get to supporting this hypothesis.

Table 5.6: Eigenvectors of the first four principal components per satellite generation; Africa (Group 3).

Group 3 Variables	65-75	75-84	85-93	65-75	75-84	85-93	65-75	75-84	85-93	65-75	75-84	85-93
		Prin1			Prin2			Prin3			Prin4	
Main lines	0.291	0.386	0.428	-0.323	-0.078	0.110	0.416	-0.185	-0.104	0.045	0.140	-0.122
Wait. lists	0.304	0.285	0.325	0.291	-0.010	0.065	0.272	-0.139	-0.026	0.376	0.507	-0.273
Fax			0.016			0.270			-0.045			-0.081
Videotex			0.122			0.354			-0.205			0.244
Cellphones		0.041	0.211		0.623	0.341		-0.315	-0.075		-0.028	-0.274
ISDN												
PDN		0.055	0.161		0.642	0.369		-0.279	0.259		-0.035	0.292
Modems			-0.013			0.335			0.258			0.389
PCs		0.010	0.023		0.166	0.212		0.484	0.506		0.418	-0.127
Population	0.358	0.334	0.334	-0.466	-0.208	-0.029	0.110	-0.220	-0.197	0.076	0.000	-0.064
GDP	0.309	0.409	0.374	-0.076	-0.117	-0.111	-0.026	-0.108	-0.050	-0.136	0.045	-0.051
Exports	0.263	0.256	0.170	0.096	0.197	-0.294	-0.588	0.465	0.455	0.217	-0.234	-0.129
Imports	0.289	0.222	0.208	0.080	0.223	-0.249	-0.469	0.450	0.464	0.384	-0.137	-0.092
Frgn assets	0.366	0.317	0.198	0.385	-0.003	-0.296	0.094	0.041	0.035	-0.367	0.032	0.414
Frgn liab.	0.330	0.302	0.238	0.425	0.076	-0.053	0.026	0.202	0.017	-0.454	-0.095	0.524
TV sets	0.420	0.378	0.405	-0.131	-0.032	0.048	0.173	-0.053	-0.057	0.208	0.053	-0.035
Cable TV			-0.039			0.043			-0.106			-0.036
Sat TV			-0.002			0.283			0.192			-0.169
Terrain	-0.166	-0.191	-0.201	0.475	0.115	0.200	0.367	0.106	0.181	0.505	0.677	-0.089

Table 5.7: Eigenvectors of the first four principal components per satellite generation; Middle East (Group 4).

Group 4 Variables	65-75	75-84	85-93	65-75	75-84	85-93	65-75	75-84	85-93	65-75	75-84	85-93
		Prin1			Prin2			Prin3			Prin4	
Main lines	0.364	0.465	0.432	0.167	0.064	-0.043	-0.279	0.196	-0.055	0.286	-0.125	0.034
Wait. lists	0.347	0.351	0.284	-0.167	-0.139	-0.231	-0.300	0.387	-0.088	0.612	-0.077	0.301
Fax			0.153			0.238			0.458			0.261
Videotex			0.152			0.148			0.102			0.293
Cellphones		0.097	0.088		0.267	0.438		0.255	0.047		0.540	0.324
ISDN			0.037			0.142			0.046			0.026
PDN		0.109	0.155		0.222	0.333		0.196	0.259		0.537	0.098
Modems			-0.010			0.255			0.353			-0.108
PCs												
Population	0.421	0.427	0.381	-0.060	-0.185	-0.263	0.304	-0.309	-0.001	-0.357	0.077	-0.031
GDP	0.017	0.356	0.401	0.334	0.025	-0.087	-0.405	0.404	-0.036	-0.167	-0.213	0.100
Exports	0.007	0.003	0.042	0.404	0.411	0.259	-0.423	0.327	-0.527	-0.024	-0.248	0.256
Imports	0.473	0.125	0.175	0.141	0.050	0.228	0.004	-0.049	-0.469	-0.297	-0.491	-0.023
Frgn assets	-0.087	0.127	0.240	0.481	0.510	0.283	0.410	-0.329	-0.048	0.260	-0.066	-0.519
Frgn liab.	-0.071	0.134	0.243	0.495	0.517	0.305	0.368	-0.285	-0.056	0.323	-0.062	-0.487
TV sets	0.458	0.432	0.385	0.283	0.009	-0.158	0.101	-0.363	0.017	-0.185	0.109	0.042
Cable TV												
Sat TV			0.015			0.033			-0.024			0.095
Terrain	0.351	0.305	0.223	-0.300	-0.351	-0.292	0.290	-0.139	0.262	0.306	0.158	-0.182

In most cases, the first and second sub-periods are relatively alike. Again, in the western world and the rest of the American continent, with the exception of Mexico, the same top four variables appear with very similar weights. As the change between the first two sub-periods is relatively small, between the last two sub-periods, however, the main constituents of the principal components vary more substantially. With the introduction of new technology mainly in the last period, more weight is directed towards these new technologies to the detriment of the 'old' variables. This

is certainly more apparent or noticeable in the second group of domestic satellite owners when mobile phone, ISDN, PDN and cable television take over as the main variables in the first principal component. In the first group of domestic satellite owners, the introduction of new technology appeared in the transitory period and the change in weights of the old variables is more gradual. On the one hand, the number of facsimile machines, cellular phones and satellite television receivers have more than doubled their influence in the first principal component, and the number of personal computers has increased slightly from the second to the third generation periods. On the other hand, the importance of the number of main lines, television receivers, population and GDP have been decreasing since the first period, but more sharply in the last period.

Table 5.8: Eigenvectors of the first four principal components per satellite generation; Asia and Oceania (Groups 5 and 6).

Group 5-6 Variables	65-75	75-84	85-93	65-75	75-84	85-93	65-75	75-84	85-93	65-75	75-84	85-93
		Prin1			Prin2			Prin3			Prin4	
Main lines	0.355	0.363	0.376	0.356	0.025	-0.047	0.235	0.061	-0.022	-0.245	0.096	-0.012
Wait. lists	0.215	0.280	0.203	0.285	-0.018	-0.263	0.080	-0.261	0.225	-0.696	-0.386	0.045
Fax			0.180			0.284			0.177			0.087
Videotex			0.093			0.424			-0.220			-0.014
Cellphones			0.277			0.166			0.076			0.188
ISDN			0.101			0.410			-0.245			0.053
PDN		0.166	0.156		0.138	0.318		0.666	0.256		0.003	-0.206
Modems			0.106			0.359			0.135			0.280
PCs			0.102			0.147			-0.299			0.339
Population	0.344	0.320	0.282	-0.571	-0.399	-0.276	-0.011	-0.089	-0.229	-0.034	0.062	0.024
GDP	0.243	0.254	0.358	-0.424	-0.394	-0.119	-0.285	0.130	-0.142	-0.041	0.174	0.037
Exports	0.337	0.291	0.262	-0.006	0.406	-0.114	0.469	-0.257	0.379	0.254	-0.210	-0.158
Imports	0.342	0.296	0.234	-0.039	0.426	-0.109	0.357	-0.228	0.331	0.358	-0.181	0.007
Frgn assets	0.336	0.367	0.223	0.284	0.102	0.166	-0.494	0.227	-0.030	0.218	0.172	-0.535
Frgn liab.	0.340	0.386	0.303	0.306	0.036	0.040	-0.456	0.221	-0.146	0.234	0.068	-0.309
TV sets	0.348	0.312	0.319	0.041	-0.014	-0.117	0.169	-0.018	-0.116	0.008	0.029	0.076
Cable TV		0.115	0.177		0.040	-0.197		-0.453	-0.122		0.755	0.410
Sat TV			0.033			0.130			0.468			0.357
Terrain	-0.265	-0.172	-0.191	0.330	0.553	0.080	0.170	0.192	0.186	0.397	0.355	-0.085

Waiting lists have more or less disappeared in the western world, but this variable has increased its influence in Africa, as well as Central and South America. In general, the number of television sets as well as the GDP have an important weight in the first principal component. In all cases, however, the number of main lines in operation is in the main constituents of this first principal component. In the first sub-period, foreign assets and liabilities constitute a significant part of the second principal component. Except for the Middle East, however, this trend does not continue for the next two sub-periods; These two variables were more important for Asia and Oceania for the last two sub-periods. In the case of the second groups of domestic satellite owners, which includes South East Asian countries such as Malaysia, Thailand, Hong Kong and Korea (though further north), foreign assets and liabilities constitute an important part of the second principal component only for the first two periods, afterwards, communication related variables take over as the main constituents. Waiting lists strongly contribute to the second principal component in the last period, particularly in the western world. The advent of more sophisticated telecommunication services, such as call waiting, dedicated data lines for fax and modem transmissions as well as 'children' personal lines has contributed to increase the number of people waiting for the implementation of new telephone lines. In contrast, in African and Asian countries, waiting lists are more important in the early

periods of the sample. No general pattern can be found in the third and fourth principal components, but the results are stated because the first four of these principal components will be used in the traffic demand regressions of the next section.

Table 5.9: Eigenvectors of the first four principal components per satellite generation; Europe (Groups 7 and 8).

Group 7-8 Variables	65-75	75-84	85-93	65-75	75-84	85-93	65-75	75-84	85-93	65-75	75-84	85-93
		Prin1			Prin2			Prin3			Prin4	
Main lines	0.497	0.444	0.335	-0.008	-0.125	0.287	-0.053	0.015	0.083	0.174	0.028	0.215
Wait. lists	0.000	0.023	-0.064	0.245	-0.224	0.369	-0.032	0.191	0.168	0.817	-0.387	0.047
Fax		0.201	0.267		0.393	-0.205		-0.033	0.254		0.023	0.169
Videotex		0.130	0.316		0.231	-0.154		-0.317	-0.008		-0.083	-0.003
Cellphones		0.126	0.256		0.318	-0.338		-0.434	0.222		-0.178	-0.016
ISDN			0.191			-0.098			0.213			-0.202
PDN		0.075	0.203		0.417	-0.195		-0.170	-0.260		-0.016	0.188
Modems		0.177	0.162		0.358	-0.123		-0.015	-0.211		0.138	0.493
PCs			0.195			-0.137			0.401			0.175
Population	0.444	0.350	0.194	-0.299	-0.335	0.475	-0.132	-0.178	0.105	-0.117	0.111	0.162
GDP	0.396	0.426	0.238	0.000	-0.155	0.167	0.258	-0.034	-0.312	-0.236	0.180	-0.180
Exports	0.332	0.149	0.244	0.160	-0.013	0.109	0.297	0.061	-0.159	0.291	0.329	-0.148
Imports	0.160	0.098	0.170	0.228	-0.009	0.050	0.511	-0.220	-0.147	0.022	0.144	-0.532
Frgn assets	0.090	0.227	0.285	0.559	0.204	0.023	-0.276	0.488	-0.162	-0.186	-0.162	-0.265
Frgn liab.	0.122	0.300	0.250	0.578	0.152	-0.101	-0.208	0.433	-0.233	-0.175	-0.121	-0.065
TV sets	0.480	0.386	0.244	-0.178	-0.281	0.428	-0.205	-0.168	0.118	-0.008	0.048	0.113
Cable TV	0.084	0.256	0.340	0.240	0.087	-0.121	-0.279	0.098	0.114	-0.136	-0.443	-0.089
Sat TV			-0.063			-0.145			0.341			-0.201
Terrain	-0.045	-0.015	-0.013	0.192	0.187	-0.151	0.569	0.310	-0.393	-0.254	0.614	0.272

Table 5.10: Eigenvectors of the first four principal components per satellite generation; South and Central America (Groups 9 and 10).

Group 9-10 Variables	65-75	75-84	85-93	65-75	75-84	85-93	65-75	75-84	85-93	65-75	75-84	85-93
		Prin1			Prin2			Prin3			Prin4	
Main lines	0.367	0.414	0.395	-0.173	-0.048	-0.018	0.187	-0.001	0.189	-0.245	-0.217	-0.024
Wait. lists	0.251	0.321	0.355	-0.068	-0.230	-0.140	0.285	-0.027	-0.063	-0.675	0.025	-0.143
Fax			0.102			0.402			0.269			-0.261
Videotex												
Cellphones			0.127			0.443			0.288			0.239
ISDN												
PDN		-0.084	0.035		0.530	0.466		0.195	0.306		-0.305	0.131
Modems			-0.022			0.245			0.115			-0.585
PCs												
Population	0.449	0.412	0.391	-0.112	-0.125	-0.165	0.184	0.005	0.064	0.241	-0.072	-0.093
GDP	0.375	0.354	0.394	0.121	-0.050	-0.063	0.157	-0.055	0.065	-0.190	-0.308	-0.002
Exports	0.340	0.317	0.250	-0.157	-0.075	-0.140	-0.042	0.245	0.009	0.333	0.204	0.103
Imports	0.235	0.214	0.241	-0.322	0.058	-0.240	-0.217	-0.020	0.090	0.283	0.816	0.157
Frgn assets	0.208	0.158	0.217	0.625	0.537	0.310	-0.263	-0.525	-0.451	-0.106	0.122	0.021
Frgn liab.	0.271	0.243	0.190	0.576	0.534	0.269	-0.162	-0.015	-0.531	0.149	0.012	0.054
TV sets	0.415	0.425	0.400	-0.181	-0.054	-0.048	-0.308	-0.070	0.139	0.045	-0.177	-0.015
Cable TV												
Sat TV			0.015			0.127			0.056			0.667
Terrain	0.014	0.110	0.135	0.234	0.247	0.222	0.765	0.785	-0.416	0.404	0.078	-0.043

More could be said about these principal components, and will be as the results for the second calculation of the principal components are presented. Table 5.11 presents the results of the analysis for the whole sample period using only the variables which cover the entire period, while table 5.12 shows the results for the last period, 1985-93, using only new technology variables.

Table 5.11: Eigenvectors of the first four principal components of 'old' demand variables for the entire sample, 1965-93.

PC1\Group	1	2	3	4	5-6	7-8	9-10
Main lines	0.482	0.417	0.361	0.424	0.369	0.485	0.377
Waiting lists	-0.051	0.238	0.342	0.253	0.295	0.088	0.337
Population	0.454	0.167	0.336	0.301	0.322	0.388	0.394
GDP	0.418	0.412	0.305	0.271	0.263	0.341	0.342
Exports	0.174	0.181	0.210	0.109	0.301	0.272	0.286
Imports	0.187	0.160	0.222	0.296	0.286	0.189	0.222
Foreign assets	0.221	0.386	0.364	0.375	0.348	0.286	0.277
Foreign liabilities	0.199	0.434	0.355	0.378	0.384	0.298	0.304
TV receivers	0.478	0.415	0.412	0.441	0.351	0.455	0.405
Terrain	0.041	-0.067	-0.162	0.118	-0.201	-0.042	0.086
PC2\Group	**1**	**2**	**3**	**4**	**5-6**	**7-8**	**9-10**
Main lines	-0.100	0.017	-0.268	0.017	0.159	-0.061	-0.072
Waiting lists	-0.369	0.554	-0.210	0.287	0.088	-0.094	-0.010
Population	-0.262	0.469	-0.154	0.422	-0.445	-0.432	-0.246
GDP	-0.145	-0.045	-0.061	-0.227	-0.380	-0.039	0.085
Exports	0.129	0.268	0.660	-0.437	0.391	0.052	-0.338
Imports	0.166	0.338	0.612	0.005	0.393	0.193	-0.368
Foreign assets	0.558	-0.370	-0.010	-0.280	0.085	0.525	0.564
Foreign liabilities	0.595	-0.321	-0.017	-0.286	0.041	0.536	0.527
TV receivers	-0.168	-0.011	-0.131	0.107	-0.014	-0.279	-0.150
Terrain	-0.161	0.211	-0.171	0.570	0.555	0.344	0.242
PC3\Group	**1**	**2**	**3**	**4**	**5-6**	**7-8**	**9-10**
Main lines	-0.112	0.107	-0.070	0.187	0.166	-0.070	-0.176
Waiting lists	0.247	-0.038	0.303	0.454	-0.112	-0.625	-0.104
Population	-0.081	0.379	-0.439	-0.099	-0.282	0.047	0.154
GDP	-0.140	0.234	-0.026	0.306	0.141	0.426	-0.217
Exports	0.646	-0.555	0.057	0.453	-0.410	0.217	0.301
Imports	0.523	-0.276	0.106	0.206	-0.425	0.259	0.216
Foreign assets	-0.060	0.130	0.270	-0.458	0.490	-0.266	-0.091
Foreign liabilities	-0.068	-0.037	0.248	-0.425	0.407	-0.210	0.079
TV receivers	-0.084	-0.107	-0.058	-0.023	0.025	-0.054	-0.220
Terrain	0.441	0.612	0.747	-0.127	0.324	0.435	0.829
PC4\Group	**1**	**2**	**3**	**4**	**5-6**	**7-8**	**9-10**
Main lines	0.046	0.038	0.267	-0.238	-0.413	-0.144	-0.286
Waiting lists	-0.275	-0.135	0.144	-0.259	-0.602	0.246	-0.255
Population	-0.025	-0.252	0.291	0.255	0.207	-0.190	-0.110
GDP	-0.042	-0.098	0.143	-0.480	0.227	-0.051	-0.339
Exports	-0.181	0.082	0.088	0.271	0.226	0.474	0.209
Imports	-0.351	0.657	0.292	0.687	0.300	0.675	0.577
Foreign assets	0.108	0.222	-0.476	-0.064	0.305	-0.069	0.355
Foreign liabilities	0.093	0.223	-0.513	-0.063	0.184	-0.176	0.294
TV receivers	0.025	-0.419	0.141	0.113	-0.308	-0.134	0.024
Terrain	0.862	0.442	0.448	-0.124	0.095	-0.381	-0.370

As expected, and noted in the previous analysis, the number of main lines in operation and the number of television receivers are two of the top four variables constituting the first principal component. Although the other two variables in the 'top four' vary from one group to the next, the variation between the variables' weights is not considerable. There seems, however, to be a regional pattern: in Europe and America (the entire continent, that is), population and GDP, are the other two most important variables; while in the Middle East, Asia, Oceania and Africa, it is the foreign assets and liabilities that occupy this position. In group 2, which contains countries from both camps: Mexico, Brazil and Turkey on the one side, and Malaysia, India and Saudi Arabia on the other, variables from both regions are included: GDP and foreign liabilities. A similar pattern can be found for categories 1, 7-8 and 9-10,

Europe and America, where in this case, foreign assets and liabilities occupy the first rank in the second principal component. Africa, Asia and Oceania have similar rankings for imports and exports, but this does not extend to the Middle East, where population and terrain are more important in the second principal component. For the second group of domestic satellite owners, waiting lists and population play an important role in this second component.

Table 5.12: Eigenvectors of the first four principal components of recent variables for the last satellite generation, 1985-93.

PC1\Group	**1**	**2**	**3**	**4**	**5-6**	**7-8**	**9-10**
Fax machines	0.427	0.355	0.210	0.511	0.386	0.421	0.554
Videotex	-0.038	0.367	0.344	0.325	0.404	0.410	
Mobile phones	0.436	0.381	0.371	0.505	0.383	0.440	0.589
ISDN	0.405	0.373		0.171	0.404	0.258	
PDN	-0.183	0.292	0.557	0.495	0.361	0.292	0.513
Modems	-0.020	0.210	0.415	0.318	0.400	0.205	0.237
PCs	0.395	0.339	0.340		0.238	0.302	
Cable TV	0.424	0.435	-0.045		0.054	0.420	
Satellite TV	0.305	0.148	0.316	0.045	0.167	0.006	0.165
PC2\Group	**1**	**2**	**3**	**4**	**5-6**	**7-8**	**9-10**
Fax machines	0.270	-0.059	0.166	0.227	0.286	0.062	-0.285
Videotex	0.601	-0.053	-0.550	-0.293	-0.354	-0.162	
Mobile phones	0.096	-0.116	-0.518	0.205	0.429	0.085	0.189
ISDN	0.000	-0.303		0.601	-0.304	0.453	
PDN	0.568	-0.028	-0.074	-0.245	-0.204	-0.515	0.092
Modems	0.472	0.636	0.461	-0.402	-0.115	-0.442	-0.536
PCs	0.042	-0.331	0.343		0.233	0.375	
Cable TV	-0.094	0.232	0.032		0.624	0.028	
Satellite TV	0.008	0.565	0.255	0.488	0.136	0.395	0.766
PC3\Group	**1**	**2**	**3**	**4**	**5-6**	**7-8**	**9-10**
Fax machines	0.091	0.336	0.785	0.108	-0.109	0.087	-0.312
Videotex	0.313	-0.316	-0.071	0.146	0.283	-0.134	
Mobile phones	-0.181	0.547	0.121	-0.069	-0.090	0.089	-0.327
ISDN	0.024	-0.085		-0.554	0.318	-0.461	
PDN	0.275	0.411	-0.058	-0.090	-0.239	0.134	0.228
Modems	-0.667	-0.024	0.193	0.111	-0.208	0.155	0.735
PCs	-0.365	-0.378	-0.443		0.408	-0.057	
Cable TV	0.257	-0.406	0.279		0.304	0.095	
Satellite TV	0.375	0.065	-0.222	0.797	-0.663	0.837	0.451
PC4\Group	**1**	**2**	**3**	**4**	**5-6**	**7-8**	**9-10**
Fax machines	-0.193	0.301	-0.073	-0.021	-0.470	-0.017	0.374
Videotex	-0.383	-0.456	-0.012	-0.736	-0.062	-0.116	
Mobile phones	-0.245	0.045	0.155	-0.008	-0.255	-0.126	0.144
ISDN	0.319	0.392		0.051	0.070	-0.092	
PDN	0.282	-0.574	-0.138	0.059	-0.263	-0.284	-0.801
Modems	0.241	-0.074	-0.234	0.666	0.435	0.681	0.245
PCs	0.033	0.182	0.209		0.499	0.594	
Cable TV	-0.270	-0.098	0.863		0.102	-0.244	
Satellite TV	0.666	0.410	0.328	0.086	0.433	-0.066	0.371

As can be observed, only groups 1, 2, 5-6 and 7-8 possess the technology described by these 9 variables. In Africa, South and Central America, ISDN is not consistently present in order to appear in the principal components. In addition, in the latter and the Middle East, personal computers and cable television receivers are very scattered. The fact that cable television is a main constituent of the first principal component for domestic satellite owners and Europe presupposes that most domestic

and regional satellites are used as television feeds[16] and more importantly, that they are more widespread than direct-to-home satellite services. This concurs with tables 1.8 and 1.9 where the average percentage of cable television subscribers is between 27 % and 32 % in the Western World, while for DTH satellite television subscribers, this proportion decreases to 6-7 %. It is only as a main constituent of the second principal component that the latter appears, and that, in groups 2, 4, 7-8 and 9-10.

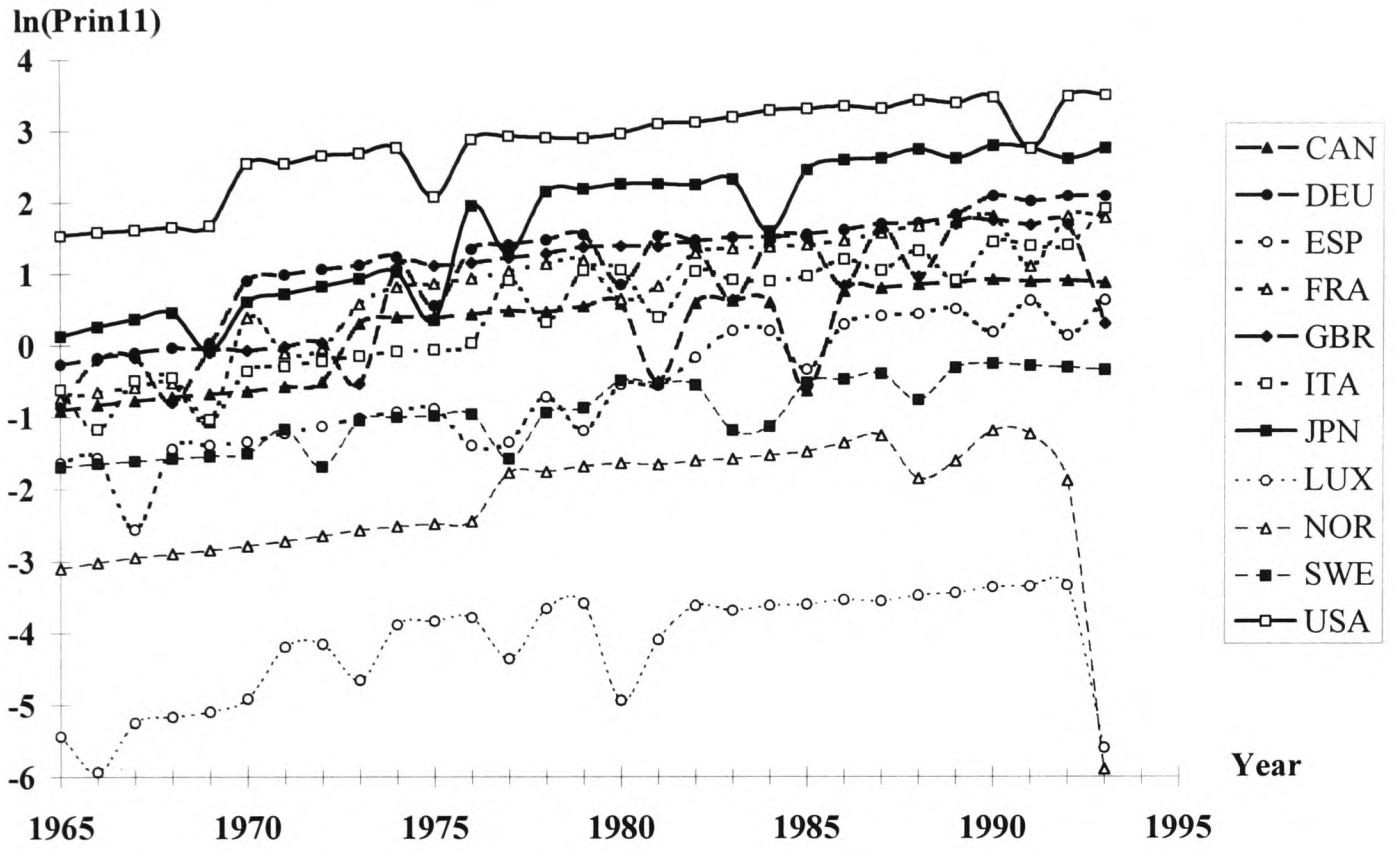


Figure 5.14: First principal component; 'old' technology; Group 1.

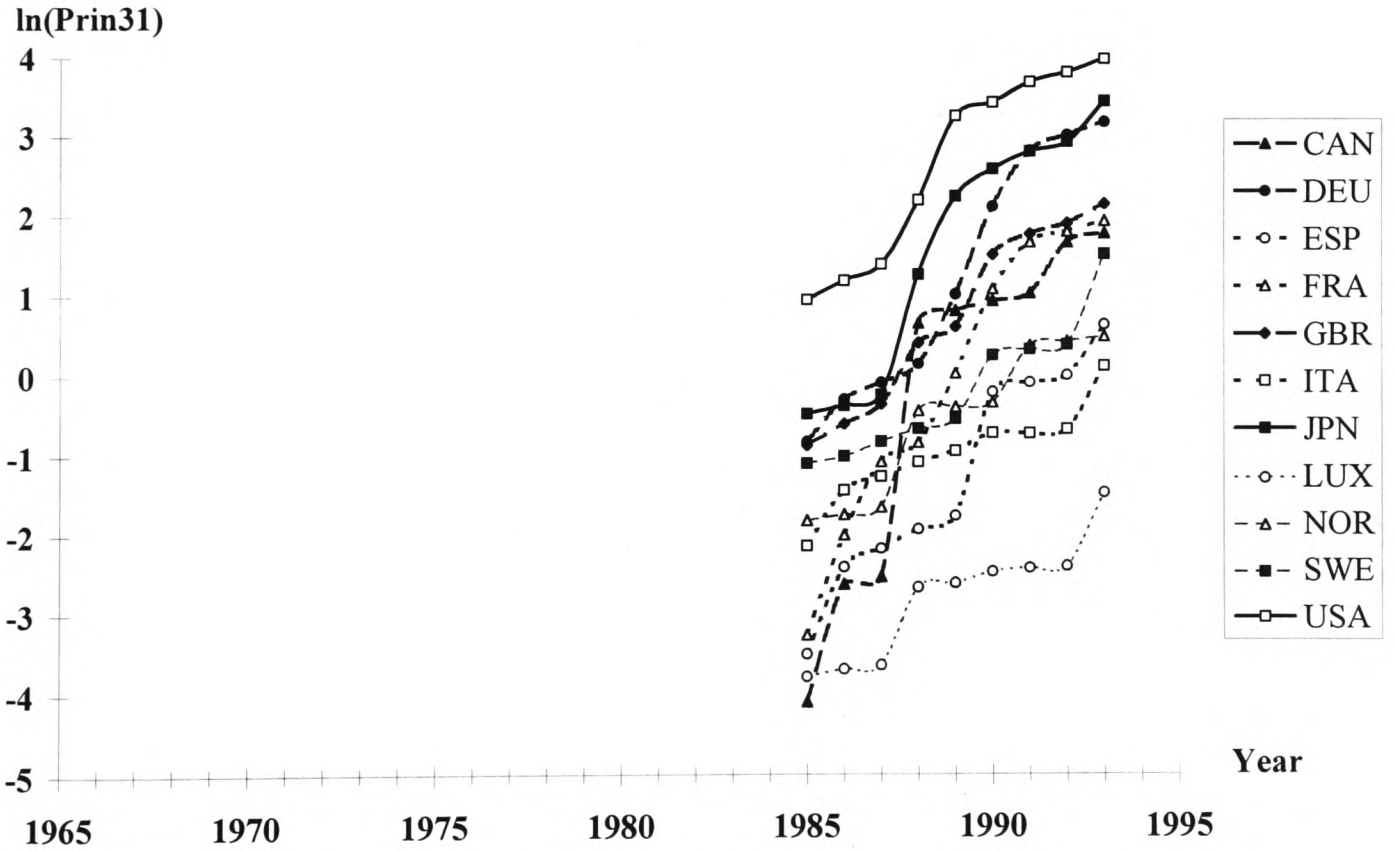


Figure 5.15: First principal component; recent technology; Group 1.

[16] Television feeds transmit television signals to local receivers which then retransmits them via cable or ground antennas to the end-user.

Figure 5.14 shows the first principal component of the 'old' technology variables and the graduation of countries is even more distinctive than when all variables are used (see figure 5.10). With the exception of Canada, the same can be said of figure 5.15, which shows the first principal component of the recent technology for the Western World domestic satellite owners. This discrepancy in the case of Canada may be due to measurement errors rather than to a real distinction.

5.3.2 Traffic demand regression

The chapter proceeds in calculating traffic demand using these principal components as regressors on the outgoing international telephone traffic. This regression will attempt to explain demand for communication services using these first four principal components. The predicted value of these will then be used in the stock demand equation. In table 5.13, are listed the obtained coefficients of these principal components. Traffic demand will be calculated using the two functional forms of equations (5.6) and (5.7) and the full regression results are situated in appendix K. These OLS regressions were performed for each country.

The regressions for Luxembourg and Sweden do not appear to be as well fitted as other countries in this group, implying that there may be some difference between them and the G7 countries which constitute the majority in this group. France neither has a very good fit, but this is due to the data which is particularly poor for this country compared with the rest. In the second group, however, all regressions have a significant F-value, that is not to say that the principal components explain all the variance, as shown by some low values of the adjusted R^2. Observing results from the second regression method, similarities between Canada and the United States can be found for the first and second principal components of the 'old' variables. Similarly, Spain, Italy and Luxembourg have close values for these first two coefficients. Some patterns can also be found in the second group, between Australia and Hong Kong, for the first principal component; between Indonesia and India for all four principal components; and between Malaysia and Thailand for the first and second principal components.

In the first model, the coefficient of the dummy variable for the last period of the sample is mostly positive and significant, implying an important difference between before and after the introduction of new technology. This favours the second method, which analyses the two types of variables separately. Comparing the first and second methods of calculating the principal components and the ensuing traffic demand, outlines that 'old' variables play a very important role in the demand for outgoing international telephone traffic. Indeed, very few countries have significant coefficients for the principal components calculated using only the new technology variables. The regressions using the second method, however, seem to explain more of the variance, but this may be due to the greater number of variables of this model.

Figures 5.16 and 5.17 present the two obtained predicted traffic demand calculated from the two methods defined in equations (5.6) and (5.7). While the first method of calculating the predicted traffic demand provided a more stable evolution over the years, the second method seems to provide erroneous results for some countries during the early period of the sample. The aggregation of all three periods for the 'old' technology variables for the second method yields too small values prior to 1970, and these results will be kept in mind in the subsequent statistical analysis. Early years will be eliminated from the stock adjustment analysis to remedy these surprising results.

Table 5.13: International outgoing communication traffic capacity regression; first method (equation 5.6); Groups 1 and 2, results for the other 8 country regions are provided in appendix K.

Group	Country	α	θ_1	θ_2	θ_3	θ_4	d_t	SSE	MSE	R^2	Adj R^2
1	CAN	5.062 ***	1.030 *	-1.425 *	1.178	-0.828	-2.002	1.6671	0.1389	0.8927	0.8479
1	DEU	5.922 ***	0.312 ***	0.102	0.018	0.298 ***	1.220 ***	0.5332	0.0533	0.9413	0.9120
1	ESP	4.972 ***	0.483 ***	0.046	-0.125	-0.078	1.607 ***	1.2268	0.0944	0.9188	0.8876
1	FRA	5.643 ***	-0.024	-0.449 *	0.795 **	0.048	2.017 ***	1.5811	0.1437	0.8637	0.8017
1	GBR	4.365 ***	0.320	-0.042	0.446	-0.444 ***	2.079 ***	1.8450	0.1845	0.8558	0.7837
1	ITA	4.664 ***	0.737 ***	0.052	0.059	0.007	2.442 ***	2.6160	0.1137	0.9356	0.9216
1	JPN	3.130 ***	0.482 ***	-0.081	0.063	0.000	2.017 ***	0.4507	0.0347	0.9825	0.9758
1	LUX	3.107	0.291	0.577	-0.291 **	8.217	4.050 **	2.2225	0.1235	0.8305	0.7835
1	NOR	4.993 ***	0.594 ***	0.047	-0.228	-0.203	1.701 ***	3.2632	0.1419	0.8938	0.8707
1	SWE	4.139 ***	0.461	0.283	0.014	-0.030	2.641 **	6.9985	0.5832	0.7222	0.6064
1	USA	3.019 ***	0.745 ***	0.026	-0.057	-0.123	2.535 ***	1.0481	0.0806	0.9627	0.9483
2	AUS	2.138 ***	0.351 **	-0.172	-0.675 ***	-0.133 *	3.699 ***	1.2751	0.0981	0.9489	0.9292
2	BRA	3.000 ***	0.227 **	-0.130	-0.103	-0.269	2.623 ***	0.9556	0.0735	0.9263	0.8979
2	HKG	1.283 ***	1.368 ***	0.053	0.673 **	-0.190	4.065 ***	1.4398	0.1200	0.9620	0.9461
2	IDN	0.697	1.002 ***	1.163 ***	0.157	0.253	5.378 ***	2.2368	0.1721	0.9080	0.8727
2	IND	0.134	0.506	0.785 ***	0.257	-0.262	3.692 **	3.1315	0.2409	0.9246	0.8956
2	KOR	3.323 ***	0.152 ***	-0.533	0.332	-0.256	0.812	0.2589	0.0518	0.9663	0.9327
2	MEX	1.142	0.976 ***	-2.361	1.482	-4.369	4.333 ***	0.1570	0.0314	0.9565	0.9130
2	MYS	0.947 ***	1.056 ***	-0.630	-0.115	-0.284	1.803	1.3101	0.1092	0.9595	0.9427
2	SAU	3.706	1.805 ***	0.862	0.951	0.154	6.417 ***	11.0996	0.8538	0.7750	0.6885
2	THA	-1.253	1.306 **	2.688 *	-2.538 *	-0.565	6.290 ***	0.8175	0.1635	0.9168	0.8335
2	TUR	2.685 ***	0.956 ***	-0.519 **	-0.295 **	0.112	2.863 ***	3.7335	0.1623	0.9624	0.9542

Table 5.14: International outgoing communication traffic capacity regression; second method (equation 5.7); Groups 1 and 2, results for the other 8 country regions are provided in appendix K.

Group	Country	α	θ_1'	θ_2'	θ_3'	θ_4'	θ_1''	θ_2''	θ_3''	θ_4''	SSE	MSE	R^2	AdjR^2
1	CAN	3.234 ***	6.969 ***	-1.945 ***	-0.182	3.514 **	-0.012	0.677	-0.726	0.370 **	0.0986	0.0110	0.9937	0.9880
1	DEU	-2.447	13.116 ***	-5.612 ***	0.523	11.309 ***	-1.727 ***	-0.543 *	1.134 ***	-3.069 ***	0.1826	0.0261	0.9799	0.9569
1	ESP	4.569 ***	3.542 ***	-1.314 ***	-0.665 ***	0.243	0.187	-0.154	1.137	0.063	0.3550	0.0355	0.9765	0.9577
1	FRA	0.887	6.238 ***	-2.971 ***	-0.869 *	1.080	0.101	-0.196	0.354	0.148	0.1858	0.0232	0.9840	0.9680
1	GBR	-16.446 *	22.919 **	-7.078 *	-3.885 **	3.204 **	-2.363 *	0.896	-2.296	2.181 **	1.5474	0.2211	0.8791	0.7409
1	ITA	3.340 ***	3.080 ***	-1.228 ***	-0.457 ***	0.440 *	-0.784 ***	-0.999 ***	-1.610 ***	-2.299 ***	0.5227	0.0261	0.9871	0.9820
1	JPN	-5.116	3.844 **	-1.367 **	-0.612 **	0.819	0.344 *	-0.339	0.549	-0.127	0.7048	0.0705	0.9726	0.9508
1	LUX	21.307 ***	3.479 ***	-1.544 ***	-0.406 ***	-33.909	-0.168	0.133	-0.719	-0.298	0.1244	0.0083	0.9905	0.9855
1	NOR	-3.981 ***	1.933 ***	-1.458 ***	5.224 ***	-4.062 ***	0.273 **	-0.005	-0.306	0.254	0.6414	0.0321	0.9791	0.9708
1	SWE	31.078 *	26.598	-10.289	-4.559 *	-0.042	-1.094	2.277	0.861	4.713	5.7346	0.6372	0.7724	0.5700
1	USA	-15.496 ***	7.763 ***	-2.744 ***	-1.354 ***	-1.319	0.085	0.235	-0.072	0.049	0.2708	0.0271	0.9904	0.9827
2	AUS	-1.595	3.718 **	-4.785 ***	-2.813 ***	-14.088 ***	-0.384	-1.475 *	0.515	-0.286	1.5382	0.1538	0.9383	0.8890
2	BRA	1.989 **	0.682 ***	0.106	-0.024	-0.378	-1.406 **	-7.913	0.094	-0.343	1.0192	0.1019	0.9214	0.8585
2	HKG	-3.030	3.688 ***	-1.964 **	0.308	0.327	-0.291	-0.370	-0.063	0.177	0.1658	0.0184	0.9956	0.9917
2	IDN	-1.341 **	1.395 ***	1.678 ***	1.339 ***	-0.796 ***	-1.295	-46.722	-5.404	-1.920	0.3181	0.0318	0.9869	0.9765
2	IND	-3.435 ***	1.774 ***	1.676 ***	1.392 ***	-0.636 ***	-3.170	-22.300	0.000	0.000	0.9362	0.0780	0.9775	0.9662
2	KOR	3.168 **	0.159	-0.795	-0.122	-0.052	-0.034	-0.808 *	0.082	-0.357	0.0222	0.0111	0.9971	0.9856
2	MEX	-0.194	2.570 **	-1.105	0.454	-4.714 **	-1.201 **	-1.317 *	1.306 **	0.615	0.0036	0.0018	0.9990	0.9950
2	MYS	0.111	1.744 ***	2.277 **	1.694 **	-0.461	-0.440 **	-2.500 ***	0.804 ***	-0.634 ***	0.1409	0.0157	0.9956	0.9918
2	SAU	2.610	2.714 ***	-0.483	-1.658	0.242	2.203 *	18.486	0.408	-0.008	3.9382	0.3938	0.9202	0.8563
2	THA	2.395 ***	1.084 **	1.007	1.201 **	-6.244 **	-0.815 **	-2.017 *	0.575 ***	-0.676	0.0011	0.0006	0.9999	0.9994
2	TUR	2.960 ***	1.158 ***	-0.504	0.043	0.434 **	-0.027	0.179	-0.297	0.225	2.5258	0.1263	0.9746	0.9644

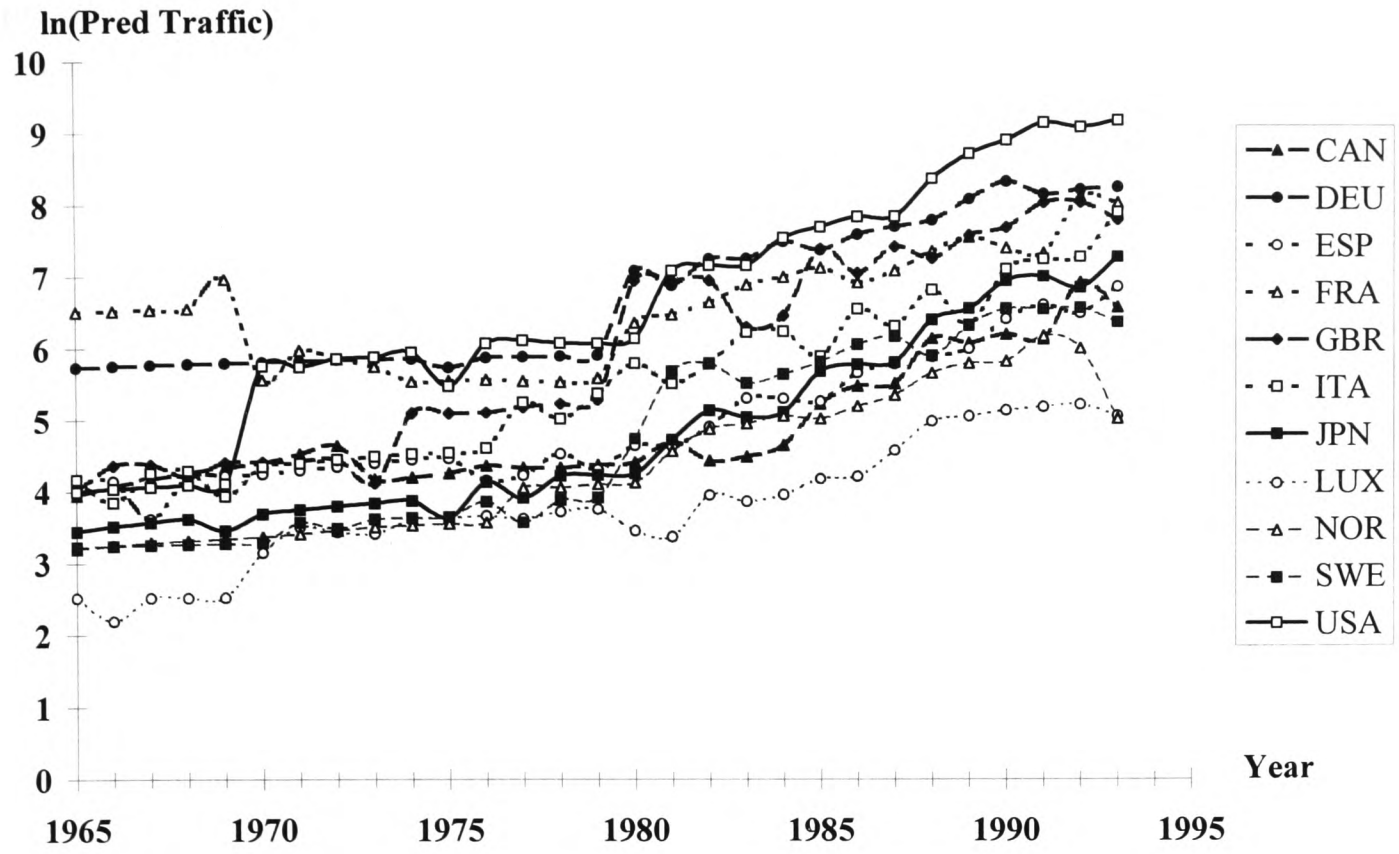


Figure 5.16: First predicted traffic demand results (in logs - 6[17]); equation (5.6); Western World domestic satellite owners (Group 1).

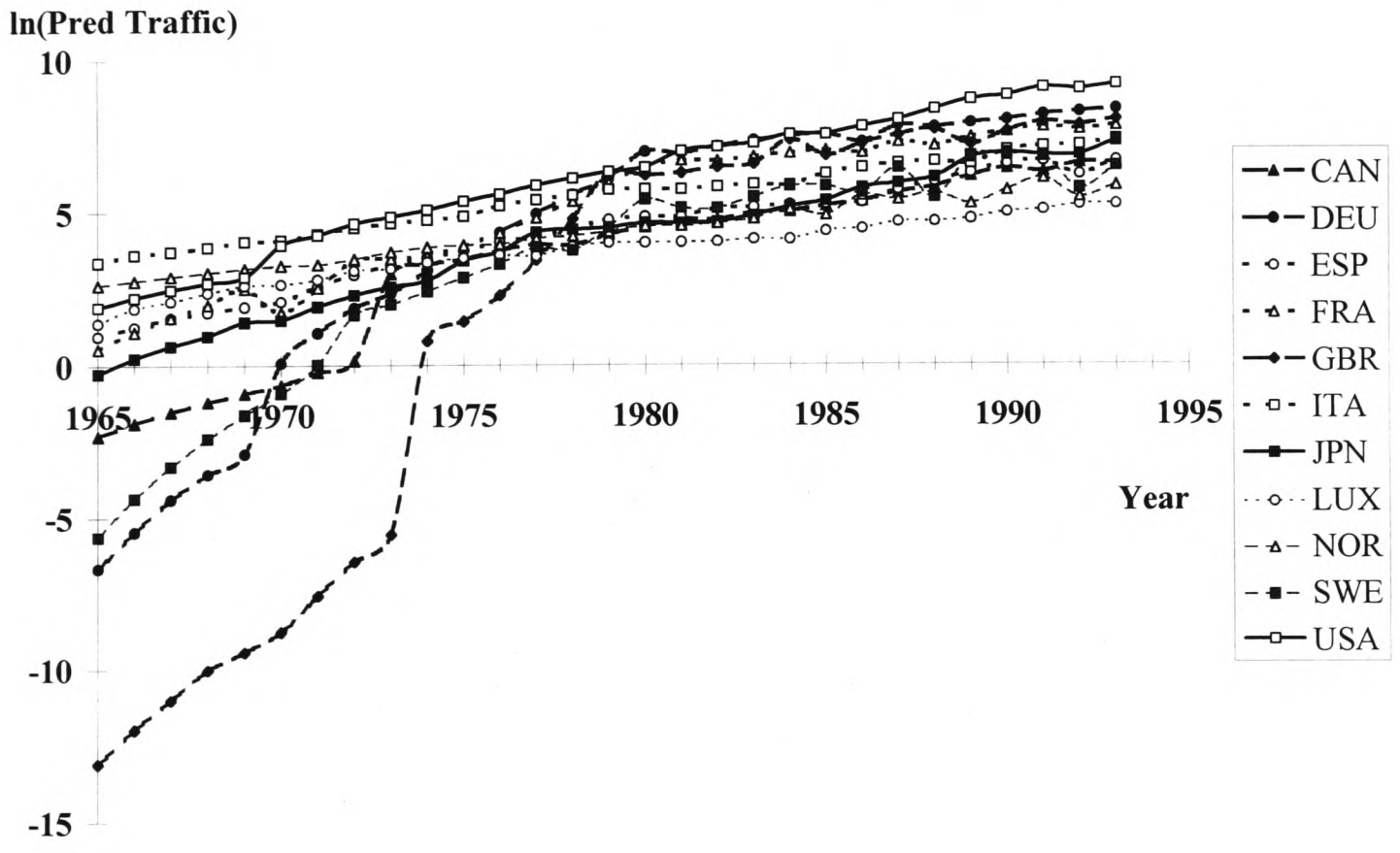


Figure 5.17: Second predicted traffic demand results (in logs - 6); equation (5.7); Western World domestic satellite owners (Group 1).

5.3.3 Desired satellites stock

We can now use the predicted value of the outgoing international telephone traffic in the calculation of the stock demand, or desired stock. As $S_{is}^{*}(t)$ of equation (5.11) may take the value 0 at some points in time because the country does not own

[17] Traffic is measured in millions of calls, hence the -6.

any of the satellites servicing this area, the analysis must take into account this truncation in the data. Since before 1965, there were no civilian commercial communication satellites, and ultimately, adjustment speed is the interest of this exercise, years for which a country does not own a satellite will simply be eliminated from the study. As most countries with reasonable data joined Intelsat at a relatively early date, very few countries are lacking more than 10 years of data for this dependent variable.

We list here the coefficients of the regression performed on the simpler linear model in equation (5.11). Tables 5.15 and 5.16 display the regression results for this model per country examined. The regression shown uses the price index from the third supply regression model for North American manufacturers (see table 3.12). Other regressions using a price index from the third model of the regression for all manufacturers are provided in appendix L. The regressions presented in the table below were deemed the most appropriate among those examined and gave the best results overall.

Examining tables 5.15 and 5.16, one notices that the coefficient on the bandwidth efficiency is generally negative, except for a few cases such as India, Korea, Malaysia, Thailand. This is quite intuitive as the bandwidth to equivalent voice channels decreases with time as calculated in appendix G. The occasional positive coefficient possibly implies that international outgoing telephone traffic is increasing much faster than the stock of capacity and the efficiency acts as a dampening effect, hence the positive coefficient. Note also that these countries have a higher than average significant coefficient on the linear trend (the year), while the quadratic version of the year is negative.

Analysing the results of the stock demand equation, many similarities can be found between various countries. Indeed, Germany and Italy, and to some extent Luxembourg as well, possess similar coefficients for the efficiency, the trend and the quadratic in time. Slight differences occur between the traffic demand calculated using the first and second methods (equations 5.6 and 5.7), for instance, in the first case (table 5.13), Canada is very similar to the United States, while in table 5.14, this similarity almost disappears. It was mentioned earlier, that because this country, Canada, was the first to launch a domestic satellite, most of its significant growth would appear before the start of the first decade, i.e., before 1975. The same is true for the US, but somehow, subsequent growth within this country has not affected its rank as much as its northern neighbour. Many reasons exist to say that Canada should differ from the United States as the latter has 9 times the population of the former, satellite services have mushroomed in terms of international business services and potentially provide for Canadian private business traffic, as most of Canada's satellite bandwidth is still used for television feeds. This discrepancy can also be emphasised by the difference between figure 5.16 and 5.17, i.e. in the method of calculating traffic demand from the principal components. It is very surprising that the only measure of country specific variable, the predicted value of the outgoing international telephone traffic, is not significant, while variables such as the efficiency, trend and quadratic in time that are constant for all countries, are significant. In group 1, only Canada, France and Luxembourg have significant coefficients on the predicted demand shift, while in group 2, Australia, Malaysia and Turkey fall in this category (in table 5.14). The price index does not appear to have any influence on the stock demand in the first group of domestic satellite owners, while, this variable is positive and significant for at least half of the countries in the second group of domestic satellite owners.

Table 5.15: Stock demand regression results (equation 5.11); first traffic demand predicted results (equation 5.6); North American manufacturers price index, model 3 (table 3.12); Groups 1 and 2, results for the 8 other country regions are provided in appendix L.

Group	Country	α	β	γ	ε	φ	ψ	DF	SSE	MSE	R^2	AdjR^2
1	CAN	-91.015	-0.229	-2.129	0.676	2.149	-0.012	22	11.5474	0.5249	0.9326	0.9173
1	DEU	55.862 ***	-0.322	-5.592 ***	0.401	-1.705 ***	0.011 ***	22	3.3733	0.1533	0.9708	0.9641
1	ESP	-3.107	0.864 **	-4.511 ***	-0.186	-0.174	0.001	22	2.0278	0.0922	0.9786	0.9737
1	FRA	40.089 **	-0.276	-4.696 ***	0.629	-1.264 **	0.009 ***	22	2.7350	0.1243	0.9749	0.9691
1	GBR	10.630	-0.282	-4.164 ***	0.235	-0.530	0.004	22	2.2359	0.1016	0.9764	0.9710
1	ITA	74.686 ***	-0.539	-6.504 ***	-0.601	-2.199 ***	0.014 ***	22	3.8832	0.1765	0.9663	0.9587
1	JPN	103.783 ***	0.514	-8.472 ***	-0.084	-3.018 ***	0.018 ***	20	4.4171	0.2209	0.9621	0.9526
1	LUX	19.007	0.538	-3.609	-0.097	-0.820	0.005	19	1.3454	0.0708	0.9704	0.9626
1	NOR	33.781 **	-0.127	-4.718 ***	0.182	-1.121 **	0.007 ***	22	2.0245	0.0920	0.9772	0.9720
1	SWE	38.606 **	-0.164	-4.712 ***	0.314	-1.250 ***	0.008 ***	22	2.2182	0.1008	0.9765	0.9712
1	USA	-118.862 ***	0.031	-0.051	-1.234	2.898 ***	-0.016 ***	22	4.5288	0.2059	0.9805	0.9761
2	AUS	-40.804	0.313	-0.291	1.539 *	0.993	-0.005	20	2.8899	0.1445	0.9412	0.9265
2	BRA	2.467	0.387	-3.849 ***	1.586 **	-0.248	0.002	22	3.0339	0.1379	0.9662	0.9586
2	IDN	-53.630 *	-0.272	-0.628	1.883 **	1.177	-0.006	20	2.6036	0.1302	0.9501	0.9376
2	IND	-138.618 ***	-0.194	13.747 **	1.135	3.799 **	-0.020 **	18	4.2186	0.2344	0.9255	0.9048
2	KOR	-100.284 **	-0.138	2.743	2.018 **	2.456 **	-0.014 **	20	4.2308	0.2115	0.8955	0.8693
2	MEX	61.354	0.043	-3.924 *	1.864	-1.841 *	0.012 **	21	13.8026	0.6573	0.9013	0.8778
2	MYS	-100.785 ***	0.402	5.095	1.400	2.687 ***	-0.015 ***	20	3.8371	0.1919	0.8983	0.8729
2	SAU	15.595	0.110	-3.301 ***	1.901 **	-0.561	0.004	22	3.5822	0.1628	0.9583	0.9488
2	THA	-97.305 **	0.079	6.895	0.013	2.616 *	-0.014 *	18	3.7124	0.2062	0.8772	0.8431
2	TUR	65.235 **	0.395 *	-9.038 ***	0.337	-1.961 ***	0.011 ***	20	2.0315	0.1016	0.9602	0.9503

Table 5.16: **Stock demand regression results (equation 5.11); second traffic demand predicted results (equation 5.7); North American manufacturers price index, model 3 (table 3.12); Groups 1 and 2, results for the 8 other country regions are provided in appendix L.**

Group	Country	α	β	γ	ε	φ	ψ	DF	SSE	MSE	R^2	AdjR^2
1	CAN	-21.139	0.743 ***	-2.080	0.173	0.554	-0.004	22	6.8459	0.3112	0.9600	0.9510
1	DEU	60.793 **	0.013	-6.043 ***	0.227	-1.849 ***	0.012 ***	22	3.5384	0.1608	0.9693	0.9624
1	ESP	10.135	-0.237	-4.729 ***	0.575	-0.539	0.004	22	2.4262	0.1103	0.9744	0.9686
1	FRA	-19.899	-0.614 ***	-4.067 ***	0.110	0.178	0.000	22	2.1709	0.0987	0.9800	0.9755
1	GBR	-14.681	-0.076	-4.232 ***	0.287	0.056	0.000	22	2.2505	0.1023	0.9762	0.9708
1	ITA	68.090 ***	-0.115	-6.554 ***	-0.406	-2.038 ***	0.013 ***	22	4.2392	0.1927	0.9633	0.9549
1	JPN	104.482 ***	-0.424	-8.717 ***	0.003	-3.123 ***	0.020 ***	20	4.3807	0.2190	0.9624	0.9530
1	LUX	60.472 **	-1.384 **	-9.484 ***	0.374	-2.081 ***	0.013 ***	19	1.2362	0.0651	0.9728	0.9656
1	NOR	38.996 **	0.114	-4.984 ***	0.085	-1.256 ***	0.008 ***	22	2.0422	0.0928	0.9770	0.9717
1	SWE	50.718 *	0.050	-4.997 ***	0.251	-1.542 **	0.010 **	22	2.2890	0.1041	0.9758	0.9703
1	USA	-99.384 ***	0.505	0.155	-1.464	2.466 ***	-0.014 ***	22	4.3714	0.1987	0.9812	0.9769
2	AUS	-59.577 **	0.350 *	1.051	1.423 *	1.505 **	-0.008 **	20	2.6259	0.1313	0.9465	0.9332
2	BRA	12.403	0.448	-3.224 ***	1.618 **	-0.459	0.003	22	2.7890	0.1268	0.9690	0.9619
2	IDN	-49.594 *	-0.204	-1.152	1.623 **	1.067	-0.005	20	2.6141	0.1307	0.9499	0.9374
2	IND	-130.778 **	-0.509	11.128 *	1.639	3.427 **	-0.017 *	18	4.1349	0.2297	0.9269	0.9066
2	KOR	-90.111 **	-0.411	2.275	2.067 **	2.167 **	-0.012 *	20	4.0886	0.2044	0.8990	0.8737
2	MEX	62.052	0.043	-3.797 *	1.805	-1.850 *	0.013 **	21	13.8209	0.6581	0.9012	0.8777
2	MYS	-130.535 ***	0.653 ***	10.658 ***	1.547 **	3.692 ***	-0.021 ***	20	2.9882	0.1494	0.9208	0.9010
2	SAU	23.973	0.138	-3.443 ***	1.742 **	-0.759	0.005	22	3.5188	0.1600	0.9591	0.9497
2	THA	-119.214 **	0.026	8.817	0.262	3.190 **	-0.017 **	18	4.0401	0.2245	0.8664	0.8293
2	TUR	62.053 **	0.501 *	-8.958 ***	0.782	-1.874 ***	0.011 ***	20	1.9600	0.0980	0.9616	0.9521

In this second group, India, Malaysia, Thailand, and to some extent, Korea, all possess similar coefficients for the efficiency, time trend and quadratic. Some other similarities can be found between Brazil and Mexico in terms of efficiency, and between Mexico and Turkey for the time variables. It is not surprising to find closeness between Malaysia, Thailand and Korea, as all three countries developed their telecommunication infrastructure and services roughly around the same time, ordered and launched their first domestic systems in the 1990s. The same can be said of Brazil and Mexico, but their coefficients on the time variables differ slightly (only significant for Mexico). This would mean that both countries are reasonably similar in terms of bandwidth efficiency, it has increased at the same speed as the traffic, but that somehow, Mexico has had a more rapid increase in terms of stock. This may be due to the increasing US and Canadian interest in this country and to the fact that US satellites generally cover part of the Mexican territory.

In the second group of domestic satellite owners, countries can be grouped as the following: India-Korea-Malaysia-Thailand, Mexico-Turkey for the coefficient on the trend or Brazil-Mexico-Saudi Arabia for the efficiency. For these domestic satellite owners, there is a clear distinction between the countries that introduced satellite communications in the 1980s and those for which this innovation is more recent. The former experienced a faster growth trend of their stock of satellites. Comparing this result with the rates of growth calculated in the first chapter, we observe that Brazil and Mexico have the slowest growth in the first decade (1975-85), but this changes dramatically for Mexico in the second decade, when the country experienced the fastest rate of growth. Brazil on the other hand, increased slightly its level of growth from one decade to the next.

Growth rates appear as a possible distinction between countries, and the next section will examine these rates further as the speed at which countries adjust their stock of satellites is calculated.

5.4 Stock adjustment model

In the previous sections, a measure of the stock demand of satellite capacity was calculated. The goal of this section is to determine whether countries adjust their stock of satellites at a different pace and if so, what are the determining factors that influence these decisions. In a first instance, simple linear regressions will be performed in a double-log format. The desired stock will be replaced by the stock demand equation in the stock adjustment model. Subsequently, the assumption of a fixed adjustment parameter will be relaxed and the time aspect of this coefficient will be examined. First, the adjustment parameter will be replaced by a simple measure of the world growth of satellite orders. Second, the country-specific aspect will be partially eliminated by calculating the adjustment coefficient for each of the 10 groups of countries under study, as well as for two groups, domestic satellite owners versus the rest of the world.

5.4.1 Fixed stock adjustment

Two methods are examined in this section. First, the reduced form of the stock adjustment, equation (5.14), will be estimated for each country, and the same four combinations of price indices and traffic demand. Second, a pooled analysis of the same equation will be analysed in order to verify whether there is ground for treating each country separately, i.e. whether there are country fixed effects or not.

The coefficients of all other variables can be compared with the values obtained in the stock demand analysis, but remember that the coefficients do not map directly from one equation to the next, apart from a_6, which is the negative value of the λ. All other variable coefficients are multiplied by this variable coefficient, as described in equation (5.14).

Tables 5.17 and 5.18 present the analysis of the pooled sample. Country fixed effects associated with these regressions are located in appendix M. A map of the fixed effects for the model using the second traffic demand calculation and the price index calculated for all manufacturers (table 3.3) follows these two tables (see figure 5.18). Note that the fixed effects in this map are relative to the coefficient of the dummy variable for Hong Kong, which has the lowest value. Comparing the four sets of results, the non-significance of the coefficient a_3 in half the results is noticeable. A simple reason explains this, because the US manufacturing price index was calculated for a subset, however significant, of the sample, all the satellites manufactured outside North America are not accounted for by this index. Consequently, it was to be expected that the index calculated from the entire sample would fit a pooled regression better. In addition, the coefficients of all the other variables, with the exception of the predicted traffic demand, are significant. As can be seen in appendix M, the majority of country fixed effects are significant, suggesting separate regressions for each country.

Table 5.17: Stock adjustment pooled results, fixed λ (equation 5.14); first traffic demand predicted results (equation 5.6); All (left) and North American (right) manufacturers price indices, model 3 (tables 3.3 and 3.12); Coefficients of the country dummies are provided in appendix M.

	SSE	MSE	R2	Adj R2			SSE	MSE	R2	Adj R2	
	279.4161	0.1291	0.248	0.2080			283.2638	0.1308	0.237	0.1969	
	Estimate	**Std Err**	**T-Value**	**Prob>|T|**			**Estimate**	**Std Err**	**T-Value**	**Prob>|T|**	
a_0	16.9807	2.5471	6.667	0.0001	***	a_0	9.6730	2.3331	4.146	0.0001	***
a_1	0.0022	0.0015	1.457	0.1451		a_1	0.0022	0.0015	1.468	0.1423	
a_2	-2.0012	0.2226	-8.991	0.0001	***	a_2	-1.6288	0.2139	-7.616	0.0001	***
a_3	-0.3635	0.0655	-5.552	0.0001	***	a_3	-0.0099	0.0703	-0.141	0.8880	
a_4	-0.4898	0.0686	-7.145	0.0001	***	a_4	-0.3110	0.0635	-4.899	0.0001	***
a_5	0.0028	0.0004	7.344	0.0001	***	a_5	0.0019	0.0004	5.232	0.0001	***
a_6	-0.2882	0.0168	-17.148	0.0001	***	a_6	-0.2983	0.0174	-17.185	0.0001	***

***: significant at the 1 % level

Table 5.18: Stock adjustment pooled results, fixed λ (equation 5.14); second traffic demand predicted results (equation 5.7); All (left) and North American (right) manufacturers price indices, model 3 (tables 3.3 and 3.12); Coefficients of the country dummies are provided in appendix M.

	SSE	MSE	R2	Adj R2			SSE	MSE	R2	Adj R2	
	281.2415	0.1284	0.245	0.2052			285.1951	0.1302	0.235	0.1942	
	Estimate	**Std Err**	**T-Value**	**Prob>|T|**			**Estimate**	**Std Err**	**T-Value**	**Prob>|T|**	
a_0	16.7744	2.5720	6.522	0.0001	***	a_0	9.5013	2.3549	4.035	0.0001	***
a_1	0.0009	0.0008	1.221	0.2221		a_1	0.0010	0.0008	1.249	0.2120	
a_2	-1.9772	0.2250	-8.789	0.0001	***	a_2	-1.6056	0.2160	-7.432	0.0001	***
a_3	-0.3605	0.0660	-5.461	0.0001	***	a_3	-0.0085	0.0709	-0.120	0.9042	
a_4	-0.4839	0.0692	-6.988	0.0001	***	a_4	-0.3058	0.0641	-4.771	0.0001	***
a_5	0.0028	0.0004	7.186	0.0001	***	a_5	0.0019	0.0004	5.101	0.0001	***
a_6	-0.2865	0.0169	-16.952	0.0001	***	a_6	-0.2963	0.0174	-16.988	0.0001	***

***: significant at the 1 % level

Tables 5.19 and 5.20 show the results for the first two groups of the country regressions using the two traffic demand methods. Despite the previous finding that the price index calculated for the entire sample was significant while that for the North American built satellite was not, when country regressions are presented, only the results obtained with the North American builders price index will be used (all results are provided in appendix M). The reason for this preference is simple, most satellites were produced in the US, and certainly all the Intelsat spacecraft. In terms of individual countries, therefore, the North American manufacturers price index is more appropriate. In general, this price index will not suit Europe, but neither would the more general price index anyway, for the reasons elaborated in the third and fourth chapters. In addition, only domestic satellite owners will be studied in greater details in this thesis, the case of Intelsat being extremely complex as for the decision to adjust its stock of satellite capacity. Recall that Intelsat is an international organisation within which any decision must be voted upon by all the member states.

Two columns follow the coefficient a_6, which is the negative value of the adjustment coefficient: the first column represents the level of significance of the rejection of the null hypothesis that the coefficient is different from 0; the second column is the reciprocal results for a coefficient significantly different from 1. Note that the latter test is the most pertinent in our case, i.e. deciding whether there is an adjustment lag or not. While most adjustment coefficients are significantly different from zero for domestic satellite owners, they are not all significantly different from one. For Japan and the US, the adjustment coefficient cannot be rejected as being different from one. This does not mean however that these two countries adjust their stock of satellite capacity immediately. Luxembourg has the biggest adjustment lag with an adjustment coefficient of about 0.4. Mexico, which adjusts the slowest of group 2, possesses a coefficient of 0.1, but the fit of the regression is very doubtful, even though in the stock demand calculation, the fit was better. Apart from Luxembourg, all nations of group 1 adjust their stock of satellite capacity faster than group 2. Indeed, while most countries of group 1 appear as green and red in the adjustment coefficient map, the members of the second group appear as yellow and green. The adjustment coefficients for Europe, group 7, range between 0.6 and 0.8. Consult figure 5.19 for a world representation of the adjustment coefficient.

Many similarities can be found between the coefficients of table 5.16 and 5.20, for a certain number of countries. Coefficients are generally scaled down from one table to the other and that is normal as explained above. Further, the coefficients on the predicted traffic are not overwhelmingly significant, on the contrary, one could expect this variable to pick up what the stock adjustment does not account for. The same was observed in the stock demand estimation, with the coefficient β being significant only in rare cases. In contrast, the coefficient on the bandwidth efficiency, a_2, is negative and significant in most countries of the first group, while the significance disappears in the second group of domestic satellite owners. This is again a similar feature to the stock demand model. This would suggest that only the Western World employs software compression techniques available. In addition, similar adjustment coefficients are obtained for groups of countries: for example, Spain, Italy, Sweden and the UK have very close coefficients according to table 5.20. This is so throughout the world within and across the predefined ten groups. A more complex model of the stock adjustment mechanism may shed some light on these differences (significant country fixed effects) and similarities (between coefficients for various countries).

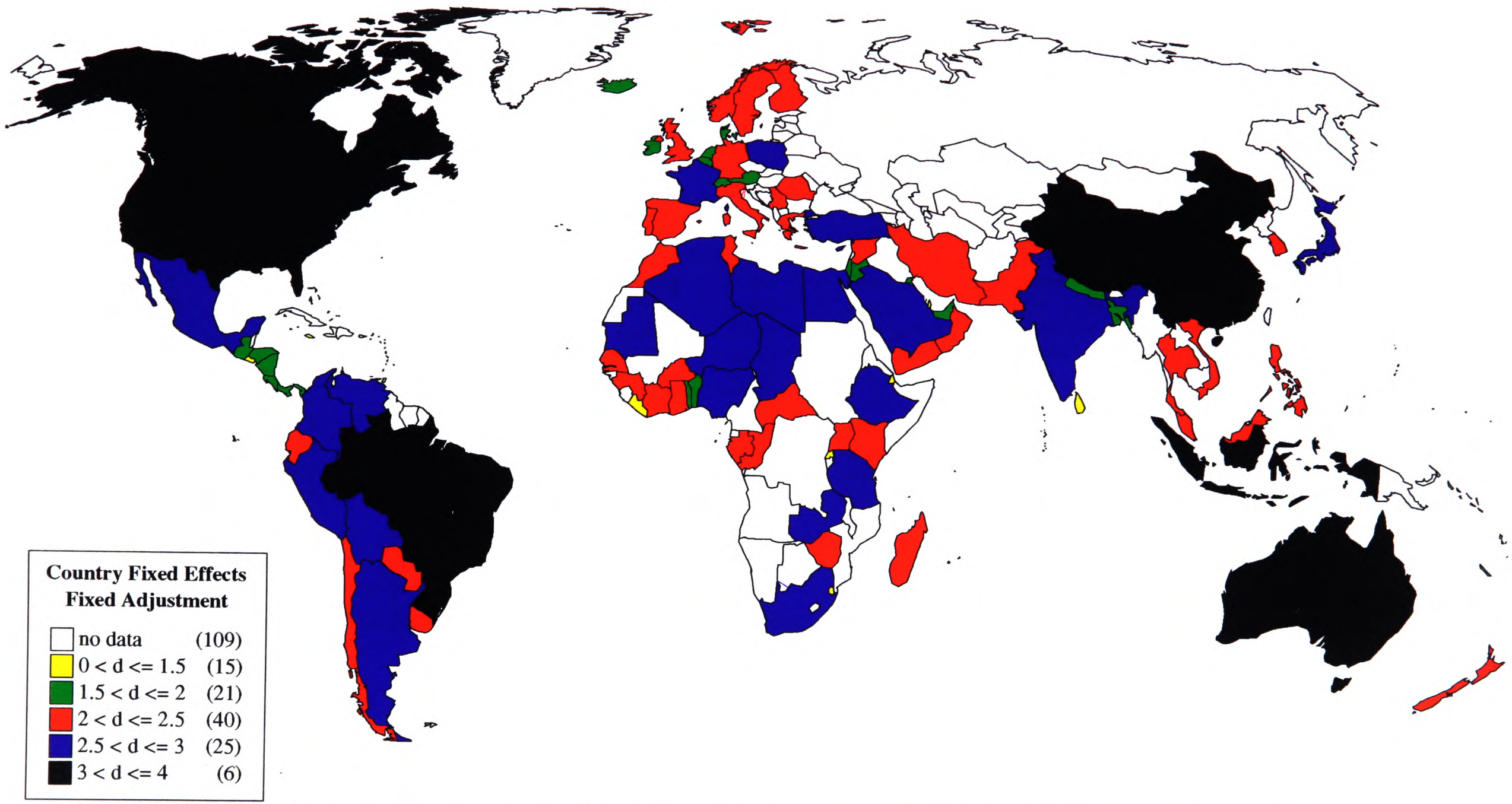


Figure 5.18: **Fixed effects results, fixed λ (equation 5.14); second traffic demand predicted results (equation 5.7); North American manufacturers price index, model 3 (table 3.12).**

Table 5.19: **Stock adjustment results, fixed λ (equation 5.14); first traffic demand predicted results (equation 5.6); North American manufacturers price index, model 3 (table 3.12); Groups 1 and 2, results for the 8 other country regions are provided in appendix M.**

Group	Country	a_0	a_1	a_2	a_3	a_4	a_5	a_6	$\neq -1$	SSE	MSE	R^2	Adj R^2
1	CAN	11.708	-0.329	-6.996 ***	0.394	-0.540	0.0032	-0.657 ***	*	6.2745	0.3137	0.5524	0.4181
1	DEU	82.789 ***	0.293	-7.684 ***	-0.188	-2.406 ***	0.0142 ***	-0.641 ***	**	1.1380	0.0569	0.6858	0.5916
1	ESP	27.012	0.559 *	-4.958 ***	-0.403	-0.891 *	0.0050	-0.647 ***	**	0.8209	0.0410	0.7216	0.6381
1	FRA	52.467 ***	0.254	-6.324 ***	0.068	-1.597 ***	0.0094 ***	-0.592 ***	**	1.1584	0.0579	0.6509	0.5462
1	GBR	46.172 ***	-0.087	-6.173 ***	0.000	-1.442 ***	0.0088 ***	-0.762 ***		0.9488	0.0474	0.6783	0.5818
1	ITA	102.244 ***	-0.201	-8.813 ***	-0.813	-2.926 ***	0.0177 ***	-0.788 ***		1.7006	0.0850	0.6705	0.5716
1	JPN	93.278	0.653	-8.719	0.038	-2.741	0.0164	-0.856 ***		4.2373	0.2354	0.5116	0.3489
1	LUX	-11.463	-0.008	2.860	0.056	0.303	-0.0010	-0.446 *	**	0.9012	0.0530	0.4915	0.3120
1	NOR	75.048 ***	0.298 *	-7.261 ***	-0.505	-2.179 ***	0.0128 ***	-0.730 ***	*	0.5628	0.0281	0.7732	0.7052
1	SWE	69.250 ***	0.132	-6.487 ***	-0.091	-2.012 ***	0.0121 ***	-0.697 ***	*	0.8657	0.0433	0.6669	0.5669
1	USA	-43.636	-0.329	-3.274 *	-0.600	0.939	-0.0049	-0.661 **		3.4957	0.1748	0.5677	0.4380
2	AUS	-48.047	0.340	2.174	1.034	1.283	-0.0071	-0.759 **		2.6115	0.1451	0.4153	0.2204
2	BRA	21.738	0.425	-3.943 **	0.614	-0.688	0.0040	-0.600 ***	*	1.7899	0.0895	0.4980	0.3474
2	IDN	-45.684	-0.327	-0.212	1.383 *	1.021	-0.0051	-0.531 **	**	2.0416	0.1134	0.4441	0.2588
2	IND	-30.864	-0.559 *	5.974	0.330	0.887	-0.0035	-0.329	***	2.4539	0.1534	0.4101	0.1889
2	KOR	-96.365 **	-0.017	5.450	1.239	2.533 *	-0.0143 *	-0.534		3.6476	0.2026	0.4259	0.2346
2	MEX	21.697	0.137	-1.895	-1.124	-0.540	0.0028	-0.162	***	7.9474	0.4183	0.2322	-0.0103
2	MYS	-108.850 **	0.417	9.316 **	0.622	3.099 **	-0.0179 **	-0.524		3.1479	0.1749	0.4686	0.2915
2	SAU	14.046	-0.052	-2.990	0.117	-0.478	0.0030	-0.393 *	**	2.3475	0.1174	0.4031	0.2241
2	THA	-1.773	0.103	-3.731	-0.300	-0.091	0.0002	-0.527 **	*	2.8480	0.1780	0.3642	0.1258
2	TUR	-9.160	0.149	2.813	-0.308	0.357	-0.0018	-0.244 *	***	0.6989	0.0388	0.6962	0.5950

***: significance at the 1 % level
**: significance at the 5 % level
*: significance at the 10 % level

Table 5.20: **Stock adjustment results, fixed λ (equation 5.14); second traffic demand predicted results (equation 5.7); North American manufacturers price index, model 3 (table 3.12); Groups 1 and 2, results for the 8 other country regions are provided in appendix M.**

Group	Country	a_0	a_1	a_2	a_3	a_4	a_5	a_6	$\neq -1$	SSE	MSE	R^2	Adj R^2
1	CAN	19.303	0.548 **	-6.311 ***	-0.011	-0.619	0.0029	-0.885 ***		4.5532	0.2277	0.6752	0.5777
1	DEU	73.693 ***	-0.043	-7.649 ***	0.124	-2.189 ***	0.0133 ***	-0.685 ***	**	1.1307	0.0565	0.6878	0.5942
1	ESP	33.064 **	-0.497 **	-6.457 ***	0.206	-1.147 ***	0.0074 ***	-0.726 ***	*	0.7501	0.0375	0.7456	0.6693
1	FRA	34.959	-0.296	-6.508 ***	0.030	-1.213 **	0.0079 **	-0.838 ***		1.1411	0.0571	0.6561	0.5529
1	GBR	14.161	-0.084 **	-5.913 ***	-0.166	-0.679	0.0044 *	-0.751 ***	*	0.7012	0.0351	0.7622	0.6909
1	ITA	99.724 ***	-1.107 **	-9.421 ***	-1.314 **	-2.858 ***	0.0179 ***	-0.747 ***	*	1.4147	0.0707	0.7259	0.6436
1	JPN	127.701 **	-0.537	-12.013 *	-0.064	-3.842 **	0.0244 **	-1.049 ***		4.2127	0.2340	0.5145	0.3526
1	LUX	17.553	-1.335 **	-2.401	-0.051	-0.609	0.0047	-0.401 **	***	0.6905	0.0406	0.6104	0.4729
1	NOR	69.698 ***	0.268	-6.915 ***	-0.289	-2.048 ***	0.0122 ***	-0.790 ***		0.6359	0.0318	0.7438	0.6669
1	SWE	51.612 **	-0.113	-6.597 ***	0.012	-1.612 ***	0.0100 ***	-0.730 ***	*	0.8632	0.0432	0.6678	0.5682
1	USA	-68.751 *	-0.504	-3.134	-0.643	1.532 *	-0.0082	-0.680 **		3.6334	0.1817	0.5507	0.4159
2	AUS	-44.655	0.389 *	0.905	0.710	1.154	-0.0067	-0.641 **		2.3400	0.1300	0.4761	0.3015
2	BRA	27.433	0.316	-3.071	0.627	-0.792	0.0048	-0.583 ***	**	1.7647	0.0882	0.5051	0.3566
2	IDN	-39.981	-0.238	-0.965	1.094	0.865	-0.0044	-0.552 **	*	2.0919	0.1162	0.4304	0.2406
2	IND	-56.771	-1.206 *	6.227	1.419	1.364	-0.0051	-0.432 **	***	2.4109	0.1507	0.4205	0.2032
2	KOR	-81.481 *	-0.326	4.449	1.274	2.107	-0.0115	-0.540 *		3.5485	0.1971	0.4415	0.2554
2	MEX	21.343	0.158	-1.186	-1.554	-0.471	0.0022	-0.116	***	7.8639	0.4139	0.2402	0.0003
2	MYS	-136.153 ***	0.658 ***	14.661 ***	0.750	4.035 ***	-0.0234 ***	-0.501 *	*	2.2923	0.1274	0.6130	0.4841
2	SAU	17.465	-0.005	-2.789	0.377	-0.551	0.0034	-0.455 **	**	2.3967	0.1198	0.3906	0.2078
2	THA	-48.671	0.073	2.750	-0.090	1.277	-0.0071	-0.486 *	**	3.1342	0.1959	0.3003	0.0380
2	TUR	-27.782	-0.092	5.194 *	-0.213	0.871	-0.0044	-0.187	***	0.7278	0.0404	0.6836	0.5782

***: significance at the 1 % level
**: significance at the 5 % level
*: significance at the 10 % level

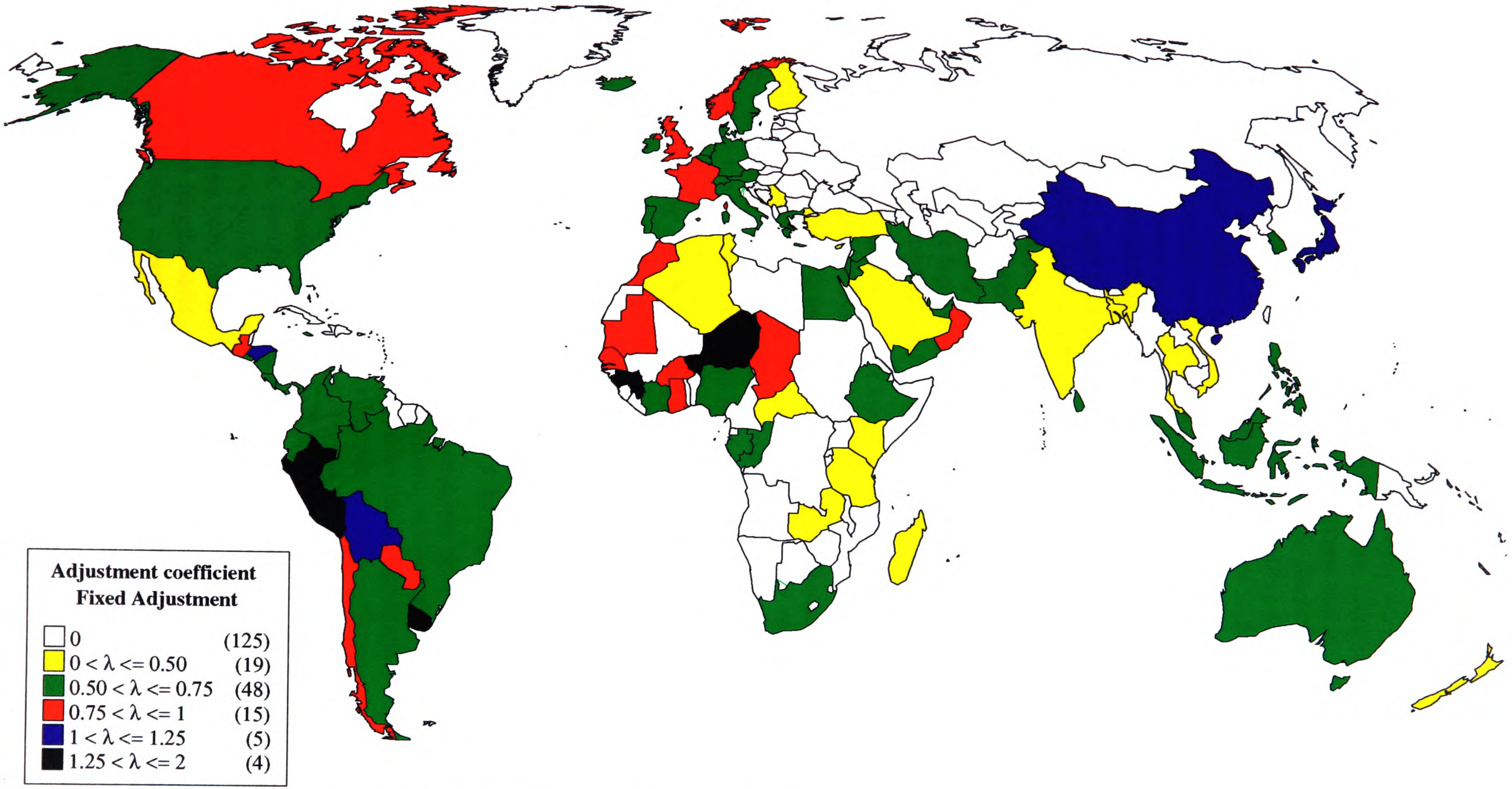


Figure 5.19: **Adjustment coefficient, fixed λ (equation 5.14); second traffic demand predicted results (equation 5.7); North American manufacturers price index, model 3 (table 3.12).**

5.4.2 Time varying stock adjustment

With changing times and technology, there is no reason to believe that countries would adjust their stock of satellite capacity at the same pace throughout the sample period. In this section, the time aspect of the adjustment parameter will be examined. The first method employed will still assume that all countries are different, but that the adjustment parameter varies with time in the form of an exponential form of the growth of other countries' orders. Then, countries will be grouped into the 10 previously defined groups, as well as completely pooled to determine whether there is a common trend for various groups of nations. Finally, the sample will be separated into two groups, country-owners of domestic satellites versus non-owners[18], in order to examine the influence of domestic ownership compared with shared ownership via organisations such as Intelsat.

Tables 5.21 and 5.22 present the country regressions for the same two groups of domestic satellite owners and categories of result as in the preceding section. Generally, with the introduction of a time varying adjustment coefficient, the fixed part of the coefficient represented by the negative value of a_6 in the tables is reduced. Once again, in these tables, the two columns to the right of the adjustment coefficient represent the difference from 0 and the difference from 1 respectively. As in the fixed case, the Japanese adjustment coefficient cannot be distinguished from 1.

If satellite operators predict that world orders will increase rapidly and follow suit, there is a danger of overshooting (making more of an adjustment). Hence a positive sign on the varying part of the adjustment coefficient, ω_i. Sometimes, though, this coefficient is negative, as in the case of France, Italy and the US to name a few. Before considering *other countries' orders* as the varying portion of the stock adjustment, a ratio of the change in *total world orders* was considered. While for most countries very similar results to those of this section were obtained, for the US however, the results were seriously different, if not disastrous. The high correlation between total world purchases of satellites and US spacecraft orders outlined in figure 5.8 was causing the model to misbehave for this particular country. This endogeneity problem was discovered after a further exam of this graph (figure 5.8) and provided great insight as to why ω_i is negative for the US. From 1982, US purchases of satellite capacity appear out of sync with the rest of the world orders. When world orders increased, those from the US decreased, hence the negative coefficient on ω_i.

By excluding the *own* country's purchases from the adjustment coefficient, and considering solely *other* countries' orders, the endogeneity problem mentioned above disappears. The negative coefficient on the change in other countries' orders in the case of the US may thus be attributable to various factors: congestion effects, launch queues, fixed production capacity, and so on. These factors contribute to the stretching of the adjustment lag for the US. For instance, when other countries' order satellites in great quantity, the limited number of satellite builders lengthens their order book, and output is rationed. In addition, there are a limited number of launches possible in a given year; launch preparation is equally complex as the development of a spacecraft and lengthy safety and testing procedures are involved. It may also be possible that foreign contracts may be more lucrative and therefore take priority for some manufacturers.

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[18] Note that these 'non-owners' of domestic satellites can be members of international and regional organisations such as Intelsat and Eutelsat.

Table 5.21: Stock adjustment results, variable λ (equation 5.17); first traffic demand predicted results (equation 5.6); North American manufacturers price index, model 3 (table 3.12); Groups 1 and 2, results for the 8 other country regions are provided in appendix M.

Group	Country	ω_i	a_0	a_1	a_2	a_3	a_4	a_5	a_6	$\neq -1$	SSE	MSE	R^2	Adj R^2
1	CAN	0.118	30.346	-0.026	0.326	-4.546	-0.874	0.0051	-0.529		0.5613	0.0510	0.9491	0.9167
1	DEU	-0.042	45.800	0.158	0.011	-2.904	-1.300	0.0080	-0.493	*	0.8942	0.0745	0.6574	0.4575
1	ESP	0.032	-7.812	0.387	-0.157	0.107	0.164	-0.0008	-0.490 *	*	0.5466	0.0456	0.7031	0.5298
1	FRA	-0.208	14.617	-0.012	0.110	-0.322	-0.419	0.0031	-0.480	*	0.7565	0.0630	0.6672	0.4730
1	GBR	-0.057	-2.422	-0.097	-0.041	0.558	0.034	0.0005	-0.499 *	*	0.5580	0.0465	0.6968	0.5200
1	ITA	-0.659	112.258 **	-0.018	-0.676	-9.409 *	-3.200 **	0.0192 **	-0.748 ***		1.2182	0.1015	0.7038	0.5311
1	JPN	0.984	110.487	0.323	-0.605	-7.956	-3.117	0.0188	-0.718 **		2.7565	0.2297	0.6477	0.4422
1	LUX	-0.259	-3.355	-0.323	0.395	2.741	0.119	0.0002	-0.308	**	0.6469	0.0588	0.5775	0.3086
1	NOR	0.245	25.029	0.984 **	-0.765 *	-0.891	-0.629	0.0031	-0.246	**	0.3199	0.0267	0.7867	0.6622
1	SWE	0.068	2.965	0.026	0.141	1.573	-0.050	0.0009	-0.371	**	0.4531	0.0378	0.7207	0.5578
1	USA	-0.259	-89.715 **	-0.163	-0.611 *	9.634 ***	2.582 ***	-0.0140 ***	-0.272 *	***	0.1024	0.0146	0.9751	0.9503
2	AUS	2.882 **	-61.184	-0.218	1.230 *	4.681	1.654	-0.0089	-0.280	***	1.2299	0.1025	0.6277	0.4106
2	BRA	-2.775	-32.903	0.913 **	-1.417 ***	4.829 *	1.056	-0.0068 *	0.204	***	0.7665	0.0639	0.6759	0.4868
2	IDN	0.830	-66.175 *	-0.849 *	2.322 **	-0.488	1.427	-0.0072	-0.261	***	1.1744	0.0979	0.5913	0.3529
2	IND	-0.275	-162.174	-0.363	0.244	30.375	5.142	-0.0267	-0.481 *	*	1.6212	0.1621	0.5010	0.1516
2	KOR	4.086 ***	-105.755 ***	0.086 **	0.919 ***	10.929 ***	3.003 ***	-0.0167 ***	-0.303 ***	***	0.9237	0.0770	0.7124	0.5446
2	MEX	0.251	-43.414	0.046	0.289	8.268	1.336	-0.0065	-0.394		6.8676	0.6243	0.3134	-0.1236
2	MYS	0.495	-36.204	0.559 ***	0.044	4.509	1.154	-0.0068	-0.594 **	*	0.7625	0.0635	0.7259	0.5659
2	SAU	-0.390	-25.454	0.045	0.320	4.574	0.800	-0.0041	-0.288	***	0.9659	0.0805	0.5871	0.3463
2	THA	0.695	-36.994	0.351	-0.549	3.663	1.152	-0.0070	-0.512		2.2551	0.2255	0.3758	-0.0612
2	TUR	-0.405	-13.737	0.216	-0.149	2.745	0.471	-0.0026	-0.242	***	0.5089	0.0424	0.7577	0.6164

***: significance at the 1 % level
**: significance at the 5 % level
*: significance at the 10 % level

Table 5.22: Stock adjustment results, variable λ (equation 5.17); second traffic demand predicted results (equation 5.7); North American manufacturers price index, model 3 (table 3.12); Groups 1 and 2, results for the 8 other country regions are provided in appendix M.

Group	Country	ω_i	a_0	a_1	a_2	a_3	a_4	a_5	a_6	$\neq -1$	SSE	MSE	R^2	Adj R^2
1	CAN	0.149	48.036	-0.334	0.509	-9.498	-1.541	0.0089	-0.505 *		0.5423	0.0493	0.9508	0.9195
1	DEU	0.006	42.586	-0.072	0.023	-4.004	-1.281	0.0082	-0.568 *		0.9073	0.0756	0.6523	0.4495
1	ESP	-0.010	3.896	-0.305	0.236	-1.708	-0.226	0.0021	-0.551 *		0.5380	0.0448	0.7077	0.5372
1	FRA	-0.206	-7.155	-0.378	-0.104	-1.723	0.006	0.0011	-0.722 **		0.6403	0.0534	0.7183	0.5539
1	GBR	-0.052	-9.045	-0.049	-0.036	-0.819	0.124	-0.0002	-0.506 *	*	0.5363	0.0447	0.7086	0.5387
1	ITA	-0.429	120.406 **	-0.859	-1.414 *	-10.776 **	-3.425 **	0.0210 **	-0.742 ***		1.0690	0.0891	0.7401	0.5885
1	JPN	1.058	131.009	-0.314	-0.668	-10.284	-3.780	0.0235 *	-0.811 **		2.6798	0.2233	0.6575	0.4577
1	LUX	-0.186	20.902	-1.422 *	0.125	-2.435	-0.702	0.0053	-0.397 *	***	0.4748	0.0432	0.6899	0.4926
1	NOR	-0.175	28.310	0.266	-0.295	-1.351	-0.791	0.0050	-0.494 *	*	0.4059	0.0338	0.7293	0.5714
1	SWE	0.062	3.181	0.021	0.137	1.858	-0.043	0.0009	-0.379	**	0.4531	0.0378	0.7207	0.5578
1	USA	-0.325	-101.513 ***	-0.063	-0.753 *	10.121 ***	2.887 ***	-0.0158 ***	-0.308 *	***	0.1304	0.0186	0.9683	0.9366
2	AUS	2.798 **	-74.739 **	0.008	1.058 *	7.060 **	2.103 **	-0.0116 **	-0.232	***	1.2533	0.1044	0.6207	0.3994
2	BRA	-0.619	-41.288	0.309	-0.727	7.465	1.346	-0.0076	0.034	**	0.8038	0.0670	0.6601	0.4618
2	IDN	0.322	-10.506	-0.439	1.155	-4.798	-0.041	0.0008	-0.455 *	**	1.4688	0.1224	0.4888	0.1907
2	IND	-0.395 *	-288.395 ***	-1.666 **	0.811	59.901 **	9.190 **	-0.0456 **	-0.661 ***		1.0505	0.1051	0.6766	0.4503
2	KOR	0.529	2.132	-0.688	0.979	-1.753	-0.205	0.0021	-0.512 **	*	1.4121	0.1177	0.5603	0.3038
2	MEX	0.243	-36.112	0.075	-0.077	7.747	1.169	-0.0057	-0.356	*	6.7827	0.6166	0.3219	-0.1097
2	MYS	0.565	-89.942 **	0.566 ***	0.623	10.645 **	2.714 **	-0.0156 **	-0.553 **	**	0.8509	0.0709	0.6941	0.5156
2	SAU	-0.411	-20.181	0.081	0.269	4.960	0.699	-0.0035	-0.271	***	0.9153	0.0763	0.6087	0.3805
2	THA	0.389	287.720 **	-1.441 ***	0.831	-44.147 **	-8.942 **	0.0506 **	-0.544 **	**	0.8417	0.0842	0.7670	0.6039
2	TUR	-0.381	-25.635	-0.004	0.042	4.135	0.778	-0.0040	-0.247	***	0.5627	0.0469	0.7321	0.5758

***: significance at the 1 % level
**: significance at the 5 % level
*: significance at the 10 % level

It is unlikely that this capacity constraint is binding as there are not enough countries other than the US that order domestic satellites, and they do not purchase in enough quantities. This situation may change in the future as more countries enter the space age. A second possibility that may occur in conjecture with the congestion effects described above, concerns the different cycles or orders mentioned in the first chapter (consult section 1.3.1). One cycle corresponds to the 'old' domestic satellite owners replacing their fleet, and the second cycle represents the more recent domestic satellite owners. If one considers the US to be the main constituent of this 'old' domestic satellite owners' group, this justifies the negative coefficient on the time varying part of the adjustment.

In what follows, nations will be grouped first into the ten different categories used earlier in this chapter, then completely pooled, in an attempt to discover whether the time trend in the adjustment coefficient is common across the sample. Tables 5.23 to 5.26 present the time varying stock adjustment results for each 10 groups of countries. The country dummy variables accompanying these regressions are provided in appendix M. Pooling nations into 10 groups increases the significance of the fixed portion of the adjustment coefficient but does not provide a common time varying coefficient. Only in the case of Africa and Central America is ω_i significant. Significant time trends are observed for categories 2 to 7, with the second group of domestic satellite owners (2), the Middle East (4) and Asia (5) possessing similar values. The coefficient on the price index gives close values for Africa (3), Asia (5), group 2 and the Middle East (4). It is possible that this variable may be corresponding to an 'Intelsat' effect as the matching of coefficient corresponds to the position of Intelsat over the Indian and Atlantic oceans.

Following the partial grouping of the countries of the sample, a complete pooling of the nations is provided below. Once again, the country dummy variables are provided in appendix M, and a map of the fixed effects follows these tables (tables 5.27 and 5.28). All four versions of the model yield almost identical results. The fixed part of the adjustment coefficient is around 0.32, significantly different both from 0 and 1, but the time varying portion of the adjustment is not significantly different from 0. In contrast, the bandwidth efficiency, has lost its significance from the previous analyses. Presumably, this variable has an influence on the capacity that is ordered. All the sign switching from the previous analyses is due to the introduction of an extra time varying variable in the model. Country fixed effects calculated from the pooled regressions presented in the two previous tables have been mapped, and the map (see figure 5.20) of the last regression (table 5.28 right-hand side) is presented below. In that map, the fixed effects are relative to the lowest coefficient of the country dummy variables, in this case, Hong Kong was that lowest value. So compared to Hong Kong, the United States appear to have a significantly different fixed effect.

The fixed effects presented in the map (see figure 5.20) appear once again related to the size of the country. This is perfectly understandable as bigger countries have greater needs for communication satellites as their population is more scattered throughout the area, and distances to cover, if they were to lay a cable or fibre optics network, are considerable. In contrast, in Europe the need for communication satellites is more restraint because of the small size of the countries. Furthermore, in Europe, a great number of communication satellites were launched with the sole purpose of providing DTH television broadcasting rather than voice transmissions.

Table 5.23: Stock adjustment results, by groups of countries, variable λ (equation 5.17); first traffic demand predicted results (equation 5.6); All manufacturers price index, model 3 (table 3.3); Country dummy variables are provided in appendix M.

Group	ω_1	a_0	a_1	a_2	a_3	a_4	a_5	a_6	$\neq -1$	SSE	MSE	R^2	Adj R^2	DFE
1	-0.0131	3.721	0.1009 *	-0.1396	1.276	-0.0512	0.00072	-0.3149 ***	***	19.566	0.1009	0.5209	0.4764	194
2	0.0749	-32.394 **	0.0494 **	0.0726	3.940 ***	0.9532 **	-0.00513 **	-0.2643 ***	***	26.374	0.1490	0.2681	0.1937	177
3	-0.0711 ***	-13.515 ***	0.0120	-0.1118	2.330 ***	0.4357 ***	-0.00210 ***	-0.3595 ***	***	16.843	0.0410	0.5587	0.5190	411
4	-0.0114	-30.646 ***	0.0014	0.1686	3.994 ***	0.9336 ***	-0.00487 ***	-0.3019 ***	***	15.624	0.0785	0.4279	0.3704	199
5	0.0101	-45.177 ***	0.0022	0.6162 **	3.124 *	1.2210 ***	-0.00655 **	-0.4486 ***	***	16.751	0.1299	0.3253	0.2469	129
6	0.0003	132.985	0.2802 ***	-0.0814	1.710	1.3626 *	-0.00794 **	-0.5334 ***	***	2.976	0.0902	0.4952	0.3575	33
7	-0.0622	-20.833 ***	-0.0126	-0.0483	3.504 ***	0.6250 ***	-0.00304 **	-0.3049 ***	***	6.623	0.0364	0.6486	0.6139	182
8	-0.1049	-4.863	0.4228 *	-0.2858	3.127	0.2474	-0.00113	-0.4185 *	**	0.264	0.0264	0.7023	0.4045	10
9	-0.0643 **	-4.856	0.0271	-0.3853 ***	0.971	0.1867	-0.00062	-0.6254 ***	***	6.171	0.0435	0.8261	0.8065	142
10	-0.0085	11.274	-0.0316	-0.4909 ***	0.295	-0.1082	0.00105	-0.5794 ***	***	8.079	0.0553	0.4865	0.4267	146

***: significance at the 1 % level
**: significance at the 5 % level
*: significance at the 10 % level

Table 5.24: Stock adjustment results, by groups of countries, variable λ (equation 5.17); first traffic demand predicted results (equation 5.6); North American manufacturers price index, model 3 (table 3.12); Country dummy variables are provided in appendix M.

Group	ω_i	a_0	a_1	a_2	a_3	a_4	a_5	a_6	$\neq -1$	SSE	MSE	R^2	Adj R^2	DFE
1	-0.0133	-0.840	0.0978	0.0375	1.601	0.0639	0.00010	-0.3127 ***	***	19.615	0.1011	0.5197	0.4751	194
2	0.0731	-33.738 ***	0.0486 **	0.1997	3.905 ***	0.9831 ***	-0.00530 ***	-0.2754 ***	***	26.305	0.1486	0.2700	0.1958	177
3	-0.0783 ***	-14.618 ***	0.0092	-0.3330 ***	2.906 ***	0.4889 ***	-0.00239 ***	-0.3174 ***	***	16.384	0.0399	0.5707	0.5321	411
4	-0.0094	-27.107 *	0.0017	0.0813	3.760 ***	0.8589 ***	-0.00448 ***	-0.3016 ***	***	15.687	0.0788	0.4256	0.3679	199
5	0.0085	-33.947 **	0.0022	0.2166	2.227	0.9304 **	-0.00502 *	-0.4564 ***	***	17.413	0.1350	0.2987	0.2171	129
6	0.0622	-59.560 **	0.2812 ***	0.3035	1.927	1.5396 **	-0.00887 **	-0.6044 ***	**	2.934	0.0917	0.5023	0.3468	32
7	-0.0636	-22.015 ***	-0.0120	-0.0219	3.623 ***	0.6574 ***	-0.00322 ***	-0.3008 ***	***	6.628	0.0364	0.6484	0.6136	182
8	-0.1480	-26.025	0.3998 *	-0.6252	7.954	0.9686	-0.00496	-0.3808 *	**	0.230	0.0230	0.7409	0.4817	10
9	-0.0587 *	-12.682	0.0367	0.0545	1.325	0.3768	-0.00163	-0.6398 ***	***	6.483	0.0457	0.8173	0.7967	142
10	-0.0095	-1.618	-0.0285	-0.0088	1.016	0.1751	-0.00047	-0.5694 ***	***	8.627	0.0591	0.4517	0.3878	146

***: significance at the 1 % level
**: significance at the 5 % level
*: significance at the 10 % level

Table 5.25: Stock adjustment results, by groups of countries, variable λ (equation 5.17); second traffic demand predicted results (equation 5.7); All manufacturers price index, model 3 (table 3.3); Country dummy variables are provided in appendix M.

Group	ω_i	a_0	a_1	a_2	a_3	a_4	a_5	a_6	$\neq -1$	SSE	MSE	R^2	Adj R^2	DFE
1	-0.0109	2.665	-0.0061	-0.1244	1.490	-0.0165	0.00064	-0.3156 ***	***	19.839	0.1023	0.5142	0.4691	194
2	0.0757	-33.849 **	0.0643 ***	0.0564	4.246 ***	1.0035 ***	-0.00541 **	-0.2675 ***	***	25.952	0.1466	0.2798	0.2066	177
3	-0.0697 **	-13.102 ***	0.0057	-0.1164	2.342 ***	0.4268 ***	-0.00205 ***	-0.3572 ***	***	16.855	0.0410	0.5584	0.5186	411
4	-0.0112	-32.673 **	-0.0049	0.1971	4.172 ***	0.9867 ***	-0.00516 ***	-0.2992 ***	***	14.857	0.0825	0.4069	0.3443	180
5	0.0090	-44.546 ***	0.0015	0.6054 **	2.948 *	1.1993 ***	-0.00645 **	-0.4503 ***	***	16.598	0.1287	0.3315	0.2538	129
6	0.0002	250.969	0.4517 ***	-0.0864	1.101	1.3964 **	-0.00837 **	-0.6028 ***	**	2.784	0.0844	0.5276	0.3988	33
7	-0.0539	-21.024 ***	-0.0271	-0.0507	3.418 ***	0.6264 ***	-0.00304 **	-0.3111 ***	***	6.602	0.0363	0.6497	0.6151	182
8	-0.1447	-37.891	0.2192	-0.2155	9.650	1.3110	-0.00658	-0.5176 **	***	0.327	0.0327	0.6322	0.2644	10
9	-0.0641 *	-3.309	0.0561	-0.3959 ***	0.936	0.1525	-0.00046	-0.6163 ***	***	6.106	0.0430	0.8279	0.8085	142
10	-0.0082	11.182	-0.0182	-0.4856 ***	0.168	-0.1088	0.00105	-0.5868 ***	***	8.125	0.0557	0.4836	0.4234	146

***: significance at the 1 % level
**: significance at the 5 % level
*: significance at the 10 % level

Table 5.26: Stock adjustment results, by groups of countries, variable λ (equation 5.17); second traffic demand predicted results (equation 5.7); North American manufacturers price index, model 3 (table 3.12); Country dummy variables are provided in appendix M.

Group	ω_i	a_0	a_1	a_2	a_3	a_4	a_5	a_6	$\neq -1$	SSE	MSE	R^2	Adj R^2	DFE
1	-0.0109	-1.882	-0.0058	0.0603	1.799	0.0971	0.00002	-0.3135 ***	***	19.871	0.1024	0.5134	0.4682	194
2	0.0720	-35.627 ***	0.0638 ***	0.2012	4.235 ***	1.0445 ***	-0.00564 ***	-0.2798 ***	***	25.876	0.1462	0.2819	0.2089	177
3	-0.0771 **	-14.242 ***	0.0054	-0.3370 ***	2.918 ***	0.4808 ***	-0.00234 ***	-0.3153 ***	***	16.387	0.0399	0.5706	0.5320	411
4	-0.0086	-28.722 *	-0.0049	0.1124	3.896 ***	0.9044 ***	-0.00473 ***	-0.3006 ***	***	14.929	0.0829	0.4040	0.3411	180
5	0.0073	-33.425 **	0.0016	0.2029	2.065	0.9116 **	-0.00492 *	-0.4574 ***	***	17.244	0.1337	0.3055	0.2247	129
6	0.0002	353.036	0.4567 ***	0.2872	1.153	1.5441 **	-0.00915 **	-0.6753 ***	*	2.759	0.0836	0.5320	0.4043	33
7	-0.0553	-22.251 ***	-0.0267	-0.0271	3.548 ***	0.6603 ***	-0.00323 ***	-0.3062 ***	***	6.607	0.0363	0.6495	0.6148	182
8	-0.1811	-61.660	0.1600	-0.5357	14.654	2.1020	-0.01079	-0.4929 **	**	0.303	0.0303	0.6586	0.3171	10
9	-0.0566 *	-11.321	0.0538	0.0451	1.313	0.3480	-0.00149	-0.6305 ***	***	6.438	0.0453	0.8185	0.7981	142
10	-0.0095	-1.832	-0.0170	-0.0170	0.904	0.1728	-0.00047	-0.5761 ***	***	8.661	0.0593	0.4495	0.3854	146

***: significance at the 1 % level
**: significance at the 5 % level
*: significance at the 10 % level

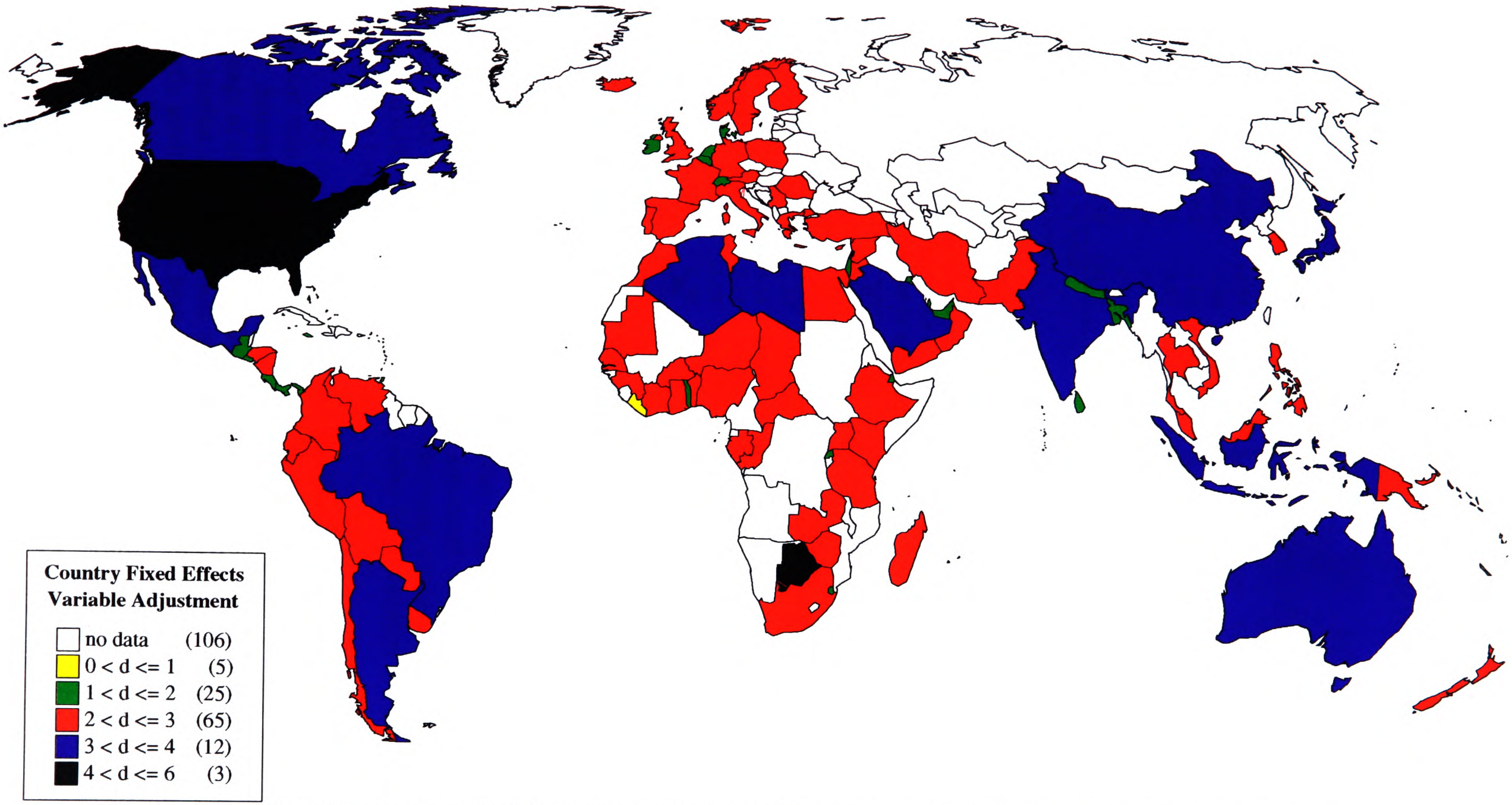


Figure 5.20: **Fixed effects results, variable λ (equation 5.17); second traffic demand predicted results (equation 5.7); North American manufacturers price index, model 3 (table 3.12).**

Table 5.27: Stock adjustment pooled results, variable λ (equation 5.17); first traffic demand predicted results (equation 5.6); All (left) and North American (right) manufacturers price indices, model 3 (tables 3.3 and 3.12); Coefficients of the country dummies are provided in appendix M.

	SSE	MSE	R^2	Adj R^2		SSE	MSE	R^2	Adj R^2
	138.9544	0.0832	0.44	0.3896		138.9871	0.0832	0.44	0.3894
	Estimate	**Std Err**	**T-Ratio**	**Prob>|T|**		**Estimate**	**Std Err**	**T-Ratio**	**Prob>|T|**
ω	-0.0111	0.0094	-1.19	0.2356	ω	-0.0114	0.0094	-1.21	0.2253
a_0	-18.7731	4.1605	-4.51	0.0001 ***	a_0	-19.7449	3.8881	-5.08	0.0001 ***
a_1	0.0032	0.0014	2.30	0.0215 **	a_1	0.0032	0.0014	2.30	0.0215 **
a_2	-0.0606	0.0592	-1.02	0.3063	a_2	-0.0515	0.0636	-0.81	0.4180
a_3	3.1718	0.3658	8.67	0.0001 ***	a_3	3.2737	0.3563	9.19	0.0001 ***
a_4	0.6375	0.0949	6.72	0.0001 ***	a_4	0.6617	0.0895	7.39	0.0001 ***
a_5	-0.0032	0.0005	-6.04	0.0001 ***	a_5	-0.0033	0.0005	-6.61	0.0001 ***
a_6	-0.3201	0.0159	-20.14	0.0001 ***	a_6	-0.3179	0.0164	-19.40	0.0001 ***

***: significant at the 1 % level
**: significant at the 5 % level

Table 5.28: Stock adjustment pooled results, variable λ (equation 5.17); second traffic demand predicted results (equation 5.7); All (left) and North American (right) manufacturers price indices, model 3 (tables 3.3 and 3.12); Coefficients of the country dummies are provided in appendix M.

	SSE	MSE	R^2	Adj R^2		SSE	MSE	R^2	Adj R^2
	138.3581	0.0839	0.43	0.3860		138.3930	0.0839	0.43	0.3858
	Estimate	**Std Err**	**T-Ratio**	**Prob>|T|**		**Estimate**	**Std Err**	**T-Ratio**	**Prob>|T|**
ω	-0.0114	0.0095	-1.20	0.2320	ω	-0.0117	0.0096	-1.22	0.2218
a_0	-18.7473	4.1348	-4.53	0.0001 ***	a_0	-19.7256	3.8635	-5.11	0.0001 ***
a_1	0.0016	0.0007	2.12	0.0339 **	a_1	0.0016	0.0007	2.12	0.0338 **
a_2	-0.0602	0.0597	-1.01	0.3138	a_2	-0.0498	0.0642	-0.78	0.4380
a_3	3.1616	0.3694	8.56	0.0001 ***	a_3	3.2625	0.3598	9.07	0.0001 ***
a_4	0.6350	0.0958	6.63	0.0001 ***	a_4	0.6594	0.0904	7.30	0.0001 ***
a_5	-0.0032	0.0005	-5.96	0.0001 ***	a_5	-0.0033	0.0005	-6.52	0.0001 ***
a_6	-0.3193	0.0160	-19.97	0.0001 ***	a_6	-0.3173	0.0165	-19.25	0.0001 ***

***: significant at the 1 % level
**: significant at the 5 % level

In what follows (see figures 5.29 and 5.30), the coefficient ω was separated into two separate values depending on whether countries own domestic satellites or not: the dummy variable for the first group associated with ω_1 takes the value 1 if the country owns a domestic satellite and 0 otherwise; conversely, the dummy variable associated with the second group takes the value 0 if the country possesses a domestic satellite, and 1 otherwise.

Only ω_2 has a negative and significant value, and this value is more important than the measure calculated in the previous tables (see tables 5.27 and 5.28). Separating the time varying adjustment coefficient into two values had the advantage of rendering the coefficient for non-domestic satellite owners, i.e. countries using Intelsat satellite services only, negative and significant. In other words, non-domestic satellite owners have a different purchasing agenda than domestic satellite owners. This would further suggest that Intelsat and US satellite operators alternate their orders to the North American spacecraft producers. Moreover, we also note that a_6 has generally decreased towards -0.26 while previously, its value was around -0.32. Otherwise, the results are very similar to the two previous tables (see tables 5.27 and 5.28).

Table 5.29: Stock adjustment pooled results, variable λ (equation 5.18); first traffic demand predicted results (equation 5.6); All (left) and North American (right) manufacturers price index, model 3 (table 3.3 and 3.12); Coefficients of the country dummies are provided in appendix M.

	SSE	MSE	R^2	Adj R^2		SSE	MSE	R^2	Adj R^2
	146.0967	0.0874	0.4078	0.3586		146.0546	0.0874	0.4080	0.3588
	Estimate	**Std Err**	**T-Ratio**	**Prob>|T|**		**Estimate**	**Std Err**	**T-Ratio**	**Prob>|T|**
ω_1	0.0099	0.0251	0.39	0.6943	ω_1	0.0097	0.0254	0.38	0.7036
ω_2	-0.0431	0.0116	-3.71	0.0002 ***	ω_2	-0.0440	0.0118	-3.74	0.0002 ***
a_0	-24.0025	3.3902	-7.08	0.0001 ***	a_0	-24.4412	3.1628	-7.73	0.0001 ***
a_1	0.0027	0.0014	1.89	0.0590 *	a_1	0.0027	0.0014	1.89	0.0584 *
a_2	-0.0502	0.0603	-0.83	0.4053	a_2	-0.0702	0.0646	-1.09	0.2770
a_3	3.6860	0.3645	10.11	0.0001 ***	a_3	3.7754	0.3532	10.69	0.0001 ***
a_4	0.7268	0.0955	7.61	0.0001 ***	a_4	0.7409	0.0900	8.23	0.0001 ***
a_5	-0.0037	0.0005	-7.01	0.0001 ***	a_5	-0.0038	0.0005	-7.53	0.0001 ***
a_6	-0.2622	0.0148	-17.70	0.0001 ***	a_6	-0.2589	0.0152	-16.99	0.0001 ***

***: significant at the 1 % level
*: significant at the 10 % level

Table 5.30: Stock adjustment pooled results, variable λ (equation 5.18); second traffic demand predicted results (equation 5.7); All (left) and North American (right) manufacturers price index, model 3 (table 3.3 and 3.12); Coefficients of the country dummies are provided in appendix M.

	SSE	MSE	R^2	Adj R^2		SSE	MSE	R^2	Adj R^2
	145.4368	0.0881	0.4050	0.3549		145.3996	0.0881	0.4052	0.3551
	Estimate	**Std Err**	**T-Ratio**	**Prob>|T|**		**Estimate**	**Std Err**	**T-Ratio**	**Prob>|T|**
ω_1	0.0100	0.0253	0.40	0.6920	ω_1	0.0098	0.0256	0.38	0.7013
ω_2	-0.0439	0.0119	-3.68	0.0002 ***	ω_2	-0.0448	0.0121	-3.71	0.0002 ***
a_0	-23.9357	3.4213	-7.00	0.0001 ***	a_0	-24.3786	3.1919	-7.64	0.0001 ***
a_1	0.0015	0.0008	1.87	0.0617 *	a_1	0.0015	0.0008	1.88	0.0604 *
a_2	-0.0492	0.0608	-0.81	0.4187	a_2	-0.0678	0.0651	-1.04	0.2980
a_3	3.6788	0.3680	10.00	0.0001 ***	a_3	3.7663	0.3567	10.56	0.0001 ***
a_4	0.7252	0.0964	7.52	0.0001 ***	a_4	0.7393	0.0908	8.14	0.0001 ***
a_5	-0.0037	0.0005	-6.93	0.0001 ***	a_5	-0.0038	0.0005	-7.45	0.0001 ***
a_6	-0.2613	0.0149	-17.54	0.0001 ***	a_6	-0.2581	0.0153	-16.85	0.0001 ***

***: significant at the 1 % level
*: significant at the 10 % level

5.4.3 Comments on the results

Many models, type of analyses have been performed and examined in order to determine the rate of adjustment of different countries concerning their fleet of communication satellites. In the following commentary, we will attempt to explain why do countries adjust at different rates.

Adjustment coefficients vary considerably within the G7. Canada, Japan and the United States seem to adjust their stock of satellites relatively fast, and that in many versions of the model. To our knowledge, these two North American neighbours are the only ones to have sold off their excess capacity to other customers. Recall that US-owned satellites Satcom Ku3 and Ku4, were sold to SES of Luxembourg (renamed Astra 1A), and Intelsat (renamed Intelsat K) respectively. From Canadian ownership, Anik D2 was leased to GE-Americom to replace their Satcom 4 that failed prematurely, then returned to Telesat, and later sold to Arabsat to supplement Arabsat 1C before the launch of Arabsat 2 (Matra-Marconi, 1995). If

many more satellites had been sold on the 'second-hand' market, a coefficient larger than 1 for the adjustment parameter would have expected, but as the phenomenon is still regarded as an exception, this is not the case.

In general, it was found that the second group of domestic satellite owners adjust more slowly than their richer counterparts. In the rest of the world, not only does adjustment speed suffer from the long time-to-build framework of the industry, but also from the heavy infrastructure intrinsic to Intelsat. The decision to launch a new series of satellites above a certain region involves all the member states of the organisation. As a consequence, adjustment follows regional demand as opposed to individual countries demand. In Western Europe, most countries are relatively similar in their adjustment parameter, as the majority lies within a 0.2 interval. In contrast, in Africa and the Middle East, countries cover almost the entire spectrum of adjustment values. In South America, where there are talks of a joint organisation consisting of Bolivia, Colombia, Ecuador, Peru and Venezuela, operating a satellite called Condor, most of these are amongst the moderate adjusters. In the south of this sub-continent, Argentina, which has a relatively slow adjustment coefficient compared to its peers, has ordered 2 Nahuel satellites from the D2A consortium[19].

Compared with the groups obtained by Antonelli (1995) when classifying countries by rate of growth of telecommunication intensity, within the domestic satellite club, the US and Japan are falling behind in term of telecommunication intensity, but their adjustment coefficient can certainly not be considered as laggard compared with the rest of the world. Comparing communication via satellite, and particularly the evolution of the stock of satellites itself, with the entire telecommunication market is relatively difficult as satellites only occupy a small part of total communication investment, and international telephone traffic, represents a fraction of the total telephone traffic (local, national and international). Consequently, comparing the rate of growth of investment in telecommunication with the aforementioned adjustment coefficient, can only lead to speculation on the growth of alternative technologies. For example, the US has a very high adjustment coefficient compared with a moderate telecommunication investment growth, suggesting that the country may not invest as much as expected in alternative methods such as fibre optics and cable to satisfy international and national telecommunication traffic demand. This, however, is untrue as the US is a pioneer in fibre optics technology, and this has caused serious damage to the market share of the satellites in global communications services. In the late 1980s, the country experienced an over capacity of satellite bandwidth and had to sell off satellites to foreign customers.

The above commentary concentrated on countries owning domestic communication satellites. Unfortunately, the very heavy organisational infrastructure of Intelsat renders the analysis of the stock adjustment for non-domestic satellite owners, i.e. the majority of Intelsat member states, rather difficult to analyse.

5.5 Conclusions

In the first part of the chapter, we have developed a stock adjustment model that makes use of a great number of telecommunication indicators. Principal components were extracted from too numerous but relevant demand variables in order to reduce their number to a more practical size. The number of main lines in

[19] Consortium consisting of DASA (Deutsche Aerospace), Aérospatiale and Alenia.

operation and the number of television receivers were found to be two of the main constituents of the first principal component throughout the 7 country groups under consideration. From these principal components, the traffic demand was constructed using two methods: the first calculated standard principal components, whereas the second treated new technology as separate and assumed that the weights on the main or 'old' technology variables are the same through the entire sample. These two calculations of the traffic demand were introduced in the stock demand equation.

The stock demand equation was then introduced into the stock adjustment model. A first series of regressions were fitted to a fixed adjustment model. In this model, Japan was the fastest adjuster of the domestic satellite club, but Canada and the USA followed closely with a more humble position as moderate adjusters. Not surprisingly, Luxembourg was at the bottom of the league in this group, and this is due to the small usage of the satellites it launches because of its small population and area.

The significance of the country dummy variables and the similarities between the coefficients in the country regressions led us to believe that a fixed adjustment coefficient might be too simplistic. Two models were then introduced to deal with the variability of the adjustment parameter. The first, divided the coefficient into an exponential depending on the growth of other countries' purchases of commercial communication satellites and a fixed adjustment, and the second, divided the exponential into two subgroups, the owners of domestic satellites versus the rest of the world. Analysing the former model, more than half the countries under study kept a significant adjustment coefficient, but very few had a significant coefficient on the growth rate of other countries' orders. For the United States, the time varying part of the adjustment coefficient was negative, implying that it is increasing its rate of change of satellite capacity when the rest of the world rate of orders declines. This is also supported by the fact that the US purchases of satellites were out of sync with that of the rest of the world from the early 1980s. Two main reasons for this discrepancy between the US and the rest of the planet were proposed. First, there may be capacity constraints on the satellite production side: long launch queues or congestion effects. Second, the industry may simply follow two different cycles of orders as first postulated in the first chapter, the 'old' domestic satellite owners renewing their fleet of satellites after the later adopters launched their fleet, and before these new comers replaced their obsolete fleet of spacecraft.

Both models were fitted to the whole sample in an attempt to verify the claim that all countries adjust at the same pace following the rate of growth of other countries' orders. In the first case, the model was very well fitted and the coefficient on one of the constituent of the time varying adjustment parameter was significant. In addition, the results on the last version of the model showed that the part of the time varying coefficient that is related to domestic satellite owners is not significant. This assumes that these countries adjust at a different pace than the rest of the world. In a sense, this result is not very surprising as each country in the rest of the world owns a proportion of all Intelsat satellites in view, when one satellite is launched over a given region, all country members show an increase in their satellite stock. Whereas in the case of domestic satellite owners, only one country benefits from the launch of a satellite. This second model only picks up the fact that country owners of domestic satellites are different from one another, while in the rest of the world the similarity is forced by the structure of the likes of Intelsat. The first model of time varying adjustment coefficient is therefore preferred to the second one for this reason. We

have discovered that countries do adjust as a different pace, and that this pace varies with time but not necessarily as a function of the rate of growth of other countries' orders. Instead, the time varying aspect of the adjustment has allowed us to identify cycles of orders.

Domestic satellite owning countries in the western world seem to adjust faster than their less wealthy counterparts. Further, the emerging South East Asia is increasing its impact on the world of satellite communications with a rate of adjustment greater than the rest of the second group of domestic satellite owners. Furthermore, in the calculation of the principal components, the importance of the financial markets was noted for this second group of satellite owners as well as for South East Asia in general. It is possible that the financial sector of these countries may be pushing the need for more sophisticated telecommunications. Moreover, with the introduction of the global satellite services provided by the likes of Motorola Iridium now starting to appear and offer global services, the shape of the world telecommunication industry may change dramatically.

Annex 5.1 Logit approximation

Because $S_{if}(t)$ could not be evaluated accurately, it has to be approximated.

We might start with a logistic function:

$$\Phi(t) = S_{js}(t) + S_{f}(t) = S_{i}^{*}(t)\frac{1}{1+e^{-\varphi t}} \tag{5.i}$$

the stock of satellite of country *i*, thus becomes:

$$S_{is}^{*}(t) = S_{i}^{*}(t)\frac{e^{-\varphi t}}{1+e^{-\varphi t}} \tag{5.ii}$$

Taking logs, we get:

$$\ln\left(S_{ist}^{*}\right) = \ln\left(S_{it}^{*}\right) - \varphi t - \ln\left(1+e^{-\varphi t}\right) \tag{5.iii}$$

Because of the short time series available for this study, such a non-linear framework may prove troublesome and a simplified version of this equation may be needed. Expanding the last term of this equation using Taylor-MacLaurin series yields:

$$\ln\left(1+e^{-\varphi t}\right) \cong \ln\left(1+e^{-\varphi t}\right)\Big|_{t=0} - \frac{\varphi e^{-\varphi t}}{\left(1+e^{-\varphi t}\right)}\Big|_{t=0} t + \frac{\varphi^{2} e^{-\varphi t}}{\left(1+e^{-\varphi t}\right)^{2} 2!}\Big|_{t=0} t^{2}$$

$$- \frac{\varphi^{3} e^{-\varphi t}\left(1-e^{-\varphi t}\right)}{\left(1+e^{-\varphi t}\right)^{3} 3!}\Big|_{t=0} t^{3} \tag{5.iv}$$

$$+ \frac{\varphi^{4} e^{-\varphi t}\left(1-4e^{-\varphi t}+e^{-2\varphi t}\right)}{\left(1+e^{-\varphi t}\right)^{4} 4!}\Big|_{t=0} t^{4} + \ldots$$

Replacing t by 0 yields:

$$\ln\left(1+e^{-\varphi t}\right) \cong \ln(2) - \frac{\varphi t}{2} + \frac{\varphi^{2} t^{2}}{4 \cdot 2!} - \frac{\varphi^{4} t^{4}}{8 \cdot 4!} + \ldots \tag{5.v}$$

Using a second degree polynomial as an approximation to this, equation (5.29) becomes:

$$\ln\left(S_{ist}^{*}\right) = \ln\left(S_{it}^{*}\right) + \varphi t + \psi t^{2} \tag{5.vi}$$

6. Conclusion

Commercial communication satellites, in the industry producing them, have evolved considerably during the three decades following their introduction in 1965. Not only has the technology of the satellite changed but there are now more vendors and the industry supplying them is no longer exclusively dominated by US companies. In the beginning, aerospace manufacturing firms used the experience gained in the provision of missiles and communication systems to produce and launch civilian satellites. In the late 1960s, Intelsat was the only purchaser of commercial communication satellites; Hughes Aircraft and TRW shared the market for these spacecraft up until the mid-1970s. Since then, the market share of these two spacecraft producers has contracted to the benefit of other North American and European manufacturers. The decline in concentration on the supply side of the communication satellite market has been paralleled by a similar trend on the demand side, as the number of satellite service providers grew steadily from the mid-1970s onwards. The latter trend has accelerated following the deregulation of telecommunications.

Despite the entrance of a number of satellite suppliers, there is little indication of excess capacity having developed in the industry. Only a few firms are credible bidders for a contract promising rapid delivery because of the lengthy period required to build communication satellites and the fact that many other firms' facilities are engaged in fulfilling past orders. The pressure on existing capacity is increased by the fact that the number of new satellite orders appears to be bunched in time and has followed a cyclical rhythm over the industry's history. The descriptive account of the industry in chapter 1 takes note of the volatility in the behaviour of satellite orders within the period studied, and traces this primarily to the behaviour of orders for regionally and nationally owned equipment. Intelsat has kept the pace of demand by continually launching satellites. Other nationally and regionally owned satellites were first launched in early 1970s and these have generated two visible waves of replacements, the first in the early 1980s and the second a decade later, in the early 1990s.

In the case of complex goods involving high technology, it is very difficult to understand supply and demand without prior knowledge of the nature of that product. The examination of the technical characteristics of satellites in chapter 2 identified three distinct generations of equipment corresponding to the satellites ordered from 1965-75, 1976-84, and 1985-93. Furthermore, systematic differences were found in the characteristics built by European and North American manufacturers and there were corresponding differences in the attributes of satellites of different groups of purchasers. In addition, clusters of satellites with common purposes were identified: direct broadcasting satellites consistently possessed a high power to bandwidth capacity ratio, and, similarly to mobile communication satellites, possessed a higher effective isotropic radiated power to bandwidth capacity ratio.

In the first part of chapter 3, the relationship between the price of a civilian communication satellite and individual technical characteristics, which were thought to be important by engineers, was examined. A reasonably consistent relationship appears to exist between a satellite's launch mass and its price, and the engineering

'rule of thumb' stipulating a constant price per kilogram of spacecraft appears to decline over the period as a whole. We have investigated this more closely and controlled for other characteristics. To do so, hedonic price regressions were estimated. The shadow values to the purchasers of 15 distinct technical aspects were evaluated by this technique which showed the launch mass to have a strong statistically significant relationship with the contract price. Furthermore, customers' willingness to pay for power shifted as a consequence of improvements in the technology, from crude power to the more precise effective isotropic radiated power, which is taken to be an approximate measure of the quality of the signal and a good indicator of the facilities necessary to its good reception on earth. In addition, the effect of sophisticated software compression techniques was reflected on the shadow values of the number of transponders and their bandwidth capacity was reduced. Tests for structural change pointed to the validity of separating the industry's technological history into three time periods corresponding to the three generations of satellites mentioned above. Statistically significant differences in the shadow values assigned to some characteristics were found across the regions of ownership and manufacture. In Europe for instance, the greater use of satellites for direct broadcasting services increases the valuation placed on the end-of-life power of the satellite.

Price indexes for satellites of a constant quality were constructed from the estimates obtained from the hedonic regressions of the third chapter. The price trend of constant quality satellites was found to be downward over the period as a whole, but this was not a continuous or a steady trend and reflected differences between the various regions. The price of spacecraft ordered by non-European countries other than the US actually increased during the first half of the period and decreased thereafter. A possible explanation for this is that the orders from those countries were not pushing the boundaries of the technology, but instead called for copies of designs that had been developed earlier, mainly for the US domestic market. In the 1970s, the satellites bought by non-European countries other than US were cheaper than those of a similar quality level ordered by these countries around 1980. This may be a consequence of the lower willingness, and possibly ability, in these countries, to pay for a new technology that requires considerable related investment in ground infrastructure. More appropriately, this is a case of intertemporal price discrimination as the cheaper satellites were purchased at a later date once the main fixed costs of development had been absorbed by the original design contract.

Comparing the prices of European and US satellites, holding constant their characteristics, it was discovered that US-built satellites were more expensive to European customers than their own European-built spacecraft. In addition, US manufacturers supplied satellites to Europe at a lower price than they would have done to US customers. Because of the small number of 'transatlantic' orders, i.e. a manufacturer from one side of the ocean supplying a customer from the other side, the discovery that European builders are cheaper than US producers for spacecraft bought by Europe is puzzling. A possible explanation is that European manufacturers, having entered the commercial space age at a later date, have developed a technology appropriate to their needs, one that used a higher frequency in signal transmission than was typical in the US at the time. Heavier sunk costs in the US for lower frequency equipment prevented the migration of US service providers to newer technology. This

permitted European manufacturers to become leaders in higher frequency transponder technology.

Focusing on the regression results for US-built satellites, it was found that contract prices bore a stable relationship to a particular measure of the engineering complexity. The same relationship was preserved within each of the three sub-periods corresponding the three generations. We interpreted this result as indicating that vendors follow a simple mark-up pricing rule, because the 'complexity' of a spacecraft is more immediately related to its total unit cost than to the strength of market demand that depends upon the technical characteristics of satellites. It is plausible to suppose that the military procurement history of the US vendors has left a legacy of mark-up pricing, originating in 'cost plus' contracts, and that such formulas are still being followed by spacecraft vendors. From this evidence, it would appear that although the degree of concentration has declined over the years, this has not altered the degree of monopoly that characterises the US market. Over time, within each technological regime, the same relationship between the variations in the price and complexity levels is found for a given price. Although, from one technological regime to the next, the mean price to complexity ratio has declined. The basic technological changes are being passed along to the consumer. The mark-up relationship within each technological regime greatly simplifies the identification problem in that it is assumed that within the technological regime, the vendors behave as if they were picking points on the demand curve rather than being price takers. The major changes over the longer run in the price complexity relationship are traceable to the decline in the cost of the components of satellites available for purchase by any vendor and therefore passed through to the purchasers by the mark-up pricing formula.

Using the hedonic price indices calculated in the third chapter, total factor productivity measures were calculated by the dual method. Gross total factor productivity rose prior to 1980, but fell back partially post-1980. Because the productivity of purchased inputs was declining, the price of components has decreased faster than that of satellites over this period, implying a substitution of purchased inputs for value added, and a consequent decrease in the ratio of gross output to purchased inputs. A net output, or real value added, productivity measure was therefore estimated by the dual method which showed that the increase in productivity was confined mainly in the pre-1980 era. The reason this productivity measure is rising faster is that there is a certain degree of monopsony power in engineering inputs and we think that the weight on labour inputs in this calculation are too heavy. Because the labour force is highly skilled, prefers to work in the aerospace industry for this reason, and has few potential employers, satellite producers are a monopsony on the labour market. Therefore we think that because of this monopsony in the labour market, satellite manufacturers employ fewer engineers and technicians than a competitive firm and are taking account of a share of labour that is too small and a share of profit that is too high. By increasing the share of labour inputs, maintaining the share in material inputs constant and constant returns, the growth of total factor productivity obtained was higher, but only post-1982, before this date, a monopsony (decrease in the labour share) in the labour market would overestimate total factor productivity growth.

Learning coefficients, calculated from these productivity measures and the cumulative complexity growth (representing a measure of experience), were only

slightly smaller than the values found for the airframe manufacturing industry more than 30 years ago. This smaller coefficient is not surprising since satellites are custom-made goods. As expected, learning coefficients obtained from the net total factor productivity growth were significantly higher than that for the gross measures. Further, an increasing degree of monopsony in the labour market increased the learning coefficient.

The driving factor behind this industry is the changing product, i.e. the satellite. Firms compete in this market and do not venture into other industries. In a sense, Schumpeterian competition in innovation for the improvement of the performance and quality of satellites is what drives this industry. The fact that Europe and the US used different frequency bands, Ku and C bands respectively, for a time only resulted from the creation of a niche market in Europe, but was also due to the fact that North America possessed and extensive network of cables for the television market. This therefore represents market segmentation in the industry. It would be interesting to see if this type of competition also applies to other high technology sectors.

Finally, the last chapter of the thesis examined the demand for commercial communication satellites using world telecommunication indicators as well as the results obtained from the supply-side analysis of the third and fourth chapters. The factors that shift demand in the countries serviced by communication satellites were investigated to find whether there are global demand drivers. In order to do so, a great number of telecommunication and broadcasting indicators available had to be reduced by extracting their principal components. The number of main lines in operation, the number of televisions, the number of inhabitants and the gross domestic product were the main constituents of the first principal component for most world regions. Traffic demand was then predicted from the international outgoing telephone traffic, using the first four principal components estimated earlier. Using this predicted traffic demand measure, a stock demand equation was fitted to the data. This stock demand is the main constituent of the stock adjustment model. By relating the growth rate of the stock of satellite capacity to the growth rate of demand for satellite services as part of the demand for communication services as a whole, we can explain investment, or launches of, satellites as a reflection of the adjustment stock of satellite capacity. One of the goals of this chapter was to discover whether various countries in the world adjust their stock of satellite capacity at a different pace. Two models of stock adjustment were examined: the first considering a fixed adjustment coefficient; and the second allowing for a time varying stock adjustment. Analysing the former model, most countries under study yielded a significant adjustment coefficient, with the Western World domestic satellite owners adjusting faster than others. In particular, Japan, was found to be the fastest adjuster in the first group of domestic satellite owners. When we introduced a time varying aspect to the adjustment coefficient, we noticed that some countries had a negative coefficient, implying that when the rest of the world orders increase, their orders decrease. This was found particularly for the US. A more in depth examination of the world orders led us to discover that the US, for instance, is out of sync with the rest of the world regarding their purchase of satellite bandwidth capacity. Further, from the graphs of the first chapter outlying the time periods corresponding to boosts of orders, it was shown that the domestic satellite market follows cycles of orders, and that two main groups of purchasers with orders separated theirs by three to five years are present. As

mentioned before, a second wave of orders is repeated about a decade later when the first group replaces its fleet and then approximately five years after that when the second group renews its fleet. The findings of the fifth chapter strongly support this hypothesis, especially for the US which clearly is part of the pioneers' group, while most of the rest of the world orders satellites a few years after. A second explanation for this difference in the time varying part of the adjustment coefficient may be attributable to capacity constraints on the manufacturers' part, long launch queues with favoured countries allowed to jump the queue, or general congestion effects.

So far, an overview of the commercial communication satellite market has been studied. A further investigation would examine key manufacturers in North America and Europe in greater details in order to calculate more accurate productivity measures. In addition, productivity measures would benefit from a precise time series of the cost-share weights of inputs in the satellite manufacturing industry. The increasing interaction between prime-contractors and their sub-contractors also needs to be examined further as it clearly affects the price of satellites. For instance, the question as to whether there is a tendency towards specialisation of firms into a few subsystems linked by joint ventures, or as is the tendency in Europe, towards the merger of specialised firms for greater vertical and horizontal integration needs to be examined. The effects of the new generation of small low earth orbit satellites launched in groups and deployed in constellations also demand further study, as economies of scale clearly enter in the production process and the launch of these smaller cheaper spacecraft. Accurate data concerning alternative technologies is also required in order to examine the extent of the competition they constitute for communication satellites.

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Appendices

APPENDIX A : LIST OF SATELLITES 251

APPENDIX B : LIST OF THE MANUFACTURERS, CUSTOMERS AND OPERATORS OF COMMUNICATION SATELLITES 260

APPENDIX C : DEMAND-SIDE COUNTRIES 263

APPENDIX D : GROWTH OF DEMAND VARIABLES 266

APPENDIX E : ORBIT DESCRIPTION 276

APPENDIX F : CHARACTERISTICS OF COMMERCIAL COMMUNICATION SATELLITES 278

APPENDIX G : NUMBER OF EQUIVALENT VOICE CHANNELS 283

APPENDIX H : HEDONIC REGRESSION MODELS 284

APPENDIX I : CHOW TESTS FOR STRUCTURAL CHANGE .. 285

APPENDIX I.1: DIFFERENCES IN TIME SCALE 286
APPENDIX I.2: DIFFERENCES IN MANUFACTURING REGION 292
APPENDIX I.3: DIFFERENCES IN PURCHASING REGION 296

APPENDIX J : LEARNING COEFFICIENTS 303

APPENDIX K : DEMAND SHIFT RESULTS 305

APPENDIX L : STOCK DEMAND CALCULATIONS 314

APPENDIX M : STOCK ADJUSTMENT ANALYSIS 327

Appendix A : List of satellites

Table A.1: Commercial communication satellites included in this thesis.

Satellite name	#	Award date	Launch date	Prime-contractor	Prime-contractor country	Customer	Customer country
ACTS	1	84.09	93.07	RCA	USA	NASA	USA
Afristar 1	1	90.11	95.01	DSI/ITI	USA	Afrispace	USA
Anik A1	3	70.09	72.11	HAC	USA	Telesat	Canada
Anik A2		70.09	73.04	HAC	USA	Telesat	Canada
Anik A3		70.09	75.05	HAC	USA	Telesat	Canada
Anik B	1	76.07	78.12	RCA	USA	Telesat	Canada
Anik C1	3	78.04	85.04	HAC	USA	Telesat	Canada
Anik C2		78.04	83.06	HAC	USA	Telesat	Canada
Anik C3		78.04	82.11	HAC	USA	Telesat	Canada
Anik D1	2	79.05	82.08	Spar	Canada	Telesat	Canada
Anik D2		79.05	84.11	Spar	Canada	Telesat	Canada
Anik E1	2	86.06	91.04	Spar	Canada	Telesat	Canada
Anik E2		86.06	91.09	Spar	Canada	Telesat	Canada
Arabsat 1A	3	81.03	85.02	AS	France	Arabsat	Saudi Arabia
Arabsat 1B		81.03	85.06	AS	France	Arabsat	Saudi Arabia
Arabsat 1C		81.03	92.02	AS	France	Arabsat	Saudi Arabia
Arabsat 2A	2	92.10	96.01	AS	France	Arabsat	Saudi Arabia
Arabsat 2B		92.10	96.01	AS	France	Arabsat	Saudi Arabia
Asiasat 1[1]	1	88.04	90.04	HAC	USA	Asiasat	Hong Kong
Asiasat 2	1	92.01	95.01	MMAS	USA	Asiasat	Hong Kong
Astra 1A[2]	1	85.09	88.12	GEAS	USA	SES	Luxembourg
Astra 1B	1	89.08	91.03	GEAS	USA	SES	Luxembourg
Astra 1C	1	90.12	93.03	HAC	USA	SES	Luxembourg
Astra 1D	1	90.12	94.03	HAC	USA	SES	Luxembourg
Aussat A1	3	82.05	85.08	HAC	USA	Aussat	Australia
Aussat A2		82.05	85.11	HAC	USA	Aussat	Australia
Aussat A3		82.05	87.09	HAC	USA	Aussat	Australia
Aussat B1	2	88.06	92.08	HAC	USA	Aussat	Australia
Aussat B2		88.06	92.12	HAC	USA	Aussat	Australia
BS 2X	1	89.01	90.02	GEAS	USA	NHK	Japan
BS 3A	2	85.02	90.08	RCA/NEC	USA	TSCJ	Japan
BS 3B		85.02	91.08	RCA/NEC	USA	TSCJ	Japan
BS 3H		85.02	91.04	RCA/NEC	USA	TSCJ	Japan
BS 3N	2	85.02	94.07	RCA/NEC	USA	TSCJ	Japan
BSB-Marcopolo 1[3]	2	87.06	89.08	HAC	USA	BSB	Sweden
BSB-Marcopolo 2[4]		87.06	90.08	HAC	USA	BSB	Norway
Comstar 1	4	73.09	76.05	HAC	USA	Com-Gen	USA
Comstar 2		73.09	76.07	HAC	USA	Com-Gen	USA
Comstar 3		73.09	78.06	HAC	USA	Com-Gen	USA
Comstar 4		79.09	81.02	HAC	USA	Com-Gen	USA
CS 2A	2	80.07	83.02	MELCO	Japan	TSCJ	Japan
CS 2B		80.07	83.08	MELCO	Japan	TSCJ	Japan
CS 3A	2	85.02	88.02	MELCO	Japan	TSCJ	Japan
CS 3B		85.02	88.09	MELCO	Japan	TSCJ	Japan

[1]Westar 6S refurbished.
[2]Satcom KU3 was sold to Société Européenne des Satellites (SES).
[3]Sold and renamed Sirius.
[4]Sold and renamed Thor.

Table A.1: Continued.

Satellite name	#	Award date	Launch date	Prime-contractor	Prime-contractor country	Customer	Customer country
DFS-Kopernicus 1	3	83.05	89.06	ANT	Germany	Bundespost	Germany
DFS-Kopernicus 2		83.05	90.07	ANT	Germany	Bundespost	Germany
DFS-Kopernicus 3		83.05	92.10	ANT	Germany	Bundespost	Germany
Eutelsat 2 F1	3	86.05	90.08	AS	France	Eutelsat	Europe
Eutelsat 2 F2		86.05	91.01	AS	France	Eutelsat	Europe
Eutelsat 2 F3		86.05	92.11	AS	France	Eutelsat	Europe
Eutelsat 2 F4	1	86.05	92.07	AS	France	Eutelsat	Europe
Eutelsat 2 F5	1	89.01	95.01	AS	France	Eutelsat	Europe
Eutelsat 2 F6	1	90.01	96.01	AS	France	Eutelsat	Europe
Eutelsat I F1	5	77.12	83.06	BADG	UK	Eutelsat	Europe
Eutelsat I F2		77.12	84.08	BADG	UK	Eutelsat	Europe
Eutelsat I F4		77.12	87.09	BADG	UK	Eutelsat	Europe
Eutelsat I F5		77.12	88.07	BADG	UK	Eutelsat	Europe
Galaxy C1	3	79.11	83.06	HAC	USA	HCI	USA
Galaxy C2		79.11	83.04	HAC	USA	HCI	USA
Galaxy C3		79.11	84.09	HAC	USA	HCI	USA
GStar 1	4	81.06	85.05	RCA	USA	GTE	USA
GStar 2		81.06	86.03	RCA	USA	GTE	USA
GStar 3		81.06	88.09	RCA	USA	GTE	USA
GStar 4		81.06	90.11	RCA	USA	GTE	USA
Hispasat 1A	3	89.12	92.10	MMS	France	Hispasat	Spain
Hispasat 1B		89.12	93.09	MMS	France	Hispasat	Spain
Hispasat 1C		89.12	spare	MMS	France	Hispasat	Spain
Inmarsat II F1	3	85.05	90.10	BADG	UK	Inmarsat	Inmarsat
Inmarsat II F2		85.05	91.03	BADG	UK	Inmarsat	Inmarsat
Inmarsat II F3		85.05	91.12	BADG	UK	Inmarsat	Inmarsat
Inmarsat II F4	1	88.04	92.04	BADG	UK	Inmarsat	Inmarsat
Inmarsat III F1	4	91.02	94.11	MMAS	USA	Inmarsat	Inmarsat
Inmarsat III F2		91.02	95.03	MMAS	USA	Inmarsat	Inmarsat
Inmarsat III F3		91.02	95.07	MMAS	USA	Inmarsat	Inmarsat
Inmarsat III F4		91.02	95.11	MMAS	USA	Inmarsat	Inmarsat
Insat 1A	2	78.07	82.04	FACC	USA	India-DOS	India
Insat 1B		78.07	83.08	FACC	USA	India-DOS	India
Insat 1C	1	85.07	88.07	FACC	USA	India-DOS	India
Insat 1D	1	86.07	90.06	FACC	USA	India-DOS	India
Insat 2A	2	85.01	92.07	ISRO	India	India-DOS	India
Insat 2B		85.01	93.04	ISRO	India	India-DOS	India
Insat 2C	3	90.01	95.01	ISRO	India	India-DOS	India
Insat 2D		90.01	96.01	ISRO	India	India-DOS	India
Insat 2E		90.01	97.01	ISRO	India	India-DOS	India
Intelsat K[5]	1	89.10	92.06	GEAS	USA	Intelsat	Intelsat
Intelsat I	2	64.04	65.04	HAC	USA	Comsat	Comsat
Intelsat II F1	5	65.11	66.10	HAC	USA	Comsat	Comsat
Intelsat II F2		65.11	67.01	HAC	USA	Comsat	Comsat
Intelsat II F3		65.11	67.03	HAC	USA	Comsat	Comsat
Intelsat II F4		65.11	67.09	HAC	USA	Comsat	Comsat
Intelsat III F2	8	66.06	68.12	TRW	USA	Comsat	Comsat
Intelsat III F3		66.06	69.02	TRW	USA	Comsat	Comsat
Intelsat III F4		66.06	69.05	TRW	USA	Comsat	Comsat
Intelsat III F6		66.06	70.01	TRW	USA	Comsat	Comsat
Intelsat III F7		66.06	70.04	TRW	USA	Comsat	Comsat
Intelsat III F8		66.06	70.07	TRW	USA	Comsat	Comsat

[5]Previously called Satcom KU4 and sold to Intelsat.

Table A.1: Continued.

Satellite name	#	Award date	Launch date	Prime-contractor	Prime-contractor country	Customer	Customer country
Intelsat IV F1	4	68.10	75.05	HAC	USA	Comsat	Comsat
Intelsat IV F2		68.10	71.01	HAC	USA	Comsat	Comsat
Intelsat IV F3		68.10	71.12	HAC	USA	Comsat	Comsat
Intelsat IV F4		68.10	72.01	HAC	USA	Comsat	Comsat
Intelsat IV F5	4	69.09	72.06	HAC	USA	Comsat	Comsat
Intelsat IV F7		69.09	73.08	HAC	USA	Comsat	Comsat
Intelsat IV F8		69.09	74.11	HAC	USA	Comsat	Comsat
Intelsat IVA F1	3	73.05	75.09	HAC	USA	Intelsat	Intelsat
Intelsat IVA F2		73.05	76.01	HAC	USA	Intelsat	Intelsat
Intelsat IVA F3		73.05	78.01	HAC	USA	Intelsat	Intelsat
Intelsat IVA F4	3	74.12	77.05	HAC	USA	Intelsat	Intelsat
Intelsat IVA F6		74.12	78.03	HAC	USA	Intelsat	Intelsat
Intelsat V F1	7	76.09	81.05	FACC	USA	Intelsat	Intelsat
Intelsat V F2		76.09	80.12	FACC	USA	Intelsat	Intelsat
Intelsat V F3		76.09	81.12	FACC	USA	Intelsat	Intelsat
Intelsat V F4		76.09	82.03	FACC	USA	Intelsat	Intelsat
Intelsat V F5		76.09	82.09	FACC	USA	Intelsat	Intelsat
Intelsat V F6		76.09	83.05	FACC	USA	Intelsat	Intelsat
Intelsat V F7		76.09	83.10	FACC	USA	Intelsat	Intelsat
Intelsat V F8	1	79.09	84.03	FACC	USA	Intelsat	Intelsat
Intelsat V F9	1	80.09	84.06	FACC	USA	Intelsat	Intelsat
Intelsat VA F10	3	80.12	85.03	FACC	USA	Intelsat	Intelsat
Intelsat VA F11		80.12	85.06	FACC	USA	Intelsat	Intelsat
Intelsat VA F12		80.12	85.09	FACC	USA	Intelsat	Intelsat
Intelsat VB F13	3	81.09	88.05	FACC	USA	Intelsat	Intelsat
Intelsat VB F15		81.09	89.01	FACC	USA	Intelsat	Intelsat
Intelsat VI F1	5	82.03	89.10	HAC	USA	Intelsat	Intelsat
Intelsat VI F2		82.03	90.03	HAC	USA	Intelsat	Intelsat
Intelsat VI F3		82.03	90.06	HAC	USA	Intelsat	Intelsat
Intelsat VI F4		82.03	91.10	HAC	USA	Intelsat	Intelsat
Intelsat VI F5		82.03	91.08	HAC	USA	Intelsat	Intelsat
Intelsat VII F1	5	88.10	93.02	FACC	USA	Intelsat	Intelsat
Intelsat VII F2		88.10	94.01	FACC	USA	Intelsat	Intelsat
Intelsat VII F3		88.10	94.01	FACC	USA	Intelsat	Intelsat
Intelsat VII F4		88.10	94.01	FACC	USA	Intelsat	Intelsat
Intelsat VII F5		88.10	94.01	FACC	USA	Intelsat	Intelsat
Intelsat VIIA F6	2	90.12	94.05	SS/L	USA	Intelsat	Intelsat
Intelsat VIIA F7		90.12	95.06	SS/L	USA	Intelsat	Intelsat
Intelsat VIIA F8	1	92.09	95.10	SS/L	USA	Intelsat	Intelsat
Intelsat VIII F1	2	92.09	95.12	MMAS	USA	Intelsat	Intelsat
Intelsat VIII F2		92.09	96.02	MMAS	USA	Intelsat	Intelsat
Italsat 1	1	85.07	91.01	Alenia	Italy	ASI/Teles	Italy
Italsat 2	1	90.01	95.01	Alenia	Italy	ASI/Teles	Italy
JCsat 1	2	85.04	89.03	HAC	USA	JCsat	Japan
JCsat 2		85.04	90.01	HAC	USA	JCsat	Japan
Koreasat 1	2	91.12	95.04	MMAS	USA	KT	Korea
Koreasat 2		91.12	95.10	MMAS	USA	KT	Korea
Marecs A	2	74.07	81.12	BADG	UK	Inmarsat[6]	Inmarsat
Marecs B		74.07	84.11	BADG	UK	Inmarsat	Inmarsat
Marisat 1	3	73.05	76.02	HAC	USA	Com-Gen[7]	USA
Marisat 2		73.05	76.06	HAC	USA	Com-Gen	USA
Marisat 3		73.05	76.10	HAC	USA	Com-Gen	USA

[6]Inmarsat leased the two Marecs satellites from ESA.

[7]Although only created in 1979, Inmarsat used Marisat to provide mobile services.

Table A.1: Continued.

Satellite name	#	Award date	Launch date	Prime-contractor	Prime-contractor country	Customer	Customer country
Measat 1	2	91.11	95.12	HAC	USA	Binariang	Malaysia
Measat 2		91.11	96.01	HAC	USA	Binariang	Malaysia
Morelos 1	2	82.10	85.06	HAC	USA	SCT	Mexico
Morelos 2		82.10	85.11	HAC	USA	SCT	Mexico
Msat	1	90.12	94.06	Spar	Canada	TMI	Canada
Msat (AMSC)	1	90.12	94.12	HAC/Spar	USA	AMSC	USA
Olympus	1	81.12	89.07	BADG	UK	ESA	Europe
Orionsat 1	2	89.07	94.12	Bae	UK	Orion	USA
Orionsat 2		89.07	95.01	Bae	UK	Orion	USA
OTS 1	2	73.12	77.09	BADG	UK	ESA	Europe
OTS 2		73.12	78.05	BADG	UK	ESA	Europe
Pacstar 1[8]	1	93.01	95.01			PSI	Papua New Guinea
Palapa B1	3	79.12	83.06	HAC	USA	Perumtel	Indonesia
Palapa B2		79.12	84.01	HAC	USA	Perumtel	Indonesia
Palapa B2P		79.12	87.03	HAC	USA	Perumtel	Indonesia
Palapa B2R		79.12	90.04	HAC	USA	Perumtel	Indonesia
Palapa B4	1	91.01	92.05	HAC	USA	Perumtel	Indonesia
PAS I	1	85.09	88.06	RCA	USA	Alyracom	USA
PAS 2 (ORB X)	3	91.08	94.06	HAC	USA	Alyracom	USA
PAS 3 (ORB X)		91.08	94.11	HAC	USA	Alyracom	USA
PAS 4 (ORB X)		91.08	95.03	HAC	USA	Alyracom	USA
Satcom 1	3	73.12	75.12	RCA	USA	Americom	USA
Satcom 2		73.12	76.03	RCA	USA	Americom	USA
Satcom 2R (7)		80.05	83.09	RCA	USA	Americom	USA
Satcom 3		73.12	79.12	RCA	USA	Americom	USA
Satcom 4	3	80.05	82.01	RCA	USA	Americom	USA
Satcom 5		80.05	82.10	RCA	USA	Americom	USA
Satcom 6	1	80.05	83.04	RCA	USA	Americom	USA
Satcom KU1	2	83.10	86.01	RCA	USA	Americom	USA
Satcom KU2		83.10	85.11	RCA	USA	Americom	USA
SBS 1	3	77.10	80.11	HAC	USA	SBS	USA
SBS 2		77.10	81.09	HAC	USA	SBS	USA
SBS 3		77.10	82.11	HAC	USA	SBS	USA
SBS 4	1	81.03	84.08	HAC	USA	SBS	USA
SBS 5	1	81.03	88.02	HAC	USA	SBS	USA
SBS 6	1	85.02	90.10	HAC	USA	SBS	USA
SBTS A1[9]	2	82.05	85.02	Spar	Canada	Embratel	Brazil
SBTS A2		82.05	86.03	Spar	Canada	Embratel	Brazil
SBTS B1	2	90.10	94.04	HAC	USA	Embratel	Brazil
SBTS B2		90.10	94.01	HAC	USA	Embratel	Brazil
Solidaridad 1	2	91.03	93.11	HAC	USA	Mexico	Mexico
Solidaridad 2		91.03	94.01	HAC	USA	Mexico	Mexico
Spacenet 1	4	81.10	84.05	RCA	USA	GTE	USA
Spacenet 2		81.10	84.10	RCA	USA	GTE	USA
Spacenet 3		81.10	88.03	RCA	USA	GTE	USA
Spacenet 4		81.10	88.12	RCA	USA	GTE	USA
Superbird A	2	86.04	89.06	FAC	USA	SCC	Japan
Superbird B		86.04	90.02	FAC	USA	SCC	Japan
Superbird E	1	90.03	92.03	SS/L	USA	SCC	Japan
TDF 1	2	81.04	88.10	EURO	France	CNES	France
TDF 2		81.04	90.07	EURO	France	CNES	France

[8]Contract delayed.

[9]Also called Brazilsat.

Table A.1: Continued.

Satellite name	#	Award date	Launch date	Prime-contractor	Prime-contractor country	Customer	Customer country
TDRSS 1	4	76.12	83.04	TRW	USA	NASA	USA
TDRSS 2		76.12	86.01	TRW	USA	NASA	USA
TDRSS 3		76.12	88.09	TRW	USA	NASA	USA
TDRSS 4		76.12	89.03	TRW	USA	NASA	USA
TDRSS 5	3	87.07	91.08	TRW	USA	NASA	USA
TDRSS 6		87.07	93.01	TRW	USA	NASA	USA
TDRSS 7		87.07	95.01	TRW	USA	NASA	USA
Tele X	1	82.10	89.04	EURO	France	SSC	Sweden
Telecom 1A	3	80.06	84.08	MMS	France	FT	France
Telecom 1B		80.06	85.05	MMS	France	FT	France
Telecom 1C		80.06	88.03	MMS	France	FT	France
Telecom 2A	3	87.12	91.12	MMS	France	FT	France
Telecom 2B		87.12	92.04	MMS	France	FT	France
Telecom 2C		87.12	95.01	MMS	France	FT	France
Telstar 301	3	80.08	83.07	HAC	USA	AT&T	USA
Telstar 302		80.08	84.08	HAC	USA	AT&T	USA
Telstar 303		80.08	85.06	HAC	USA	AT&T	USA
Telstar 401	3	89.07	93.03	GEAS	USA	AT&T	USA
Telstar 402		89.07	94.01	GEAS	USA	AT&T	USA
Thaicom 1	2	91.06	93.12	HAC	USA	Shinawatra	Thailand
Thaicom 2		91.06	94.02	HAC	USA	Shinawatra	Thailand
Turksat 1	2	90.12	93.10	AS	France	Turk-PTT	Turkey
Turksat 2		90.12	94.01	AS	France	Turk-PTT	Turkey
Tvsat 1	2	81.04	87.11	EURO	Europe	Bundespost	Germany
Tvsat 2	1	81.04	89.09	EURO	Europe	Bundespost	Germany
Westar 1	3	72.04	74.04	HAC	USA	West-Un	USA
Westar 2		72.04	74.10	HAC	USA	West-Un	USA
Westar 3		72.04	79.08	HAC	USA	West-Un	USA
Westar 4	2	80.01	82.02	HAC	USA	HCI	USA
Westar 5		80.01	82.06	HAC	USA	HCI	USA
Westar 6	1	81.05	84.02	HAC	USA	HCI	USA

Table A.2: First generation of civil communication satellites.

Satellite program	Number of satellites ordered	Number of satellites successfully launched	Customer	Prime-contractor
Commercial				
Intelsat I	2	1	Intelsat	HAC
Intelsat II	5	3	Intelsat	HAC
Intelsat III	8	5	Intelsat	TRW
Intelsat IV	8	7	Intelsat	HAC
Intelsat IVA	6	5	Intelsat	HAC
Marisat	3	3	Inmarsat	HAC
Marecs	2	2	Inmarsat	BADG
Anik A	3	3	Canada	HAC
Comstar	4	4	United States	HAC
Palapa A	2	2	Indonesia	HAC
Satcom	3	3	United States	RCA
Westar	3	3	United States	HAC
Sub total	**49**	**41**		
Experimental				
BSE (Yuri)	1	1	Japan	RCA
CS (Sakura)	1	1	Japan	FAC
CTS Hermes	1	1	Canada	RCA
ECS (Ayame)	2	0	Japan	FAC
ETS (Kiku)	2	2	Japan	FAC
OTS	2	2	ESA	BADG
Sirio	1	1	Italy	CAN
Symphonie	2	2	France-Germany	ASMB
Sub total	**12**	**10**		
Total	**61**	**51**		

Table A.3: Second generation of civil communication satellites.

Satellite program	Number of satellites ordered	Number of satellites successfully launched	Customer	Prime-contractor
Commercial				
Anik B	1	1	Canada	RCA, Spar
Anik C	3	3	Canada	HAC, Spar
Anik D	2	2	Canada	Spar
Anik E	2	2	Canada	Spar
Arabsat 1	3	3	Saudi Arabia	AS
ASC	2	2	United States	GEAS
Asiasat 1	1	1	Hong Kong	HAC
Astra 1A	1	1	Luxembourg	RCA
Aussat A	3	3	Australia	HAC
BS 2	2	2	Japan	RCA, NEC
BS 3	2	2	Japan	RCA, NEC
BS 3 (NH)	2	1	Japan	RCA, NEC
BSB-Marcopolo	2	2	Sweden	HAC
CS 2	2	2	Japan	MELCO
CS 3	2	2	Japan	MELCO
DFS-Kopernikus	3	3	Germany	MBB, DASA
Eutelsat I	5	4	Eutelsat	BADG
Eutelsat II	4	4	Eutelsat	AS
Galaxy C	3	3	United States	HAC
Gstar	4	4	United States	RCA
Inmarsat II	4	4	Inmarsat	BADG
Insat 1	4	4	India	FAC
Insat 2	2	2	India	ISRO
Intelsat V	9	8	Intelsat	FAC
Intelsat VA	6	5	Intelsat	FAC
Intelsat VI	5	5	Intelsat	HAC
Italsat 1	1	1	Italy	Alenia
JCSat	2	2	Japan	HAC
Morelos	2	2	Mexico	HAC
Palapa B	3	3	Indonesia	HAC
PAS 1	1	1	United States	RCA
Satcom R	4	4	United States	RCA
Satcom C	4	4	United States	GEAS
Satcom KU	2	2	United States	RCA
SBS	6	6	United States	HAC
SBTS A	2	2	Brazil	Spar
Spacenet	4	4	United States	RCA
Superbird A	4	2	Japan	FAC, MELCO
TDF	2	2	France	EURO, AS
TDRSS	7	6	United States	TRW
Telecom 1	3	3	France	Matra, Alcatel
Telecom 2	3	3	France	Matra, Alcatel
Tele X	1	1	Sweden	EURO AS
Telstar 3	3	3	United States	HAC
Tvsat	2	1	Germany	EURO, MBB
Westar	3	3	United States	HAC
Subtotal	**138**	**130**		
Experimental				
ACTS	1	1	United States	RCA
ETS (Kiku)	3	3	Japan	MELCO
Olympus	1	1	Europe	BADG, Alenia
Subtotal	**5**	**5**		
Total	**143**	**135**		

Table A.4: Proposed third generation of civil telecommunication satellites purchased from 1989.

	Satellite program	Number of satellites ordered	Customer	Prime-contractor
	Commercial			
*	Afristar 1	1	United States	DSI, ITI
	Apstar	2	Hong Kong	HAC
*	Arabsat 2	2	Saudi Arabia	AS, DASA, Alenia
*	Asiasat 2	1	Hong Kong	GEAS
*	Astra 1 (B)	1	Luxembourg	GEAS
*	Astra 1 (CD)	2	Luxembourg	HAC
*	Aussat B	2	Australia	HAC
*	BS 2X	1	Japan	GEAS
*	CS 4	2	Japan	MELCO
	DirecTV	4	United States	HAC
	Echostar	2	United States	MMAS
*	Eutelsat II	2	Europe	AS
	Eutelsat Hotbird	2	Europe	MMS
*	Galaxy C	5	United States	HAC
*	Galaxy KU	3	United States	HAC
	GE 1	1	United States	MMAS
	Globalstar	48	United States	SS/L
*	Hispasat 1	3	Spain	MMS
	Indostar	4	Indonesia	DSI/CTA
*	Inmarsat III	4	Inmarsat	GEAS, Marconi
*	Intelsat K	1	Intelsat	GEAS
*	Intelsat VII	6	Intelsat	SS/L
*	Intelsat VIIA	3	Intelsat	SS/L
*	Intelsat VIII	6	Intelsat	MMAS
	Iridium	66	United States	Lockheed
*	Italsat 2	1	Italy	Alenia
*	Koreasat 1	2	Korea	GEAS, MMS
*	Measat	2	Malaysia	HAC
*	MSat	1	Canada	Spar
*	MSat (AMSC)	1	United States	HAC, Spar
	Nahuel	2	Argentina	DASA, AS, Alenia
*	N Star	2	Japan	SS/L
*	Orionsat	2	United States	MMS
*	Pacstar 1	1	Papua New Guinea	
*	Palapa B4	1	Indonesia	HAC
*	PAS (ORB X)	3	United States	HAC
	Sajac	2	Japan	HAC
	Sarit	3	Italy	Alenia
*	Satcom HY	1	USA	GEAS
*	SBTS B	2	Brazil	HAC
*	Solidaridad	2	Mexico	HAC
*	Superbird E	1	Japan	SS/L
*	Telstar 4	3	United States	GEAS
	Tempo	2	United States	SS/L
*	Thaicom	2	Thailand	HAC
*	Turksat	2	Turkey	AS
	Zohreh	2	Iran	Alcatel, AS
	Subtotal	**100 +114**		

Table A.4: Continued.

Satellite program	Number of satellites ordered	Customer	Prime-contractor
Experimental			
Artemis	1	Europe	Alenia
Comtets	1	Japan	NEC
ETS	1	Japan	TOSHIBA
Subtotal	**3**		
Total	**103 + 117**		

*Note: marks the satellites included in the database available to the author

Table A.5: Number of satellites launched or on firm order for the period 1989-1996 as of December 1992 (source: Euroconsult's ECOSPACE database).

Year	Number of satellites
1989	12
1990	17
1991	15
1992	15 out of 18
1993	10
1994	25 to 32
1995	29 to 38
1996	5 to 12

Appendix B : List of the manufacturers, customers and operators of communication satellites

Table B.1: List of prime-contractors, their abbreviations used in the text and their country of origin.

Abbreviation	Prime-contractor	Country	Remarks
ALCATEL	Alcatel Espace	France	part of Space Systems/Loral
ALENIA	Alenia Spazio	Italy	merger of Aeritalia and Selenia in December 1990
ANT	ANT Nachrichtentechnik	Germany	
AS	Aérospatiale	France	part of Space Systems/Loral
BADG	British Aerospace Defense Group	UK	merged with Matra Marconi Space
BAe	British Aerospace	UK	merged with Matra Marconi Space
CTA	CTA	USA	formerly Defense Systems Inc.
DSI	Defense Systems Inc.	USA	now CTA since 1992
DASA	Deutsche Aerospace	Germany	merger from Dornier and MBB in 1989
DORN	Dornier	Germany	merged into DASA in 1989
ESA	European Space Agency	Europe	
EURO	Eurosatellite gMBH	Europe	European consortium
FAC	Ford Aerospace Corporation	USA	now part of Loral Aerospace Corporation
FAIR	Fairchild Space Company	USA	now part of Matra Dédense Espace as Matra Aerospace Inc. since 1989
GEAS	General Electric Astro Space	USA	now Martin Marietta Astro Space part of Lockheed Martin
HAC	Hughes Aircraft Company	USA	
ITI	International Technologies Inc.	USA	
ISRO	Indian Space Research Organisation	India	
LOCKHEED	Lockheed Missiles and Space Company	USA	merged with Martin Marietta
LORAL	Loral	USA	formerly Ford Aerospace Corp. and now part of Space Systems/Loral
MARCONI	GEC-Marconi	UK	space business of GEC-Marconi merged with Matra's to form Matra Marconi Space in 1989
MATRA	Matra Espace	France	merged with Marconi in 1990
MMAS	Martin Marietta Astro Space	USA	previously GEAS and merged with Lockheed
MMS	Matra Marconi Space	France	space business of Matra
MBB	Messerschmitt-Bolkov-Blohm	Germany	merged into DASA in 1989
MELCO	Mitsubishi Electric Company	Japan	
MOT	Motorola		
NEC	Nippon Electric Company	Japan	
RCA	Radio Corporation of America	USA	became General Electric Astro Space and then Martin Marietta
SPAR	Spar Aerospace Ltd	Canada	Acquired the Montréal branch of RCA in 1977
SS/L	Space Systems/Loral	USA	now Space Systems/Alliance
TOSH	Toshiba	Japan	
TRW	TRW Inc.	USA	

Table B.2: List of the customers and operators or communication satellites, their abbreviations used in the text and their country of origin.

Abbreviation	Contractor's name	Country	Remarks
Afrispace	Afrispace Inc.	USA	International Technologies
Alyracom	Alpha Lyracom Space Communications	USA	
Americom	GE American Communication	USA	
AMSC	American Mobile Satellite Corporation	USA	
Arabsat	Arab Satellite Communication Organisation	Saudi Arabia	
ASC	American Satellite Company		subsidiary of Contel Corp.
ASI	Italian Space Agency	Italy	
Asiasat	Asia Satellite Corporation	Hong Kong	
AT&T	American Telephone and Telegraph	USA	
Aussat	Aussat Pty Ltd	Australia	now Optus Communication Pty Ltd
Binariang	Binariang	Malaysia	
BSB	British Satellite Broadcasting	UK	merged with Sky television to form BSkyB
BSkyB	British Sky Broadcasting	UK	
Bundespost	Bundes Ministerium Post-Fernmeldewen	Germany	
CNES	Centre National d'Études Spatiales	France	
Com-Gen	Comsat General	USA	
Comsat	Comsat	USA	
Contel	Contel Corporation	USA	merger with GTE Corporation in 1990
DOC	Department of Communication Canada	Canada	
Embratel	Empresa Brasileira de Telecommunicações	Brazil	
ESA	European Space Agency	Europe	
Eutelsat	European Telecommunication Satellites	Europe	
FT	France Telecom	France	absorbed Télédiffusion de France in 1990
GE-AMER	General Electric American Communication	USA	
GEOSTAR	Geostar Corporation	USA	bancrupted in 1991
GTE	GTE Spacenet Corporation	USA	
HCI	Hughes Communication Inc.	USA	
Hispasat	Hispasat SA	Spain	Telefonica and Retevision
India-DOS	Indian Department of Space	India	
Inmarsat	International Maritime Satellites	Inmarsat	
Intelsat	International Telecommunication Satellite Company	Intelsat	
JCsat	Japan Communication Satellite	Japan	
JSB	Japan Satellite Broadcasting Company	Japan	
KT	Korea Telecom	Korea	
MELCO	Mitsubishi Electric Company	Japan	
Motorola	Motorola	Japan	
NASA	National Aeronautics and Space Administration	USA	
NASDA	National Space Development Agency	Japan	
NHK	Nippon Hoso Kyokai	Japan	
Orion	Orion Network Systems Inc.	USA	
PanAmSat	PanAmSat LP	USA	formerly Alpha Lyracom Space Communication Inc.
Perumtel	Perumtel	Indonesia	now PT Telekomunikasi Indonesia
PSI	Pacific Satellite Inc.	Papua New Guinea	
Qualcom	Qualcom	USA	

Table D.2: Continued

Abbreviation	Contractor's name	Country	Remarks
RCA-AMER	RCA American Communication	USA	
SBS	Satellite Business Systems	USA	called Satellite Transponder Leasing Corporation
SCC	Space Communication Corporation	Japan	
SCT	Secretaria de Communicaciones y Transportes	Mexico	
SES	Société Européenne des Satellites	Luxembourg	
Shinawatra	Shinawatra Computer	Thailand	
SJC	Satellite Japan Corporation	Japan	
SSC	Swedish Space Corporation	Sweden	
TDF	Télédiffusion de France	France	absorbed by France Telecom in 1990
Teles	Telespazio	Italy	
Telesat	Telesat Canada	Canada	
Telkom	PT Telekomunikasi Indonesia	Indonesia	formerly Perumtel
TMI	Telesat Mobile Inc.	Canada	
TSJC	Telecommunication Satellite Corporation of Japan	Japan	
Turk-PTT	Turkish PTT	Turkey	
West-Un	Western Union Corporation	USA	acquired by Hughes Communication Inc.

Appendix C : Demand-side countries

Table C.1: Countries included in the statistical analysis.

Group	Country	Symbol	Continent
1	Canada	CAN	North America
1	France	FRA	Europe
1	Germany (W)	DEU	Europe
1	Italy	ITA	Europe
1	Japan	JPN	Asia
1	Luxembourg	LUX	Europe
1	Norway	NOR	Europe
1	Spain	ESP	Europe
1	Sweden	SWE	Europe
1	United Kingdom	GBR	Europe
1	United States	USA	North America
2	Australia	AUS	Oceania
2	Brazil	BRA	South America
2	Hong Kong	HKG	Asia
2	India	IND	Asia
2	Indonesia	IDN	Asia
2	Korea, Rep.	KOR	Asia
2	Malaysia	MYS	Asia
2	Mexico	MEX	North America
2	Saudi Arabia	SAU	Asia
2	Thailand	THA	Asia
2	Turkey	TUR	Asia
3	Algeria	DZA	Africa
3	Benin	BEN	Africa
3	Botswana	BWA	Africa
3	Burkina Faso	BFA	Africa
3	Burundi	BDI	Africa
3	Central African Republic	CAF	Africa
3	Chad	TCD	Africa
3	Comoros	COM	Africa
3	Congo	COG	Africa
3	Cote d'Ivoire	CIV	Africa
3	Ethiopia	ETH	Africa
3	Gabon	GAB	Africa
3	Ghana	GHA	Africa
3	Guinea	GIN	Africa
3	Kenya	KEN	Africa
3	Lesotho	LSO	Africa
3	Liberia	LBR	Africa
3	Libya	LBY	Africa
3	Madagascar	MDG	Africa
3	Mauritania	MRT	Africa
3	Mauritius	MUS	Africa
3	Morocco	MAR	Africa
3	Niger	NER	Africa
3	Nigeria	NGA	Africa
3	Rwanda	RWA	Africa
3	Senegal	SEN	Africa
3	Sierra Leone	SLE	Africa
3	South Africa	ZAF	Africa

Table C.1: Continued.

Group	Country	Symbol	Continent
3	Swaziland	SWZ	Africa
3	Tanzania	TZA	Africa
3	Togo	TGO	Africa
3	Tunisia	TUN	Africa
3	Uganda	UGA	Africa
3	Zambia	ZMB	Africa
3	Zimbabwe	ZWE	Africa
4	Bahrain	BHR	Asia
4	Brunei Darassalam	BRN	Asia
4	Djibouti	DJI	Africa
4	Egypt	EGY	Africa
4	Iran	IRN	Asia
4	Israel	ISR	Asia
4	Jordan	JOR	Asia
4	Kuwait	KWT	Asia
4	Lebanon	LBN	Asia
4	Oman	OMN	Asia
4	Qatar	QAT	Asia
4	Syria	SYR	Asia
4	United Arab Emirates	ARE	Asia
4	Yemen	YEM	Asia
5	Bangladesh	BGD	Asia
5	Cambodia	KHR	Asia
5	Cyprus	CYP	Asia
5	Lao P.D.R.	LAO	Asia
5	Macao	MAC	Asia
5	Maldives	MDV	Asia
5	Mongolia	MNG	Asia
5	Myanmar (Burma)	MMR	Asia
5	Nepal	NPL	Asia
5	Pakistan	PAK	Asia
5	Philippines	PHL	Asia
5	Seychelles	SYC	Asia
5	Singapore	SGP	Asia
5	Sri Lanka	LKA	Asia
5	Vietnam	VNM	Asia
6	Fiji	FJI	Oceania
6	French Polynesia	PYF	Oceania
6	Kiribati	KIR	Oceania
6	New Caledonia	NCL	Oceania
6	New Zealand	NZL	Oceania
6	Papua New Guinea	PNG	Oceania
6	Solomon Islands	SLB	Oceania
6	Vanuatu	VUT	Oceania
7	Austria	AUT	Europe
7	Belgium	BEL	Europe
7	Denmark	DNK	Europe
7	Finland	FIN	Europe
7	Greece	GRC	Europe
7	Iceland	ISL	Europe
7	Ireland	IRL	Europe
7	Malta	MLT	Europe
7	Netherlands	NLD	Europe
7	Portugal	PRT	Europe
7	Switzerland	CHE	Europe

Table C.1: Continued.

Group	Country	Symbol	Continent
8	Hungary	HUN	Europe
8	Poland	POL	Europe
8	Romania	ROM	Europe
8	Yugoslavia	YUG	Europe
9	Argentina	ARG	South America
9	Bolivia	BOL	South America
9	Chile	CHL	South America
9	Colombia	COL	South America
9	Ecuador	ECU	South America
9	French Guyana	GUF	South America
9	Paraguay	PRY	South America
9	Peru	PER	South America
9	Suriname	SUR	South America
9	Uruguay	URY	South America
9	Venezuela	VEN	South America
10	Bahamas	BHS	North America
10	Barbados	BRB	North America
10	Bermuda	BMU	North America
10	Costa Rica	CRI	North America
10	El Salvador	SLV	North America
10	Guatemala	GTM	North America
10	Honduras	HND	North America
10	Jamaica	JAM	North America
10	Nicaragua	NIC	North America
10	Panama	PAN	North America
10	Saint Lucia	LCA	North America
10	Trinidad & Tobago	TTO	North America

Appendix D : Growth of demand variables

Table D.1: Annual growth rate of main telephone lines in operation (Source: ITU World Telecommunication Indicators).

Group	Country		75-85	83-93
1	**CAN**	Canada	0.0508	0.0573
1	**DEU**	Germany	0.0978	0.0578
1	**ESP**	Spain	0.0988	0.0686
1	**FIN**	Finland	0.0618	0.0366
1	**FRA**	France	0.2244	0.0476
1	**GBR**	United Kingdom	0.0601	0.0378
1	**ITA**	Italy	0.0801	0.0549
1	**JPN**	Japan	0.0399	0.0372
1	**LUX**	Luxembourg	0.0416	0.0511
1	**NOR**	Norway	0.0923	0.0502
1	**SWE**	Sweden	0.0246	0.0178
1	**USA**	United States	0.0469	0.0339
2	**AUS**	Australia	0.0748	0.0527
2	**BRA**	Brazil	0.2272	0.0835
2	**HKG**	Hong Kong	0.1108	0.0902
2	**IDN**	Indonesia	0.1903	0.2793
2	**IND**	India	0.1160	0.2008
2	**KOR**	Korea (Rep. of)	0.5160	0.2469
2	**MEX**	Mexico	0.1144	0.1280
2	**MYS**	Malaysia	0.4672	0.2443
2	**SAU**	Saudi Arabia	0.5565	0.1042
2	**THA**	Thailand	0.1861	0.3781
2	**TUR**	Turkey	0.2303	0.5536
3	**BDI**	Burundi	0.0967	0.5399
3	**BEN**	Benin	0.1048	0.1051
3	**BFA**	Burkina Faso	0.2313	0.1921
3	**BWA**	Botswana	0.1191	0.3315
3	**CAF**	Central African Rep.		0.1386
3	**CIV**	Cote d'Ivoire	0.1376	0.0842
3	**COG**	Congo	0.0814	0.1009
3	**COM**	Comoros	0.2542	0.2342
3	**DZA**	Algeria	0.3166	0.1396
3	**ETH**	Ethiopia	0.1112	0.0581
3	**GAB**	Gabon		0.1720
3	**GHA**	Ghana	0.0223	0.0311
3	**GIN**	Guinea		-0.0113
3	**KEN**	Kenya	0.1234	0.1244
3	**LBR**	Liberia		-0.0357
3	**LBY**	Libya		0.1154
3	**LSO**	Lesotho	0.2838	0.1345
3	**MAR**	Morocco	0.1186	0.3074
3	**MDG**	Madagascar		0.0772
3	**MRT**	Mauritania	0.1974	0.1037
3	**MUS**	Mauritius	0.1565	0.2386
3	**NER**	Niger	0.1394	0.0411
3	**NGA**	Nigeria		0.0875
3	**RWA**	Rwanda	0.1247	0.1572
3	**SEN**	Senegal	0.0536	0.2226
3	**SLE**	Sierra Leone		0.0140

Table D.1: Continued.

Group	Country		75-85	83-93
3	**SWZ**	Swaziland	0.1472	0.1213
3	**TCD**	Chad	-0.0058	0.2941
3	**TGO**	Togo		0.1180
3	**TUN**	Tunisia	0.1913	0.1772
3	**TZA**	Tanzania	0.0924	0.0933
3	**UGA**	Uganda	0.0273	-0.0137
3	**ZAF**	South Africa	0.0988	0.0766
3	**ZMB**	Zambia	0.0541	0.1079
3	**ZWE**	Zimbabwe	0.0281	0.0243
4	**ARE**	United Arab Emirates	0.7023	0.2111
4	**BHR**	Bahrain	0.3950	0.1183
4	**BRN**	Brunei Darussalam		0.2249
4	**DJI**	Djibouti	0.1610	0.1028
4	**EGY**	Egypt	0.1587	0.2831
4	**IRN**	Iran (Islamic Rep. of)	0.0925	0.2210
4	**ISR**	Israel	0.0977	0.0882
4	**JOR**	Jordan		0.1901
4	**KWT**	Kuwait	0.1493	0.0755
4	**LBN**	Lebanon		-0.1000
4	**OMN**	Oman	1.0711	0.5915
4	**QAT**	Qatar	0.4650	0.0842
4	**SYR**	Syria	0.2438	0.0503
4	**YEM**	Yemen		0.2230
5	**BGD**	Bangladesh		0.1342
5	**CYP**	Cyprus	0.2175	0.2111
5	**KHM**	Cambodia		-0.0086
5	**LAO**	Lao P.D.R.	0.0104	0.0535
5	**LKA**	Sri Lanka	0.1063	0.1147
5	**MAC**	Macau		0.6593
5	**MDV**	Maldives		0.4247
5	**MMR**	Myanmar	0.0850	0.1821
5	**MNG**	Mongolia		0.0476
5	**NPL**	Nepal	0.1914	0.3406
5	**PAK**	Pakistan	0.1191	0.2976
5	**PHL**	Philippines	0.0797	0.0753
5	**SGP**	Singapore	0.2827	0.0796
5	**SYC**	Seychelles	0.2982	0.1504
5	**VNM**	Vietnam		0.2824
6	**FJI**	Fiji	0.0853	0.1035
6	**KIR**	Kiribati		0.2417
6	**NCL**	New Caledonia	0.1100	0.1317
6	**NZL**	New Zealand	0.0312	0.0300
6	**PNG**	Papua New Guinea	0.0714	0.0426
6	**PYF**	French Polynesia	0.2500	0.1497
6	**SLB**	Solomon Islands		0.2105
6	**VUT**	Vanuatu	0.0551	0.1353
7	**AUT**	Austria	0.0814	0.0405
7	**BEL**	Belgium	0.0639	0.0560
7	**CHE**	Switzerland	0.0327	0.0378
7	**DNK**	Denmark	0.0490	0.0273
7	**GRC**	Greece	0.0848	0.0748
7	**IRL**	Ireland	0.1130	0.0907
7	**ISL**	Iceland	0.0360	0.0529
7	**MLT**	Malta	0.1966	0.1046
7	**NLD**	Netherlands	0.0746	0.0397
7	**PRT**	Portugal	0.0800	0.1611

Table D.1: Continued.

Group	Country		75-85	83-93
8	**HUN**	Hungary	0.0454	0.1214
8	**POL**	Poland	0.0795	0.0993
8	**ROM**	Romania	0.1291	0.0446
8	**YUG**	Yugoslavia	0.1870	0.0988
9	**ARG**	Argentina	0.0642	0.0801
9	**BOL**	Bolivia		0.0562
9	**CHL**	Chile	0.0808	0.2480
9	**COL**	Colombia	0.1032	0.1480
9	**ECU**	Ecuador	0.0628	0.1259
9	**GUF**	French Guyana	0.4032	0.1542
9	**PER**	Peru	0.0727	0.0861
9	**PRY**	Paraguay	0.1573	0.1104
9	**SUR**	Suriname	0.1634	0.1222
9	**URY**	Uruguay	0.0540	0.1141
9	**VEN**	Venezuela	0.1422	0.1040
10	**BHS**	Bahamas	0.0841	0.1100
10	**BMU**	Bermuda	0.0704	0.0531
10	**BRB**	Barbados	0.1111	0.0626
10	**CRI**	Costa Rica	0.1592	0.0869
10	**GTM**	Guatemala	0.1694	0.1178
10	**HND**	Honduras	0.1700	0.2312
10	**JAM**	Jamaica	0.0543	0.2247
10	**LCA**	Saint Lucia	0.1101	0.3845
10	**NIC**	Nicaragua	0.0976	0.0689
10	**PAN**	Panama		0.0743
10	**SLV**	El Salvador	0.0881	0.1157
10	**TTO**	Trinidad and Tobago	0.1894	0.1902

Table D.2: Annual growth rate of telecommunication investment (Source: ITU World Telecommunication Indicators).

Group	Country		75-85	83-93
1	**CAN**	Canada	0.0224	0.0179
1	**DEU**	Germany	0.1176	0.2371
1	**ESP**	Spain	-0.0016	0.1658
1	**FIN**	Finland	0.0316	0.0464
1	**FRA**	France	0.0466	0.0792
1	**GBR**	United Kingdom	0.0190	0.0772
1	**ITA**	Italy	0.0572	0.1195
1	**JPN**	Japan	0.0419	0.2187
1	**LUX**	Luxembourg	-0.0054	0.6542
1	**NOR**	Norway	0.1363	-0.0051
1	**SWE**	Sweden	0.1635	0.0564
1	**USA**	United States	0.1076	0.0350
2	**AUS**	Australia	0.0252	0.0296
2	**BRA**	Brazil	-0.0263	0.1893
2	**HKG**	Hong Kong	0.2580	0.3162
2	**IDN**	Indonesia	-0.0659	1.1015
2	**IND**	India	0.2295	0.1536
2	**KOR**	Korea (Rep. Of)	0.7444	0.1203
2	**MEX**	Mexico	0.1270	0.6114
2	**MYS**	Malaysia		0.0941
2	**THA**	Thailand		0.0642
2	**TUR**	Turkey	0.2540	0.3383

Table D.2: Continued.

Group	Country		75-85	83-93
3	**BFA**	Burkina Faso		1.3142
3	**BWA**	Botswana	0.0581	1.4869
3	**DZA**	Algeria	0.0994	0.0468
3	**ETH**	Ethiopia	-0.0922	0.0843
3	**KEN**	Kenya	0.2144	-0.0301
3	**MRT**	Mauritania		0.4395
3	**MUS**	Mauritius		3.4731
3	**SEN**	Senegal		0.2046
3	**SWZ**	Swaziland	0.0293	
3	**TUN**	Tunisia		0.3525
3	**ZAF**	South Africa	0.1735	-0.0153
3	**ZMB**	Zambia	0.0129	0.0798
3	**ZWE**	Zimbabwe		0.2010
4	**ARE**	United Arab Emirates		-0.0233
4	**EGY**	Egypt	0.5129	0.0068
4	**IRN**	Iran (Islamic Rep. of)		-0.0811
4	**ISR**	Israel	2.6418	0.1260
4	**OMN**	Oman	0.3678	0.7671
4	**SYR**	Syria	0.3009	-0.0719
5	**CYP**	Cyprus	0.4294	0.1544
5	**LKA**	Sri Lanka		0.4585
5	**MAC**	Macau		0.1183
5	**NPL**	Nepal	2.0124	-0.0704
5	**SGP**	Singapore	0.1977	0.1250
6	**NCL**	New Caledonia	0.0642	0.4241
6	**NZL**	New Zealand		0.1475
6	**PNG**	Papua New Guinea	0.0910	
6	**PYF**	French Polynesia	0.3909	0.2632
7	**AUT**	Austria	0.0814	0.1438
7	**BEL**	Belgium	-0.0136	0.2241
7	**CHE**	Switzerland	0.0481	0.1198
7	**DNK**	Denmark	0.0131	0.0668
7	**GRC**	Greece	0.0863	0.1552
7	**IRL**	Ireland	0.0521	-0.0035
7	**ISL**	Iceland	-0.0981	0.2092
7	**NLD**	Netherlands	0.0275	0.2349
7	**PRT**	Portugal	0.0495	0.2610
8	**HUN**	Hungary	0.1358	0.5806
8	**ROM**	Romania		0.4669
9	**ARG**	Argentina		0.5041
9	**CHL**	Chile		0.9593
9	**COL**	Colombia	0.7524	-0.0267
9	**ECU**	Ecuador	0.0632	0.4761
9	**PRY**	Paraguay	0.3411	0.1295
9	**SUR**	Suriname		-0.0767
9	**URY**	Uruguay	0.1921	0.1328
9	**VEN**	Venezuela	0.0108	0.2367
10	**BHS**	Bahamas	0.5853	
10	**BMU**	Bermuda		0.0358
10	**BRB**	Barbados		0.0444
10	**CRI**	Costa Rica	-0.0122	
10	**HND**	Honduras		0.6308
10	**JAM**	Jamaica		3.1790
10	**PAN**	Panama		0.1006
10	**SLV**	El Salvador	-0.0116	
10	**TTO**	Trinidad and Tobago		-0.0764

Table D.3: Annual growth rate of international outgoing telephone traffic (Source: ITU World Telecommunication Indicators).

Group		Country		75-85	83-93
1	**CAN**	Canada	*	0.4622	0.4651
1	**DEU**	Germany			0.2139
1	**ESP**	Spain		0.4535	0.3765
1	**FRA**	France			0.1298
1	**GBR**	United Kingdom			0.2190
1	**ITA**	Italy		0.3413	0.2587
1	**JPN**	Japan		0.5658	0.7605
1	**LUX**	Luxembourg		0.1634	0.1838
1	**NOR**	Norway		0.2713	0.1826
1	**SWE**	Sweden			0.1425
1	**USA**	United States		0.9190	0.6257
2	**AUS**	Australia		0.8765	0.3209
2	**BRA**	Brazil		0.4652	0.2038
2	**HKG**	Hong Kong	*	1.4220	1.3438
2	**IDN**	Indonesia		0.6963	0.5996
2	**IND**	India		1.0240	1.4630
2	**KOR**	Korea (Rep. Of)			1.0847
2	**MEX**	Mexico			0.4019
2	**MYS**	Malaysia	*	1.2394	1.4010
2	**SAU**	Saudi Arabia		9.0826	0.1301
2	**THA**	Thailand			1.3647
2	**TUR**	Turkey		1.7944	0.5406
3	**BDI**	Burundi			0.2380
3	**BEN**	Benin			0.0806
3	**BFA**	Burkina Faso			0.2878
3	**BWA**	Botswana			0.4362
3	**CAF**	Central African Rep.			0.0592
3	**CIV**	Cote d'Ivoire			0.1106
3	**COG**	Congo			0.1523
3	**COM**	Comoros			0.4426
3	**ETH**	Ethiopia			0.5129
3	**GAB**	Gabon			0.0781
3	**GIN**	Guinea			0.3465
3	**KEN**	Kenya			0.2979
3	**MAR**	Morocco			0.1115
3	**MDG**	Madagascar			0.0463
3	**MRT**	Mauritania			1.2871
3	**MUS**	Mauritius			1.1193
3	**NER**	Niger			0.0252
3	**NGA**	Nigeria			0.2190
3	**RWA**	Rwanda	*	2.0571	1.3869
3	**SEN**	Senegal			0.0816
3	**SLE**	Sierra Leone	*	0.3247	0.1212
3	**SWZ**	Swaziland	*	-0.0803	
3	**TCD**	Chad			0.4615
3	**TGO**	Togo			1.9640
3	**TUN**	Tunisia		0.3908	0.1107
3	**ZAF**	South Africa			0.1685
3	**ZMB**	Zambia	*	0.1907	0.2642
3	**ZWE**	Zimbabwe			0.4569
4	**ARE**	United Arab Emirates			0.3016
4	**BHR**	Bahrain	*	14.5730	0.2268
4	**BRN**	Brunei Darussalam	**	1.2294	0.3040

*1976-86

**1977-87

Table D.3: Continued.

Group		Country		75-85	83-93
4	**BRN**	Brunei Darussalam	**	1.2294	0.3040
4	**DJI**	Djibouti	**	0.6232	0.0906
4	**EGY**	Egypt			0.3644
4	**IRN**	Iran (Islamic Rep. of)			0.5954
4	**ISR**	Israel	*	0.4546	0.3916
4	**JOR**	Jordan			0.6144
4	**KWT**	Kuwait	**	0.9094	0.1412
4	**OMN**	Oman			0.6177
4	**QAT**	Qatar	*	0.6105	0.1743
4	**SYR**	Syria	*	0.6273	0.2491
4	**YEM**	Yemen			0.5851
5	**BGD**	Bangladesh	**	-0.1000	1.8356
5	**CYP**	Cyprus		0.8585	0.3351
5	**LAO**	Lao P.D.R.			0.5134
5	**LKA**	Sri Lanka			0.5500
5	**MAC**	Macau			0.8850
5	**MMR**	Myanmar			0.3571
5	**NPL**	Nepal			2.1613
5	**PAK**	Pakistan			0.9296
5	**PHL**	Philippines		0.7404	0.4390
5	**SGP**	Singapore		0.3167	0.4200
5	**SYC**	Seychelles	*	-0.1000	0.4454
6	**FJI**	Fiji			0.4905
6	**KIR**	Kiribati			0.7191
6	**NCL**	New Caledonia	*	0.6275	0.2065
6	**NZL**	New Zealand		0.9051	0.5248
6	**PNG**	Papua New Guinea			0.1602
6	**PYF**	French Polynesia	*	1.1371	0.1777
7	**AUT**	Austria		0.1810	0.2066
7	**BEL**	Belgium			0.1998
7	**CHE**	Switzerland		0.1658	0.1587
7	**DNK**	Denmark			0.1606
7	**FIN**	Finland		0.2558	0.1581
7	**GRC**	Greece		0.2820	0.1785
7	**IRL**	Ireland			1.5308
7	**ISL**	Iceland			0.3226
7	**MLT**	Malta			0.2938
7	**NLD**	Netherlands			0.1542
7	**PRT**	Portugal		0.5003	0.5661
8	**HUN**	Hungary		0.6855	0.7200
8	**POL**	Poland			0.8308
8	**ROM**	Romania			0.2561
8	**YUG**	Yugoslavia			0.1284
9	**ARG**	Argentina		0.3918	0.3097
9	**BOL**	Bolivia			0.5818
9	**CHL**	Chile			0.5187
9	**COL**	Colombia		0.9478	0.2558
9	**ECU**	Ecuador			0.1908
9	**PER**	Peru		0.2647	0.4839
9	**PRY**	Paraguay		0.7572	0.2363
9	**SUR**	Suriname			0.6232
9	**URY**	Uruguay			0.2167
9	**VEN**	Venezuela		0.4335	0.0703

*1976-86
**1977-87

Table D.3: Continued.

Group		Country		75-85	83-93
10	**BMU**	Bermuda			0.1510
10	**BRB**	Barbados			0.3339
10	**CRI**	Costa Rica			0.2763
10	**GTM**	Guatemala			0.1595
10	**HND**	Honduras			0.3281
10	**JAM**	Jamaica			-0.0102
10	**LCA**	Saint Lucia			0.2637
10	**NIC**	Nicaragua	*	-0.1000	0.0822
10	**PAN**	Panama			0.0876
10	**SLV**	El Salvador	*	0.3584	0.1160
10	**TTO**	Trinidad and Tobago			0.0828

*1976-86
**1977-87

Table D.4: Number of cable television subscribers as a percentage of households (Source: ITU World Telecommunication Indicators).

Group		Country	1970	1975	1980	1985	1990	1991	1992	1993	1994
1	**CAN**	Canada					73.69	73.81	73.74	73.83	74.60
1	**DEU**	Germany				5.97	23.70	28.53	33.78	35.69	39.79
1	**ESP**	Spain					0.98	1.08	1.08	1.14	2.54
1	**FRA**	France					2.35	3.56	4.62	5.86	
1	**GBR**	United Kingdom				0.04	0.68	1.21	1.96	2.74	
1	**JPN**	Japan				12.07	16.64	18.13	19.87	21.94	
1	**LUX**	Luxembourg							75.86	75.34	84.69
1	**NOR**	Norway					27.22	29.55	31.37	32.13	
1	**SWE**	Sweden				2.48	39.42	41.73	47.38	47.80	
1	**USA**	United States	6.93	12.93	21.88	45.94	58.78	59.15	59.80	61.04	63.05
2	**HKG**	Hong Kong									2.25
2	**IND**	India								4.62	6.25
2	**KOR**	Korea (Rep. of)					29.62	42.24	58.43		19.79
2	**THA**	Thailand								0.94	
2	**TUR**	Turkey					0.17	0.37	1.08		
3	**CAF**	Central African Rep.							80.46	80.84	
4	**ISR**	Israel							51.67		49.66
4	**QAT**	Qatar								5.39	
5	**PHL**	Philippines								1.69	2.31
7	**AUT**	Austria				7.24	15.33	16.98	18.86	20.21	33.23
7	**BEL**	Belgium	35.29	63.97	75.37	87.30	88.72	89.53	89.85		
7	**CHE**	Switzerland			43.03	58.18	60.80	63.25	66.04	66.88	
7	**DNK**	Denmark				20.08	24.41	26.20	26.72	28.12	
7	**FIN**	Finland			11.12	33.57	36.09	37.56	38.05		
7	**IRL**	Ireland						33.80	39.09		
7	**MLT**	Malta					1.78	15.63	18.56	21.39	
7	**NLD**	Netherlands		21.25	46.57	73.04	76.53	80.85	83.12	88.77	
8	**HUN**	Hungary					12.20		20.50	21.56	
8	**POL**	Poland						1.61	4.79		
8	**ROM**	Romania						3.07			
9	**ARG**	Argentina									45.00
9	**CHL**	Chile									9.70
9	**COL**	Colombia									1.07
10	**BMU**	Bermuda								60.87	
10	**LCA**	Saint Lucia									15.46
10	**SLV**	El Salvador									1.97

Table D.5: Estimated number of DTH satellite receivers as a percentage of households (Source: ITU World Telecommunication Indicators).

Group		Country	1985	1990	1991	1992	1993	1994
1	**CAN**	Canada					2.6516	
1	**DEU**	Germany	3.7947				19.5177	22.6734
1	**ESP**	Spain					0.9386	3.2006
1	**FRA**	France					0.7142	
1	**GBR**	United Kingdom					14.0045	
1	**ITA**	Italy					0.5057	0.5059
1	**JPN**	Japan		5.7974	9.2958	11.9337	13.7942	
1	**LUX**	Luxembourg					2.7397	6.4893
1	**NOR**	Norway					8.7432	
1	**SWE**	Sweden				8.1600	9.4552	
1	**USA**	United States		3.2138	3.3930	3.5539	3.7348	3.9606
2	**HKG**	Hong Kong				0.0049	0.0259	0.0517
2	**IDN**	Indonesia					1.6730	2.7778
2	**IND**	India						0.9375
2	**KOR**	Korea (Rep. of)					3.9216	
2	**MYS**	Malaysia					1.0000	
2	**THA**	Thailand					0.0975	0.8861
2	**TUR**	Turkey				0.8511	0.9167	
3	**SLE**	Sierra Leone					0.0427	
3	**SWZ**	Swaziland					0.0316	0.0341
3	**TCD**	Chad				0.0042	0.0071	
3	**TGO**	Togo				0.0073	0.0144	0.0449
3	**TUN**	Tunisia				0.6753	1.0868	1.6430
4	**JOR**	Jordan				0.2069	0.4105	0.8847
5	**CYP**	Cyprus				0.2697	0.3535	0.4762
5	**MAC**	Macau			7.0965	32.0000	32.3529	32.3810
5	**MDV**	Maldives						0.2035
5	**MMR**	Myanmar					0.0157	0.0154
5	**MNG**	Mongolia					0.0195	0.0455
5	**PHL**	Philippines					0.2026	
5	**SYC**	Seychelles						0.0647
6	**FJI**	Fiji				0.0076	0.0188	0.0526
6	**SLB**	Solomon Islands					0.0348	0.0385
7	**AUT**	Austria					21.7178	26.7742
7	**BEL**	Belgium					0.8861	
7	**CHE**	Switzerland					4.1937	8.4327
7	**DNK**	Denmark					7.5480	41.5674
7	**FIN**	Finland					1.7073	
7	**IRL**	Ireland				3.3333	5.2727	
7	**MLT**	Malta			0.0236	0.0333	0.0571	0.1228
7	**NLD**	Netherlands					4.3232	4.4615
7	**PRT**	Portugal					7.1386	7.7335
8	**HUN**	Hungary					16.6393	28.9245
8	**POL**	Poland					9.1076	
9	**SUR**	Suriname					0.1286	0.1395
10	**BMU**	Bermuda					13.0435	
10	**HND**	Honduras						0.0332
10	**JAM**	Jamaica				5.8621	6.6102	
10	**LCA**	Saint Lucia						0.1247

Table D.6: Annual growth rate of the owner stock of satellites.

Group		Country	1975-85	1985-95
1	CAN	Canada	0.3858	0.0192
1	DEU	Germany	0.9170	1.3490
1	ESP	Spain	0.8141	0.7464
1	FRA	France	3.9618	0.4417
1	GBR	United Kingdom	0.8141	0.1195
1	ITA	Italy	0.9266	1.1686
1	JPN	Japan	8.1862	0.2609
1	LUX	Luxembourg	0.9744	137.1047
1	NOR	Norway	0.9755	0.2281
1	SWE	Sweden	1.0969	0.2863
1	USA	United States	1.6024	0.0601
2	AUS	Australia	0.3875	0.0747
2	BRA	Brazil	0.2302	0.4059
2	IDN	Indonesia	0.8679	0.1181
2	IND	India	4.3636	0.1700
2	KOR	Korea (Rep. of)	0.4154	-0.0017
2	MEX	Mexico	0.3212	6.1795
2	MYS	Malaysia	0.3226	0.0199
2	SAU	Saudi Arabia	0.4123	0.1384
2	THA	Thailand	1.2173	1.4114
2	TUR	Turkey	1.0792	0.4930
3	BFA	Burkina Faso		0.1245
3	CAF	Central African Republic	0.4074	0.0843
3	CIV	Cote d'Ivoire	0.2502	0.1749
3	COG	Congo		0.1078
3	DZA	Algeria	0.3474	0.1716
3	ETH	Ethiopia	0.3523	0.0771
3	GAB	Gabon	0.3474	0.1268
3	GHA	Ghana	0.3467	0.1271
3	GIN	Guinea		0.2275
3	KEN	Kenya	0.3400	0.0765
3	LBR	Liberia		1.6282
3	LBY	Libya	0.3895	0.1242
3	MAR	Morocco	0.1858	0.2853
3	MDG	Madagascar	0.4391	0.0765
3	MRT	Mauritania	0.1858	0.2502
3	NER	Niger		0.1245
3	NGA	Nigeria	0.3467	0.1271
3	SEN	Senegal	0.1858	0.2309
3	TCD	Chad		0.0893
3	TUN	Tunisia	0.3474	0.1822
3	TZA	Tanzania	0.3400	0.0765
3	UGA	Uganda	0.3400	0.0765
3	ZAF	South Africa	0.3400	0.0789
3	ZMB	Zambia	0.3400	0.0765
4	ARE	United Arab Emirates		0.1041
4	EGY	Egypt	0.3400	0.1155
4	IRN	Iran	0.9782	0.0425
4	ISR	Israel	0.3400	0.0786
4	JOR	Jordan	0.3400	0.1134
4	KWT	Kuwait	0.7329	0.1172
4	LBN	Lebanon	0.3400	0.1155
4	OMN	Oman	1.1605	0.0835
4	QAT	Qatar		0.1172
4	SYR	Syria	0.3845	0.1134
4	YEM	Yemen	0.4845	0.1342

Table D.6: Continued.

Group	Country		1975-85	1985-95
5	BGD	Bangladesh		-0.0063
5	CYP	Cyprus	0.9676	0.0639
5	LKA	Sri Lanka	1.2173	-0.0063
5	PAK	Pakistan	1.2173	0.0082
5	PHL	Philippines	0.4154	-0.0017
5	SGP	Singapore	1.2173	-0.0048
5	VNM	Vietnam	0.3771	0.0279
6	NZL	New Zealand	0.3101	0.0002
6	PNG	Papua New Guinea		-0.0056
7	AUT	Austria	0.8877	0.0882
7	BEL	Belgium	0.8946	0.1052
7	CHE	Switzerland	0.9744	0.0931
7	DNK	Denmark	0.8620	0.0914
7	FIN	Finland	1.7141	0.0998
7	GRC	Greece	0.9676	0.0729
7	IRL	Ireland	0.8134	0.1185
7	ISL	Iceland	1.0233	0.0938
7	MLT	Malta		0.2305
7	NLD	Netherlands	0.8946	0.1052
7	PRT	Portugal	0.8141	0.1194
8	YUG	Yugoslavia	0.9229	0.0797
9	ARG	Argentina	0.2302	0.1993
9	BOL	Bolivia	0.2294	0.1866
9	CHL	Chile	0.2302	0.1768
9	COL	Colombia	0.2294	0.2086
9	ECU	Ecuador	0.2294	0.1926
9	PER	Peru	0.2294	0.1994
9	PRY	Paraguay		0.1866
9	URY	Uruguay		0.2231
9	VEN	Venezuela	0.2294	0.2231
10	BHS	Bahamas		0.1598
10	BRB	Barbados	0.2294	0.1866
10	CRI	Costa Rica	0.2294	0.1598
10	GTM	Guatemala	0.1409	0.4255
10	HND	Honduras		0.1561
10	JAM	Jamaica	0.2294	0.1561
10	NIC	Nicaragua	0.2294	0.1561
10	PAN	Panama	0.2294	0.1598
10	SLV	El Salvador		0.1929
10	TTO	Trinidad and Tobago	0.2294	0.1866

Appendix E : Orbit description

This appendix will present the general principles underlying the launch of geostationary satellites. Geostationary satellites are situated approximately 36,000 km from the surface of the earth. The launch consists of positioning the satellite into its assigned geosynchronous orbit from a launching base on the earth. A launch vehicle will first transport the satellite to the perigee[1] point of the transfer orbit, where a propulsion system (either that of the launch vehicle or of the satellite, depending on whether the satellite is equipped with this kind propulsion system) will increase the velocity of the spacecraft to inject the satellite into a transfer orbit. At the apogee[2] point of this transfer orbit, a second velocity increment (from the launch vehicle or the satellite itself, depending on the propulsion system) is needed to circularise the orbit. The satellite has thus reached its assigned geosynchronous orbit. Figure E.1 illustrates the path a satellite will travel to attain its geostationary position.

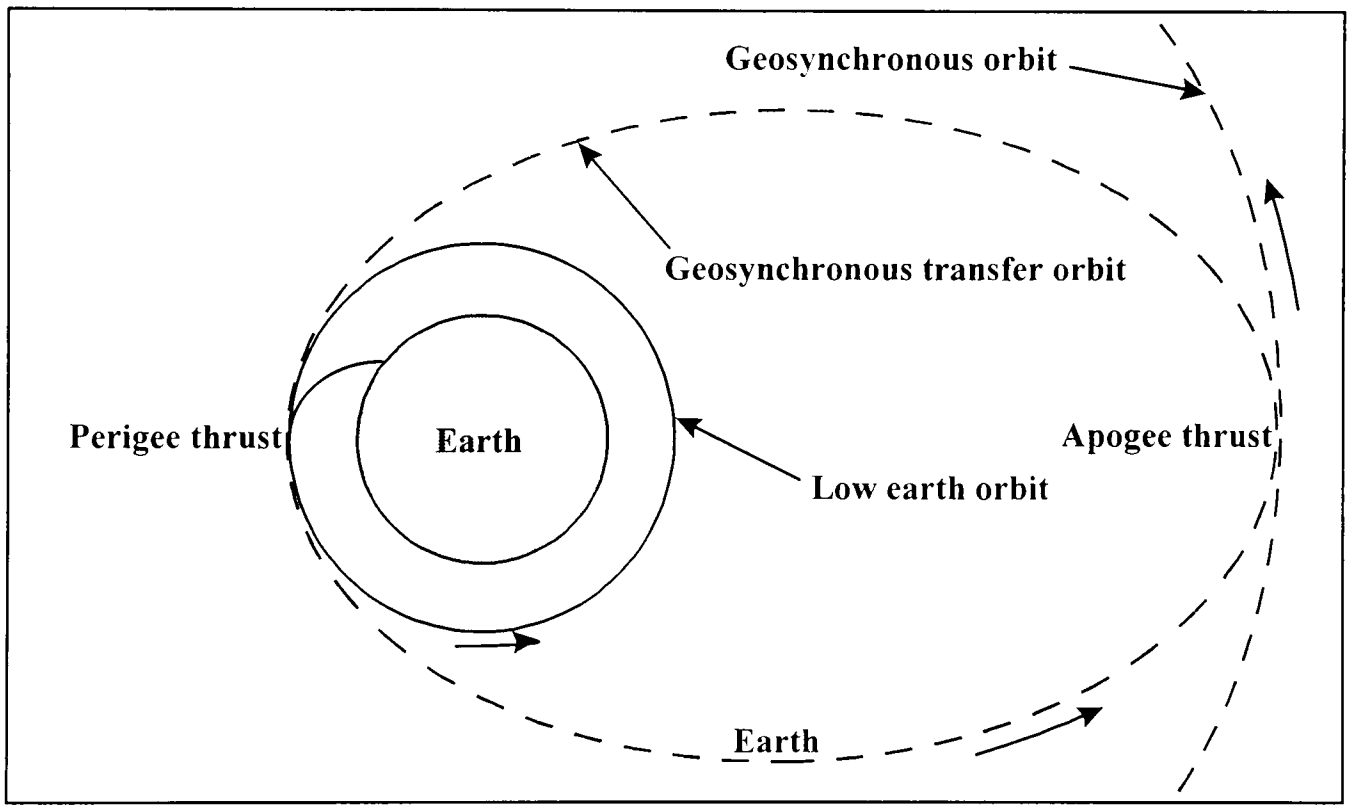


Figure E.1: Orbits used in the launch of a geostationary satellite.

Launch vehicles currently transport satellites according to three different methods: injection from low earth orbit (LEO), directly into geostationary transfer orbit (GTO), and finally directly into geostationary earth orbit (GEO). The first method is employed by the space shuttle and the Titan launch vehicle, both first reach a low earth orbit (approximately 200 km from the surface of the planet), before a perigee stage (independent of the satellite) or perigee motor (intrinsic to the satellite) increases the velocity of the spacecraft to inject it onto the transfer orbit. When the satellite arrives at the apogee point of the transfer orbit, the necessary increase in velocity is provided either by the apogee stage (independent of the satellite) or apogee motor (part of the satellite propulsion system). In the second method, at the perigee point, Ariane (Europe), Delta and Atlas Centaur launchers generally communicate the appropriate velocity to the satellite in order to inject it on the transfer orbit. Then,

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[1] The perigee is the point on an elliptical orbit that is the closest to the earth, or the celestial object it is orbiting.

[2] The apogee is the point on an elliptical orbit that is the farthest to the celestial object it is orbiting. It is situated opposite the perigee point.

when the satellite reaches the apogee point of the orbit, its apogee kick motor increases the velocity of the spacecraft necessary to circularise the orbit. The third method employed by Titan IIIC and Proton (Russia) launchers, consists of injecting the satellite directly into geostationary orbit, with the last stage of the launch vehicle propelling the satellite at the apogee[3]. The majority of commercial (this excludes Russian satellites for the reasons mentioned in the first chapter) communication satellites are launched by the second category of launchers, and generally require an apogee kick motor on board the satellite.

[3] Most of the information presented in this appendix is extracted from Maral and Bousquet (1994, chapter 11). Consult their book for more information on launch vehicles.

Appendix F : Characteristics of commercial communication satellites

Table F.1: Evolution of the weighted means of satellite characteristics by contract sub-sample periods and by region of manufacturing.

Variables	Manufacturers	1964-71	1972-75	1976-79	1980-84	1985-88	1989-93
rdev	HAC	33.000	28.750	51.000	51.944	41.500	34.643
	MMAS		24.000	29.000	37.200	71.500	37.643
	SS/L			52.800	61.571	45.778	35.000
	NAothers	30.000	67.000	64.273	61.650	56.762	49.667
	Europe		67.000	65.000	69.188	56.583	47.917
	Others				31.000	62.500	60.000
gtomass	HAC	762.444	1177.750	1140.750	1946.389	2071.250	2070.071
	MMAS		907.000	907.000	1397.667	1251.500	2711.036
	SS/L			1755.600	2018.571	2665.333	3333.500
	NAothers	300.000	936.000	2225.273	1480.475	2106.333	2013.194
	Europe		936.000	1148.000	1619.406	1687.250	2036.500
	Others				691.500	1480.500	1900.000
eolpower	HAC	250.000	955.313	836.000	1169.167	1763.625	2006.571
	MMAS		493.000	740.000	1292.133	1518.333	3414.571
	SS/L			1227.200	1351.714	2933.222	3820.500
	NAothers	110.000	648.500	1205.364	1837.100	1971.667	2601.667
	Europe		648.500	867.000	2146.750	2152.750	3015.500
	Others				347.000	772.000	1180.000
lifetime	HAC	5.333	6.625	8.375	9.667	11.250	13.429
	MMAS		8.000	7.000	9.467	8.967	11.393
	SS/L			7.000	7.000	9.333	10.000
	NAothers	5.000	5.000	8.636	7.700	9.190	9.744
	Europe		5.000	7.000	8.000	9.250	10.283
	Others				5.000	7.000	7.000
sumtr	HAC	8.000	16.313	18.500	28.167	18.125	24.286
	MMAS		24.000	18.000	20.533	9.333	25.214
	SS/L			24.800	31.571	30.222	37.750
	NAothers	2.000	4.000	19.545	12.450	19.429	21.056
	Europe		4.000	11.000	11.563	14.667	22.167
	Others				8.000	17.000	25.000
totbw	HAC	305.667	568.688	755.500	1520.056	665.875	1095.214
	MMAS		864.000	864.000	1161.600	379.333	973.186
	SS/L			1782.400	2256.286	1815.111	2431.000
	NAothers	300.000	88.000	910.545	647.875	926.190	874.722
	Europe		88.000	792.000	559.344	699.000	1046.750
	Others				1140.000	1090.000	1018.000
eqvvoice	HAC	1894.857	5421.369	8693.303	18679.927	8768.471	15054.344
	MMAS		8205.795	9286.170	14264.640	4907.811	13331.840
	SS/L			19415.588	27137.201	24157.928	33340.011
	NAothers	1083.856	838.325	10052.495	7886.283	12145.745	11928.450
	Europe		838.325	8779.058	6821.704	9197.107	14270.543
	Others				13595.028	14102.408	13896.976
hmpower	HAC	8.452	6.606	13.525	12.156	51.768	26.071
	MMAS		5.000	12.000	18.044	44.914	38.395
	SS/L			7.990	6.974	23.527	29.724
	NAothers	10.000	17.959	12.639	75.476	20.366	35.721
	Europe		17.959	20.000	92.443	30.210	41.408
	Others				5.217	4.975	4.950

Table F.1: Continued.

Variables	Manufacturers	1964-71	1972-75	1976-79	1980-84	1985-88	1989-93
gmeirp	HAC	32.496	29.433	38.988	36.276	50.116	42.689
	MMAS		34.990	38.988	40.014	52.422	44.400
	SS/L			31.909	32.794	36.333	37.630
	NAothers	35.763	35.350	40.271	46.370	41.214	46.726
	Europe		35.350	41.000	49.464	43.489	48.837
	Others				33.992	34.201	32.874
mtrp	HAC	0.000	0.125	0.000	0.000	0.016	0.004
	MMAS		0.000	0.000	0.000	0.000	0.229
	SS/L			0.047	0.010	0.044	0.000
	NAothers	0.000	0.250	0.130	0.006	0.106	0.198
	Europe		0.250	0.000	0.007	0.067	0.026
	Others				0.000	0.091	0.160
ctrp	HAC	1.000	0.875	0.500	0.646	0.125	0.616
	MMAS		1.000	0.667	0.467	0.125	0.309
	SS/L			0.777	0.800	0.579	0.488
	NAothers	1.000	0.250	0.338	0.319	0.417	0.188
	Europe		0.250	0.000	0.243	0.359	0.102
	Others				0.250	0.492	0.720
kutrp	HAC	0.000	0.000	0.500	0.354	0.859	0.375
	MMAS		0.000	0.333	0.467	0.875	0.462
	SS/L			0.176	0.190	0.291	0.416
	NAothers	0.000	0.500	0.532	0.561	0.317	0.563
	Europe		0.500	1.000	0.702	0.435	0.796
	Others				0.000	0.000	0.120
otrp	HAC	0.000	0.000	0.000	0.000	0.000	0.005
	MMAS		0.000	0.000	0.067	0.000	0.000
	SS/L			0.000	0.000	0.086	0.097
	NAothers	0.000	0.000	0.000	0.114	0.159	0.051
	Europe		0.000	0.000	0.048	0.139	0.076
	Others				0.750	0.417	0.000

Table F.2: Evolution of the weighted means of satellite characteristics by contract sub-sample periods and by region of ownership.

Variables	Customers	1964-71	1972-75	1976-79	1980-84	1985-88	1989-93
rdev	USA		28.000	54.100	37.478	49.400	46.000
	Europe		45.000	65.000	74.538	47.727	42.889
	International	33.000	43.250	54.750	73.417	55.333	40.000
	Others	25.000		52.000	37.083	57.632	38.095
gtomass	USA		959.615	2340.650	1295.435	3170.200	2711.650
	Europe		837.000	1148.000	1726.808	1772.273	2173.222
	International	626.174	1395.000	1898.500	2860.833	2407.111	3123.150
	Others	574.000		1117.773	1097.167	1857.368	1838.095
eolpower	USA		1024.154	1243.000	1100.739	1748.200	3606.300
	Europe		527.000	867.000	2342.154	2337.545	2743.333
	International	203.000	623.750	1295.750	1690.167	2375.000	3574.000
	Others	237.000		833.818	882.000	1852.316	1976.905
lifetime	USA		6.769	8.650	9.522	10.660	12.100
	Europe		3.000	7.000	8.231	9.409	11.056
	International	5.000	7.000	7.000	8.250	10.000	10.800
	Others	7.000		8.636	7.833	9.158	11.162
sumtr	USA		16.385	21.400	20.696	25.400	30.400
	Europe		6.000	11.000	8.231	16.182	16.000
	International	5.391	15.500	27.250	39.250	22.222	30.400
	Others	12.000		19.636	19.250	19.789	22.429

Table F.2: Continued.

Variables	Customers	1964-71	1972-75	1976-79	1980-84	1985-88	1989-93
totbw	USA		567.000	821.000	1039.478	1071.800	1439.600
	Europe		165.000	792.000	470.692	805.273	691.444
	International	287.217	542.750	2102.000	2671.167	1352.889	1495.760
	Others	432.000		798.545	954.625	894.526	897.619
eqvvoice	USA		5333.003	9106.404	12687.092	14070.178	19610.989
	Europe		1567.079	8779.058	5748.210	10591.464	9388.236
	International	1425.783	5281.174	22834.269	32601.554	18110.830	20604.866
	Others	3328.424		9155.060	11678.822	11695.903	12325.050
hmpower	USA		6.897	10.452	15.674	12.834	29.156
	Europe		20.000	20.000	111.750	47.957	54.067
	International	9.440	7.859	8.695	8.092	23.345	27.251
	Others	5.000		10.831	11.455	27.434	29.225
gmeirp	USA		30.680	39.084	39.067	42.853	46.279
	Europe		42.700	41.000	53.647	50.209	51.539
	International	33.438	29.132	31.874	32.661	34.940	38.162
	Others	33.990		38.008	35.189	43.523	42.980
mtrp	USA		0.154	0.143	0.000	0.214	0.189
	Europe		0.000	0.000	0.000	0.000	0.022
	International	0.000	0.125	0.009	0.006	0.089	0.320
	Others	0.000		0.036	0.010	0.047	0.073
ctrp	USA		0.846	0.471	0.565	0.407	0.330
	Europe		0.000	0.000	0.077	0.101	0.000
	International	1.000	0.875	0.771	0.800	0.757	0.448
	Others	1.000		0.661	0.585	0.304	0.500
kutrp	USA		0.000	0.386	0.391	0.379	0.481
	Europe		1.000	1.000	0.864	0.747	0.889
	International	0.000	0.000	0.220	0.194	0.154	0.232
	Others	0.000		0.303	0.280	0.521	0.399
otrp	USA		0.000	0.000	0.043	0.000	0.000
	Europe		0.000	0.000	0.059	0.152	0.089
	International	0.000	0.000	0.000	0.000	0.000	0.000
	Others	0.000		0.000	0.125	0.128	0.027

Table F.3: Yearly weighted average of the satellite characteristics by launch year.

Launch year	rdev	gtomass	eolpower	lifetime	sumtr	totbw	eqvvoice	hmpower	gmeirp
1965	12.00	68.00	46.00	2.00	1.00	50.00	240.00	7.89	24.00
1966	11.00	162.00	85.00	3.00	2.00	130.00	261.42	14.67	29.74
1967	17.33	162.00	85.00	3.00	2.00	130.00	261.42	14.67	29.74
1968	30.00	300.00	110.00	5.00	2.00	300.00	1083.86	10.00	35.76
1969	32.50	300.00	110.00	5.00	2.00	300.00	1083.86	10.00	35.76
1970	45.33	300.00	110.00	5.00	2.00	300.00	1083.86	10.00	35.76
1971	32.50	1382.00	409.00	7.00	12.00	432.00	2593.96	6.00	35.78
1972	32.00	1112.67	351.67	7.00	12.00	432.00	2970.73	5.67	35.18
1973	38.50	978.00	323.00	7.00	12.00	432.00	3159.11	5.50	34.88
1974	38.00	843.33	294.33	7.00	12.00	432.00	3581.50	5.33	28.92
1975	46.25	1094.50	428.50	7.25	17.00	612.00	5241.59	5.29	33.57
1976	33.14	1060.29	443.14	6.29	14.43	477.00	4530.28	8.48	30.77
1977	36.50	1176.00	551.00	5.00	13.00	442.50	4369.50	12.59	36.10
1978	46.20	1258.00	598.60	6.20	17.60	666.60	6613.83	9.52	34.79
1979	79.50	740.50	365.00	7.50	18.00	648.00	6041.57	5.00	30.24
1980	43.50	1526.75	1047.00	7.00	18.50	1266.00	13679.23	14.40	36.42
1981	54.00	1501.10	945.60	7.40	18.00	1101.80	12028.55	12.19	33.19
1982	43.70	1314.20	882.10	8.80	21.70	1032.20	11682.99	10.30	36.65
1983	52.00	1398.36	922.21	8.07	20.57	1065.00	12108.83	8.79	35.98
1984	54.38	1273.65	970.38	8.62	20.08	1010.85	11979.87	11.85	35.25
1985	47.20	1402.87	1151.20	8.67	22.00	1185.80	14335.96	13.84	37.03
1986	59.50	2106.75	1622.00	9.50	21.00	918.50	10924.43	19.92	41.09
1987	86.25	1359.75	1443.75	8.00	13.75	616.50	7214.55	62.65	44.66
1988	74.64	1557.46	1332.64	9.06	17.57	1041.29	12764.49	30.66	40.14
1989	77.40	2418.20	2372.40	9.10	20.50	1116.60	13767.92	67.27	48.93
1990	68.63	1879.06	1810.19	9.25	19.25	948.81	11970.43	54.77	45.57
1991	68.31	2374.77	2177.85	9.73	22.77	1168.46	14951.69	26.70	43.19
1992	60.85	1938.58	2134.23	10.23	18.54	866.81	11475.89	35.45	44.24
1993	53.00	2547.80	2455.20	10.47	24.30	1354.45	18011.83	28.71	44.74
1994	49.89	2587.84	2891.11	11.75	27.47	1337.05	18131.90	29.53	43.17
1995	52.84	2421.76	2281.21	10.66	25.05	1125.59	15425.32	24.06	42.58
1996	52.00	2235.33	3245.33	10.33	28.83	1323.67	18292.25	23.41	40.44

Table F.3: Continued.

Launch year	mtrp	ctrp	kutrp	otrp	Dtwt*	D3a*
1965	0.00	1.00	0.00	0.00	1.00	0.00
1966	0.00	1.00	0.00	0.00	1.00	0.00
1967	0.00	1.00	0.00	0.00	1.00	0.00
1968	0.00	1.00	0.00	0.00	1.00	0.00
1969	0.00	1.00	0.00	0.00	1.00	0.00
1970	0.00	1.00	0.00	0.00	1.00	0.00
1971	0.00	1.00	0.00	0.00	1.00	0.00
1972	0.00	1.00	0.00	0.00	1.00	0.00
1973	0.00	1.00	0.00	0.00	1.00	0.00
1974	0.00	1.00	0.00	0.00	1.00	0.00
1975	0.00	1.00	0.00	0.00	1.00	0.25
1976	0.29	0.71	0.00	0.00	1.00	0.14
1977	0.00	0.50	0.50	0.00	1.00	0.50
1978	0.00	0.73	0.27	0.00	1.00	0.40
1979	0.00	1.00	0.00	0.00	1.00	0.50
1980	0.00	0.39	0.61	0.00	1.00	0.50
1981	0.10	0.61	0.29	0.00	1.00	0.60
1982	0.03	0.73	0.24	0.00	1.00	0.50
1983	0.05	0.66	0.19	0.11	0.93	0.50
1984	0.05	0.68	0.26	0.01	0.92	0.54
1985	0.01	0.56	0.43	0.01	0.93	0.53
1986	0.09	0.36	0.55	0.00	1.00	0.75
1987	0.00	0.25	0.75	0.00	1.00	0.50
1988	0.04	0.35	0.47	0.13	0.79	0.79
1989	0.04	0.20	0.71	0.05	0.90	0.70
1990	0.03	0.33	0.62	0.03	0.81	0.56
1991	0.06	0.40	0.45	0.09	0.38	0.85
1992	0.04	0.30	0.60	0.06	0.69	0.92
1993	0.06	0.39	0.44	0.11	0.60	0.90
1994	0.14	0.45	0.40	0.01	0.16	0.84
1995	0.25	0.32	0.37	0.04	0.42	0.89
1996	0.05	0.59	0.36	0.00	0.50	0.83

*Note: The yearly average of dummy variables represent the percentage of satellites whose value for the dummy variable is one.

Appendix G : Number of equivalent voice channels

Table G.1: Ratio of the number of voice channels per total bandwidth for selected satellites.

adate	Name	Voice/bw	adate	Name	Voice/bw
1964	Intelsat I	0.416667	1980	Intelsat VA	0.078
1965	Intelsat II	0.541667	1981	Arabsat 1	0.04625
1966	Intelsat III	0.2	1982	Intelsat VI	0.078
1968	Intelsat IV	0.108	1982	SBTS A	0.03
1973	Intelsat IVA	0.108	1983	DFS-Kopernikus	0.0376
1973	Comstar 1	0.1329	1985	CS 3	0.183
1976	Intelsat V	0.096	1985	Italsat 1	0.02954
1977	Eutelsat I	0.1165	1986	Eutelsat II	0.0487
1978	Insat 1	0.1005	1988	Intelsat VII	0.072
1979	Comstar 2	0.1122	1990	Intelsat VIIA	0.072
1980	CS 2	0.195	1992	Intelsat VIII	0.064

The following model was used to fit the data:

$$totbw / voice = \alpha + \frac{\beta}{ADindex} \qquad \textbf{(G.1)}$$

where $ADindex = 0, 1, \ldots, 30$ corresponds to the years 1964-1992.

Using the data of Table G.1, the parameters of the model are $\alpha = 0.056292$ and $\beta = 0.440995$ with $R^2 = 0.8085$. Figure G.1 illustrates the fitted model as well as the actual values of the satellites listed in Table G.1.

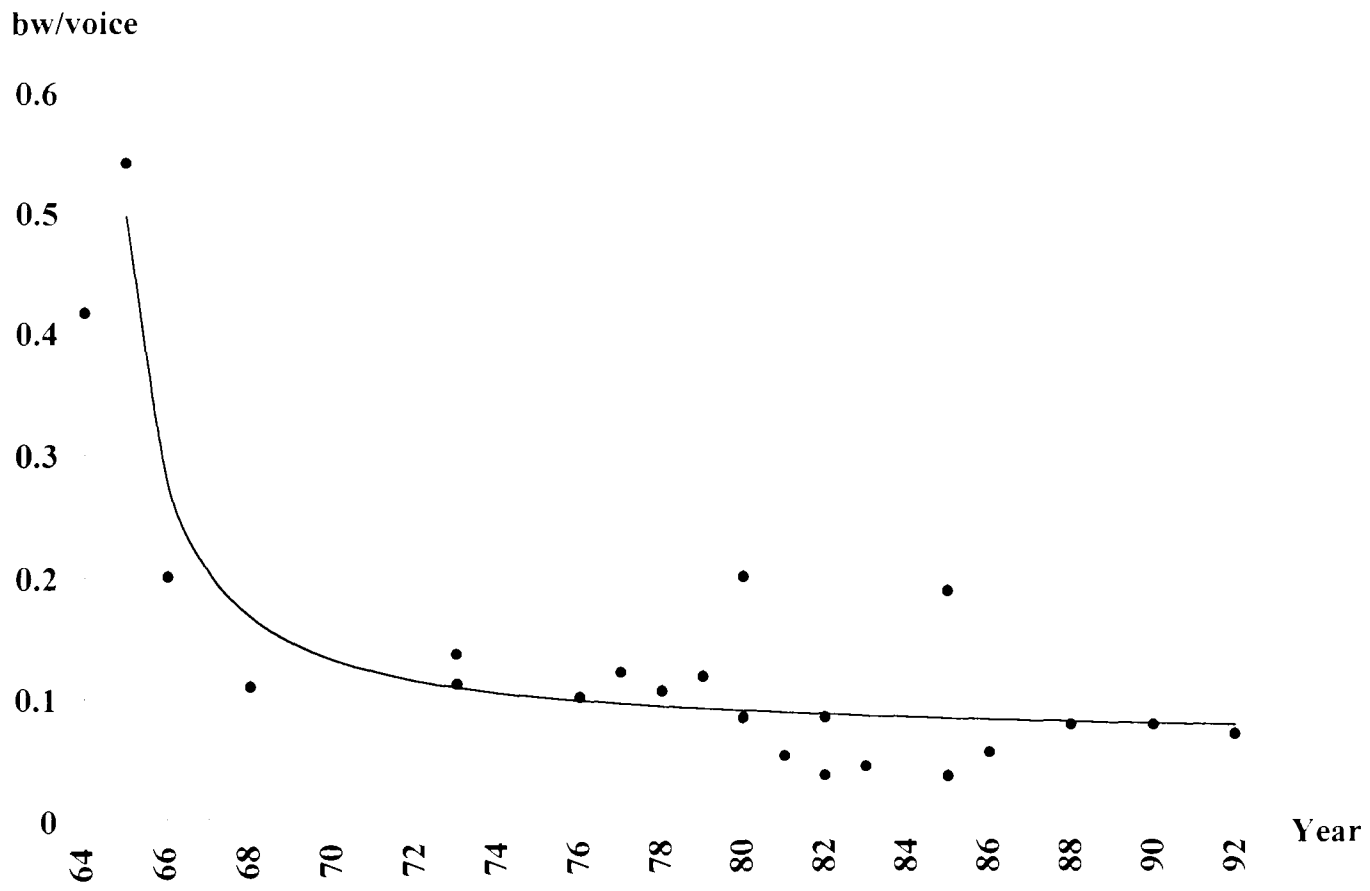


Figure G.1: Predicted bandwidth to number of voice channels ratio.

Appendix H : Hedonic regression models

The anti-log form of the four hedonic models of chapter 3 are presented below:

M1: $$p_i = e^{a}.nb_i^{\,b}.m_i^{\,c}.\prod_j X_{ji}^{\,\alpha_j}.\prod_k e^{\beta_k Dx_{ki}}.\prod_{t-1} e^{\delta_t D_t}.e^{\varepsilon_i} \quad \textbf{(H.1)}$$

where $$Complexity_{1i} = \prod_j X_{ji}^{\,\alpha_j}.\prod_k e^{\beta_k Dx_{ki}} \quad \textbf{(H.2)}$$

M2: $$p_i = e^{a}.nb_i^{\,b}.m_i^{\,c}.\prod_j e^{\alpha_j X_{ji}}.\prod_k e^{\beta_k Dx_{ki}}.\prod_{t-1} e^{\delta_t D_t}.e^{\varepsilon_i} \quad \textbf{(H.3)}$$

where $$Complexity_{2i} = e^{\sum_j \alpha_j X_{ji} + \sum_k \beta_k Dx_{ki}} \quad \textbf{(H.4)}$$

M3: $$p_i = e^{a}.nb_i^{\,b}.m_i^{\sum_j \alpha_j X_{ji} + \sum_k \beta_k Dx_{ki}}.\prod_{t-1} e^{\delta_t D_t}.e^{\varepsilon_i} \quad \textbf{(H.5)}$$

where $$Complexity_{3i} = \sum_j \alpha_j X_{ji} + \sum_k \beta_k Dx_{ki} \quad \textbf{(H.6)}$$

M4: $$p_i = e^{a}.nb_i^{\,b}.e^{\lambda_i m_i}.\prod_j e^{\alpha_j X_{ji}}.\prod_k e^{\beta_k Dx_{ki}}.\prod_{t-1} e^{\delta_t D_t}.e^{\varepsilon_i} \quad \textbf{(H.7)}$$

where $$Complexity_{4i} = e^{\lambda_i m_i + \sum_j \alpha_j X_{ji} + \sum_k \beta_k Dx_{ki}} \quad \textbf{(H.8)}$$

Appendix I : Chow tests for structural change

Recall the two F-statistics for the Chow test for structural change (different regressions):

$$F = \frac{\left(SSE_R - SSE_U\right)/k}{SSE_U/(EDF-k)} \qquad \textbf{(I.1)}$$

where SSE = sum of squared errors = residual sum of squares

subscript $_R$ corresponds to the restricted model

subscript $_U$ corresponds to the unrestricted model

$SSE_U = SSE_{U1} + SSE_{U2}$

$EDF = n - k$ = error degrees of freedom

k = number of variables

$n = n1 + n2$ = sum of the number of observations for each sub-period

and the case where ($n2 < k$) [Chow forecasting test]

$$F = \frac{\left(SSE_R - SSE_U\right)/n2}{SSE_U/EDF} \qquad \textbf{(I.2)}$$

The following tables show the tests for structural change that were performed in order to determine the most appropriate way to separate the sample for the split regression analysis. The first column of each table represents the sub-period from which the variables of the best fitting model were extracted for the calculation of the residual sums of squares. The column *exceptions* that appears in some of the tables represents the variables that had to be eliminated from the model identified by the first column to avoid multicollinearity in the regression calculations. The third column identifies the functional form utilised. The subsequent six columns are self-explanatory. The F column designates the F-statistic results and the P column the probability of rejecting the null hypothesis of a common regression between the two subsets. The last two columns illustrate the results of the tests at the 5 % and 1% level of significance; yes meaning that we reject the null hypothesis at the 5 % or 1 % level of significance, and no that the test is inconclusive.

Appendix I.1: Differences in time scale

Table I.1: Chow test for structural change between the sub-periods 1964-79 and 1980-93.

Variables	Exceptions	model	k	EDF	SSE_R	SSE_{U1}	SSE_{U2}	SSE_U	F	P	5%	1%
1964-79		M1	8	96	15.208	0.767	12.718	13.485	1.406	0.20516	no	no
		M2	7	97	15.566	1.108	12.851	13.959	1.479	0.18463	no	no
		M3	8	96	16.781	1.213	12.079	13.292	2.887	0.00666	yes	yes
		M4	10	94	16.035	1.434	11.897	13.330	1.705	0.09301	no	no
1980-93	Dtwt	M1	12	92	13.568	2.084	7.823	9.907	2.464	0.008617	yes	yes
	Dtwt, ctrp	M2	10	94	13.367	1.596	9.382	10.978	1.828	0.067876	no	no
	Dtwt	M3	11	93	14.634	1.655	9.914	11.569	1.975	0.041484	yes	no
	Dtwt, ctrp	M4	10	94	16.210	2.457	10.139	12.596	2.410	0.014278	yes	no
1964-93	Dtwt	M1	12	92	12.221	1.138	8.094	9.232	2.159	0.02171	yes	no
	Dtwt, ctrp	M2	10	94	14.221	1.147	11.202	12.349	1.273	0.2587	no	no
	Dtwt	M3	11	93	14.429	1.090	9.955	11.045	2.284	0.01724	yes	no
	Dtwt, ctrp	M4	11	93	14.760	1.443	10.172	11.615	2.018	0.03673	yes	no
all	Dtwt	M1	15	89	11.926	0.613	7.637	8.250	2.198	0.013674	yes	no
	Dtwt, ctrp	M2	14	90	12.751	0.949	8.895	9.844	1.603	0.097565	no	no
	Dtwt	M3	14	90	14.102	0.924	9.423	10.347	1.970	0.031615	yes	no
	Dtwt, ctrp	M4	14	90	13.998	0.924	8.930	9.854	2.283	0.011506	yes	no

Conclusion: Reject the null hypothesis of a common regression between the years 1964-79 and 1980-93 at the 5 % level. At the 1 % level, the null cannot be rejected.

Table I.2: Chow test for structural change between the sub-periods 1964-75 and 1976-79.

Variables	Exceptions	model	k	EDF	SSE_R	SSE_{U1}	SSE_{U2}	SSE_U	F	P	5%	1%
1964-75		M1	5	20	1.553	0.206	0.396	0.602	4.733	0.00856	yes	yes
		M2	9	16	2.408	0.147	0.454	0.601	2.339	0.13767	no	no
		M3	7	18	2.531	0.176	0.791	0.967	2.542	0.08067	no	no
		M4	9	16	2.408	0.147	0.454	0.601	2.339	0.13767	no	no
1976-79		M1	8	17	1.157	0.247	0.054	0.302	3.191	0.05168	no	no
		M2	7	18	1.159	0.289	0.054	0.342	3.752	0.02515	yes	no
		M3	8	17	1.142	0.292	0.041	0.332	2.740	0.07734	no	no
		M4	7	18	1.848	0.235	0.086	0.321	7.465	0.00188	yes	yes
1964-79		M1	8	17	0.767	0.299	0.160	0.460	0.752	0.65066	no	no
		M2	7	18	1.108	0.375	0.155	0.530	1.714	0.20377	no	no
		M3	8	17	1.213	0.370	0.081	0.451	1.899	0.17936	no	no
		M4	10	15	1.434	0.183	0.002	0.185	3.382	0.09545	no	no
		model	**k**	**EDF**	**SSE_R**	**EDF_U**	**n2**	**SSE_U**	**F**	**P**	**5%**	**1%**
all*	Dtwt, service, ctrp	M1	13	12	0.908	1	11	0.130	0.542	0.79833	no	no
	Dtwt, service, ctrp	M2	13	12	0.952	1	11	0.130	0.573	0.78672	no	no
	Dtwt, service	M3	13	12	0.924	1	11	0.130	0.554	0.79394	no	no
	Dtwt, service, ctrp	M4	13	12	1.190	1	11	0.130	0.739	0.73063	no	no

* Using Chow forecasting test

Conclusion: Cannot reject the null hypothesis of a common regression between the years 1964-75 and 1976-79 at the 5 % level.

Table I.3: Chow test for structural change between the sub-periods 1980-88 and 1989-93.

Variables	model	k	EDF	SSE_R	SSE_{U1}	SSE_{U2}	SSE_U	F	P	5%	1%
1980-88	M1	11	68	8.405	4.091	1.191	5.282	3.064	0.00276	yes	yes
	M2	9	70	10.048	5.205	2.058	7.262	2.600	0.01314	yes	no
	M3	9	70	10.074	5.137	2.078	7.215	2.686	0.01069	yes	no
	M4	10	69	9.571	4.910	2.010	6.920	2.261	0.02586	yes	no
1989-93	M1	11	68	9.483	6.642	0.675	7.317	1.534	0.14478	no	no
	M2	10	69	10.431	7.600	1.035	8.635	1.227	0.29310	no	no
	M3	8	71	12.722	10.825	1.228	12.053	0.437	0.89407	no	no
	M4	10	69	10.431	7.600	1.035	8.635	1.227	0.29310	no	no
1980-93	M1	13	66	7.449	4.734	0.721	5.455	1.491	0.15200	no	no
	M2	12	67	8.099	5.130	1.323	6.453	1.169	0.32753	no	no
	M3	12	67	8.955	5.599	1.659	7.258	1.072	0.40087	no	no
	M4	12	67	8.179	5.467	1.450	6.917	0.836	0.61356	no	no
all	M1	16	63	7.323	3.987	0.622	4.609	1.730	0.07367	no	no
	M2	16	63	7.868	4.679	0.922	5.601	1.189	0.31106	no	no
	M3	15	64	8.787	4.833	1.100	5.933	1.571	0.11742	no	no
	M4	16	63	7.882	4.344	0.946	5.291	1.439	0.16529	no	no

Conclusion: Cannot reject the null hypothesis of a common regression between the years 1980-88 and 1989-93 at the 5 % level.

Table I.4: Chow test for structural change between the sub-periods 1980-84 and 1985-93.

Variables	model	k	EDF	SSE_R	SSE_{U1}	SSE_{U2}	SSE_U	F	P	5%	1%
1980-84	M1	9	70	9.714	1.338	5.769	7.106	2.487	0.01720	yes	no
	M2	9	70	11.942	1.220	7.045	8.265	3.015	0.00484	yes	yes
	M3	10	69	11.169	1.123	6.053	7.176	3.283	0.00196	yes	yes
	M4	9	70	12.054	1.176	7.139	8.315	3.049	0.00447	yes	yes
1985-93	M1	13	66	7.449	1.268	3.156	4.424	2.788	0.00427	yes	yes
	M2	12	67	8.099	1.733	3.610	5.343	2.364	0.01559	yes	no
	M3	12	67	8.955	1.505	3.885	5.391	3.031	0.00252	yes	yes
	M4	12	67	8.179	1.679	3.561	5.240	2.571	0.00885	yes	yes
1980-93	M1	11	68	10.721	3.412	3.061	6.473	3.401	0.00114	yes	yes
	M2	12	67	8.460	2.778	3.050	5.828	2.069	0.03469	yes	no
	M3	11	68	9.973	4.041	3.434	7.475	1.732	0.08930	no	no
	M4	12	67	8.475	2.759	3.061	5.820	2.091	0.03275	yes	no
all	M1	16	63	7.323	1.215	2.835	4.050	2.373	0.01108	yes	no
	M2	16	63	7.868	1.081	2.864	3.945	2.921	0.00219	yes	yes
	M3	15	64	8.787	1.071	3.239	4.310	3.392	0.00061	yes	yes
	M4	16	63	7.882	1.059	2.871	3.930	2.954	0.00199	yes	yes

Conclusion: Reject the null hypothesis of a common regression between the years 1980-84 and 1985-93 at the 1 % level.

Table I.5: Chow test for structural change between the sub-periods 1964-75 and 1976-84.

Variables	Exceptions	model	k	EDF	SSE_R	SSE_{U1}	SSE_{U2}	SSE_U	F	P	5%	1%
1964-75		M1	5	46	7.636	0.206	6.045	6.251	1.816	0.13109	no	no
		M2	9	42	6.573	0.147	3.548	3.696	2.855	0.01325	yes	no
		M3	7	44	8.106	0.176	6.359	6.535	1.271	0.29135	no	no
		M4	9	42	6.573	0.147	3.548	3.696	2.855	0.01325	yes	no
1976-84	Dtwt	M1	9	43	8.097	0.867	3.000	3.867	4.132	0.00116	yes	yes
	Dtwt	M2	9	43	5.815	0.207	2.535	2.742	4.236	0.00096	yes	yes
	Dtwt	M3	9	43	6.113	0.257	2.399	2.656	4.917	0.00030	yes	yes
	Dtwt	M4	8	44	6.395	0.288	2.210	2.498	7.021	0.00001	yes	yes
1964-84	Dtwt, mtrp	M1	10	42	6.217	0.191	4.005	4.197	1.541	0.17058	no	no
	Dtwt, mtrp	M2	10	42	6.099	0.186	2.682	2.867	3.606	0.00271	yes	yes
	Dtwt, mtrp	M3	9	43	5.898	0.251	2.565	2.816	4.134	0.00116	yes	yes
	Dtwt, mtrp	M4	10	42	6.100	0.224	2.288	2.512	4.571	0.00047	yes	yes
all	Dtwt, totbw, ctrp	M1	13	39	5.687	0.130	3.032	3.163	1.596	0.15029	no	no
	Dtwt, totbw, ctrp	M2	13	39	5.628	0.130	2.331	2.462	2.573	0.01949	yes	no
	Dtwt, totbw	M3	13	39	6.016	0.130	2.173	2.304	3.223	0.00537	yes	yes
	Dtwt, totbw, ctrp	M4	13	39	5.729	0.130	1.989	2.120	3.405	0.00379	yes	yes
all	Dtwt, service, ctrp	M1	13	39	5.707	0.130	2.959	3.090	1.694	0.12249	no	no
	Dtwt, service, ctrp	M2	13	39	5.382	0.130	2.363	2.493	2.318	0.03301	yes	no
	Dtwt, service	M3	13	39	5.670	0.130	2.251	2.382	2.761	0.01330	yes	no
	Dtwt, service, ctrp	M4	13	39	5.530	0.130	1.936	2.066	3.353	0.00418	yes	yes

Conclusion: Reject the null hypothesis of a common regression between the years 1964-75 and 1976-84 at the 5 % level.

Table I.6: Chow test for structural change between the sub-periods 1976-84 and 1985-93.

Variables	model	k	EDF	SSE_R	SSE_{U1}	SSE_{U2}	SSE_U	F	P	5%	1%
1976-84	M1	10	80	9.725	2.781	4.472	7.253	2.385	0.01696	yes	no
	M2	10	80	10.827	2.244	5.482	7.726	2.810	0.00551	yes	yes
	M3	10	80	11.341	2.196	4.540	6.736	4.786	0.00003	yes	yes
	M4	9	81	10.779	1.995	5.743	7.738	3.144	0.00299	yes	yes
1985-93	M1	11	79	12.317	4.365	3.061	7.426	4.072	0.00014	yes	yes
	M2	12	78	9.232	3.571	3.050	6.621	2.169	0.02358	yes	no
	M3	11	79	11.286	5.094	3.434	8.528	1.999	0.04184	yes	no
	M4	12	78	9.127	3.129	3.061	6.190	2.610	0.00658	yes	yes
1976-93	M1	13	77	9.183	2.932	3.156	6.088	2.503	0.00783	yes	yes
	M2	12	78	8.984	2.496	3.531	6.027	2.698	0.00510	yes	yes
	M3	9	81	10.526	3.429	3.986	7.414	3.357	0.00175	yes	yes
	M4	12	78	8.856	2.031	3.558	5.588	3.216	0.00113	yes	yes
all	M1	16	74	8.831	2.697	2.835	5.532	2.161	0.01703	yes	no
	M2	16	74	8.899	2.080	2.864	4.944	2.899	0.00156	yes	yes
	M3	15	75	10.417	2.006	3.239	5.245	3.944	0.00007	yes	yes
	M4	16	74	8.799	1.785	2.871	4.656	3.226	0.00055	yes	yes

Conclusion: Reject the null hypothesis of a common regression between the years 1976-84 and 1985-93 at the 1 % level.

Table I.7: Chow test for structural change between the sub-periods 1976-79 and 1980-84.

Variables	Exceptions	model	k	EDF	SSE_R	SSE_{U1}	SSE_{U2}	SSE_U	F	P	5%	1%
1976-79		M1	8	30	4.224	0.054	3.618	3.672	0.414	0.90035	no	no
		M2	7	31	4.970	0.054	3.461	3.515	1.420	0.24310	no	no
		M3	8	30	6.225	0.041	4.941	4.982	0.686	0.69911	no	no
		M4	7	31	3.891	0.086	1.968	2.055	3.064	0.01879	yes	no
1980-84		M1	9	29	3.380	0.063	1.338	1.401	3.140	0.01585	yes	no
		M2	9	29	2.603	0.151	1.220	1.371	1.997	0.09492	no	no
		M3	10	28	2.292	0.077	1.123	1.200	1.637	0.17415	no	no
		M4	9	29	2.419	0.093	1.176	1.269	2.015	0.09218	no	no
1976-84	Dtwt	M1	9	29	3.000	0.078	1.502	1.580	1.998	0.09479	no	no
	Dtwt	M2	9	29	2.535	0.135	1.378	1.513	1.502	0.21420	no	no
	Dtwt	M3	9	29	2.399	0.079	1.244	1.323	1.807	0.12961	no	no
	Dtwt	M4	8	30	2.210	0.242	1.772	2.014	0.268	0.96989	no	no
		model	**k**	**EDF**	**SSE_R**	**EDF_U**	**n2**	**SSE_U**	**F**	**P**	**5%**	**1%**
all*		M1	16	22	2.697	11	11	1.215	1.220	0.37381	no	no
		M2	16	22	2.080	11	11	1.081	0.924	0.55110	no	no
		M3	15	23	2.006	12	11	1.071	0.952	0.52906	no	no
		M4	16	22	1.785	11	11	1.059	0.685	0.72941	no	no

* Using Chow forecasting test

Conclusion: Cannot reject the null hypothesis of a common regression between the years 1976-79 and 1980-84 at the 5 % level.

Table I.8: Chow test for structural change between the sub-periods 1985-88 and 1989-93.

Variables	model	k	EDF	SSE_R	SSE_{U1}	SSE_{U2}	SSE_U	F	P	5%	1%
1985-88	M1	11	41	3.216	0.493	1.053	1.546	2.947	0.00921	yes	yes
	M2	12	40	4.136	0.568	1.980	2.548	1.455	0.20028	no	no
	M3	9	43	4.593	0.857	2.103	2.960	2.084	0.05930	no	no
	M4	12	40	3.193	0.578	1.504	2.082	1.245	0.30324	no	no
1989-93	M1	11	41	3.519	1.559	0.675	2.234	1.568	0.15953	no	no
	M2	10	42	4.317	1.667	1.035	2.702	1.912	0.08034	no	no
	M3	8	44	4.491	2.279	1.228	3.507	1.263	0.29288	no	no
	M4	10	42	4.317	1.667	1.035	2.702	1.912	0.08034	no	no
1985-93	M1	11	41	3.061	0.826	1.016	1.842	1.804	0.09793	no	no
	M2	12	40	3.050	0.768	1.296	2.064	1.115	0.38697	no	no
	M3	11	41	3.434	0.965	1.659	2.623	0.842	0.60160	no	no
	M4	12	40	3.061	0.700	1.378	2.078	1.104	0.39497	no	no
all	M1	16	36	2.835	0.475	0.622	1.097	1.980	0.07457	no	no
	M2	16	36	2.864	0.544	0.922	1.465	1.193	0.34992	no	no
	M3	15	37	3.239	0.760	1.100	1.859	1.088	0.41822	no	no
	M4	16	36	2.871	0.544	0.946	1.490	1.159	0.37270	no	no

Conclusion: Cannot reject the null hypothesis of a common regression between the years 1985-88 and 1989-93 at the 5 % level.

Table I.9: Chow test for structural change between the sub-periods 1976-79 and 1980-88.

Variables	Exceptions	model	k	EDF	SSE_R	SSE_{U1}	SSE_{U2}	SSE_U	F	P	5%	1%
1976-79		M1	8	53	8.787	0.054	8.202	8.256	0.362	0.93516	no	no
		M2	7	54	9.525	0.054	8.906	8.959	0.424	0.88247	no	no
		M3	8	53	10.931	0.041	9.918	9.959	0.549	0.81297	no	no
		M4	7	54	10.301	0.086	9.731	9.817	0.331	0.93590	no	no
1980-88	Dtwt	M1	10	51	5.531	0.049	4.263	4.312	1.159	0.34498	no	no
	Dtwt	M2	8	53	7.461	0.111	5.911	6.023	1.343	0.24755	no	no
	Dtwt	M3	8	53	7.282	0.114	5.863	5.977	1.229	0.30472	no	no
	Dtwt	M4	9	52	6.303	0.107	5.359	5.466	0.732	0.67759	no	no
1976-88	Dtwt	M1	9	52	5.569	0.050	4.274	4.324	1.376	0.22892	no	no
	Dtwt	M2	9	52	6.616	0.111	5.546	5.658	0.809	0.61027	no	no
	Dtwt	M3	8	53	7.130	0.156	6.223	6.379	0.663	0.72097	no	no
	Dtwt	M4	10	51	5.505	0.002	4.749	4.751	0.651	0.76168	no	no
		model	**k**	**EDF**	**SSE_R**	**EDF_U**	**n2**	**SSE_U**	**F**	**P**	**5%**	**1%**
all*		M1	16	45	5.111	34	11	3.987	0.871	0.57536	no	no
		M2	16	45	5.738	34	11	4.679	0.699	0.73022	no	no
		M3	15	46	5.947	35	11	4.833	0.734	0.69953	no	no
		M4	16	45	5.214	34	11	4.344	0.619	0.79975	no	no

* Using Chow forecasting test

Conclusion: Cannot reject the null hypothesis of a common regression between the years 1976-79 and 1980-88 at the 5 % level.

Table I.10: Chow test for structural change between the sub-periods 1976-84 and 1985-88.

Variables	model	k	EDF	SSE_R	SSE_{U1}	SSE_{U2}	SSE_U	F	P	5%	1%
1976-84	M1	10	51	5.362	2.781	1.744	4.525	0.758	0.66671	no	no
	M2	10	51	6.699	2.244	1.972	4.215	2.416	0.02303	yes	no
	M3	10	51	6.423	2.196	0.846	3.042	4.558	0.00023	yes	yes
	M4	9	52	5.896	1.995	1.860	3.856	2.529	0.02005	yes	no
1985-88	M1	11	50	9.088	5.404	0.493	5.897	1.919	0.06675	no	no
	M2	12	49	7.418	3.591	0.568	4.159	2.416	0.01982	yes	no
	M3	9	52	6.844	2.696	0.857	3.553	4.426	0.00039	yes	yes
	M4	12	49	6.794	3.264	0.578	3.843	2.368	0.02219	yes	no
1976-88	M1	10	51	5.347	2.835	1.160	3.995	1.388	0.21992	no	no
	M2	10	51	6.127	2.310	1.308	3.619	2.842	0.00887	yes	yes
	M3	9	52	6.556	2.389	0.956	3.345	4.588	0.00028	yes	yes
	M4	11	50	5.419	2.068	1.226	3.295	2.286	0.02856	yes	no
all	M1	16	45	5.111	2.697	0.475	3.172	1.107	0.39251	no	no
	M2	16	45	5.738	2.080	0.544	2.624	2.150	0.03550	yes	no
	M3	15	46	5.947	2.006	0.760	2.766	2.377	0.02032	yes	no
	M4	16	45	5.214	1.785	0.544	2.329	2.246	0.02824	yes	no

Conclusion: Reject the null hypothesis of a common regression between the years 1976-84 and 1985-88 at the 5 % level.

Table I.11: Chow test for structural change between the sub-periods 1972-75 and 1976-84.

Variables	Exceptions	model	k	EDF	SSE_R	SSE_{U1}	SSE_{U2}	SSE_U	F	P	5%	1%
1976-84	Dtwt, D3a, ctrp	M1	7	39	7.540	0.130	4.519	4.649	2.842	0.02013	yes	no
	Dtwt, D3a, ctrp, mtrp	M2	7	39	5.615	0.130	3.126	3.256	3.312	0.00915	yes	yes
	Dtwt, D3a, ctrp, kutrp	M3	7	39	5.637	0.130	3.419	3.550	2.688	0.02616	yes	no
	Dtwt, D3a, ctrp, mtrp	M4	7	39	5.270	0.130	2.798	2.928	3.656	0.00521	yes	yes
		model	**k**	**EDF**	**SSE_R**	**EDF_U**	**n2**	**SSE_U**	**F**	**P**	**5%**	**1%**
all*		M1	16	30	4.274	22	8	2.697	1.607	0.17962	no	no
		M2	16	30	3.855	22	8	2.080	2.346	0.05418	no	no
		M3	15	31	4.478	23	8	2.006	3.542	0.00817	yes	yes
		M4	16	30	3.359	22	8	1.785	2.425	0.04781	yes	no

* Using Chow forecasting test

Conclusion: Reject the null hypothesis of a common regression between the years 1972-75 and 1976-84 at the 5 % level.

Table I.12: Chow test for structural change between the sub-periods 1980-84 and 1985-88.

Variables	model	k	EDF	SSE_R	SSE_{U1}	SSE_{U2}	SSE_U	F	P	5%	1%
1980-84	M1	9	41	5.453	1.338	1.588	2.926	3.071	0.00910	yes	yes
	M2	9	41	6.293	1.220	2.588	3.808	2.319	0.03872	yes	no
	M3	10	40	5.421	1.123	1.137	2.260	4.197	0.00107	yes	yes
	M4	9	41	6.225	1.176	2.586	3.761	2.329	0.03799	yes	no
1985-88	M1	11	39	7.978	4.439	0.493	4.931	1.572	0.16182	no	no
	M2	12	38	6.718	2.245	0.568	2.813	3.007	0.00910	yes	yes
	M3	9	41	5.584	1.635	0.857	2.492	4.412	0.00082	yes	yes
	M4	12	38	6.022	2.501	0.578	3.079	2.071	0.05852	no	no
1980-88	M1	11	39	4.091	1.329	1.152	2.481	1.652	0.13787	no	no
	M2	9	41	5.205	1.363	1.311	2.674	3.365	0.00525	yes	yes
	M3	9	41	5.137	1.292	1.326	2.618	3.421	0.00474	yes	yes
	M4	10	40	4.910	1.260	1.306	2.566	2.740	0.01591	yes	no
all	M1	16	34	3.987	1.215	0.475	1.690	1.529	0.19204	no	no
	M2	16	34	4.679	1.081	0.544	1.625	2.114	0.06407	no	no
	M3	15	35	4.833	1.071	0.760	1.831	2.186	0.05166	no	no
	M4	16	34	4.344	1.059	0.544	1.603	1.924	0.09110	no	no

Conclusion: Cannot reject the null hypothesis of a common regression between the years 1980-84 and 1985-88 at the 5 % level.

Appendix I.2: Differences in manufacturing region

Table I.13: Chow tests for structural change between North American and European manufacturers for different sub-periods.

Variables	Exceptions	model	k	EDF	SSE_R	SSE_{U1}	SSE_{U2}	SSE_U	F	P	5%	1%
US	D3a, D9193	M1	17	83	11.277	4.036	1.427	5.462	4.133	0.00002	yes	yes
Europe	D3a, D9193	M2	18	82	10.442	3.802	1.224	5.026	3.831	0.00004	yes	yes
1964-93	D3a, D9193	M3	14	86	14.307	4.775	3.815	8.590	3.423	0.00029	yes	yes
	D3a, D9193	M4	20	80	10.416	3.953	0.566	4.519	3.915	0.00002	yes	yes
US		M1	18	82	11.023	4.625	0.570	5.195	3.988	0.00002	yes	yes
Europe		M2	20	80	11.410	4.219	0.096	4.315	4.933	0.00000	yes	yes
1964-93		M3	20	80	12.432	4.541	0.110	4.650	5.020	0.00000	yes	yes
		M4	21	79	11.026	4.079	0.118	4.196	4.495	0.00000	yes	yes
US	D3a	M1	18	57	6.442	2.081	0.098	2.179	4.238	0.00008	yes	yes
Europe	D3a	M2	17	58	6.907	2.168	1.061	3.229	2.746	0.00415	yes	yes
1980-93	D3a	M3	14	61	10.622	2.563	3.353	5.916	2.671	0.00598	yes	yes
	D3a	M4	17	58	7.000	2.100	1.008	3.108	3.019	0.00193	yes	yes
US		M1	18	57	6.959	2.551	0.085	2.636	3.553	0.00045	yes	yes
Europe		M2	18	57	7.037	2.639	0.086	2.725	3.429	0.00063	yes	yes
1980-93		M3	18	57	8.399	2.839	0.089	2.928	4.049	0.00013	yes	yes
		M4	18	57	7.271	2.666	0.086	2.752	3.558	0.00045	yes	yes
		model	**k**	**EDF**	**SSE_R**	**EDF_U**	**n2**	**SSE_U**	**F**	**P**	**5%**	**1%**
US*		M1	12	25	4.045	16	9	0.483	13.125	0.00001	yes	yes
Europe		M2	14	23	2.958	14	9	0.381	10.533	0.00008	yes	yes
1976-84		M3	8	29	9.534	20	9	0.759	25.690	0.00000	yes	yes
		M4	11	26	2.799	17	9	0.410	10.991	0.00002	yes	yes
US*		M1	9	16	1.657	13	3	0.477	10.735	0.00080	yes	yes
Europe		M2	9	16	1.163	13	3	0.502	5.707	0.01020	yes	no
1964-79		M3	9	16	1.572	13	3	0.597	7.071	0.00462	yes	yes
		M4	8	17	1.700	14	3	0.502	11.124	0.00053	yes	yes

*Chow forecasting test

Conclusion: Reject the null hypothesis of a common regression between North American and European manufacturers at the 1 % level.

Table I.14: Tests for structural change across time periods; N. A. producers.

Variables	Exceptions	model	k	EDF	SSE_R	SSE_{U1}	SSE_{U2}	SSE_U	F	P	5%	1%
1964-79		M1	9	67	6.490	0.477	3.958	4.435	2.985	0.00546	yes	yes
1980-93		M2	9	67	5.467	0.502	4.076	4.578	1.252	0.28286	no	no
1964-93		M3	9	67	6.985	0.597	4.395	4.992	2.573	0.01449	yes	no
		M4	8	68	6.465	0.502	4.487	4.990	2.217	0.03847	yes	no
1964-79	Dtwt	M1	12	64	4.996	0.615	3.172	3.787	1.383	0.20392	no	no
1980-93	Dtwt, mtrp	M2	11	65	5.406	0.596	3.915	4.511	0.974	0.48053	no	no
1964-93	Dtwt	M3	9	67	7.046	0.663	4.239	4.902	2.818	0.00812	yes	yes
	Dtwt, mtrp	M4	11	65	5.648	0.519	3.872	4.391	1.406	0.19718	no	no
1964-79	Dtwt	M1	10	66	5.063	0.681	3.255	3.936	1.603	0.12954	no	no
1980-93	Dtwt, mtrp	M2	10	66	5.406	0.685	3.949	4.634	0.934	0.50970	no	no
1964-93	Dtwt	M3	8	68	5.548	0.767	4.179	4.946	0.913	0.51238	no	no
	Dtwt, mtrp	M4	12	64	5.316	0.529	3.835	4.364	0.945	0.51148	no	no
1964-79	Dtwt	M1	15	61	4.990	0.425	3.111	3.536	1.261	0.26467	no	no
1980-93	Dtwt, mtrp	M2	14	62	5.010	0.448	3.694	4.141	0.719	0.74468	no	no
1964-93	Dtwt	M3	14	62	5.408	0.463	3.737	4.200	0.987	0.48090	no	no
	Dtwt, mtrp	M4	14	62	5.107	0.441	3.605	4.046	0.899	0.56485	no	no
1964-75	service	M1	8	14	0.932	0.279	0.069	0.348	1.258	0.40107	no	no
1976-79	service	M2	8	14	0.699	0.176	0.045	0.221	1.623	0.28597	no	no
1964-79	service	M3	8	14	0.659	0.193	0.043	0.235	1.351	0.36693	no	no
		M4	8	14	0.502	0.322	0.080	0.402	0.188	0.98301	no	no
1980-88		M1	13	41	2.798	1.403	0.718	2.121	0.687	0.75894	no	no
1989-93		M2	13	41	2.875	1.545	0.591	2.136	0.746	0.70568	no	no
1980-93		M3	10	44	3.830	1.853	0.733	2.586	1.635	0.13857	no	no
		M4	13	41	2.679	1.437	0.629	2.066	0.639	0.80116	no	no
1980-88		M1	16	38	2.685	1.244	0.080	1.324	1.413	0.22257	no	no
1989-93		M2	16	38	2.776	1.503	0.164	1.667	0.915	0.56522	no	no
1980-93		M3	15	39	3.437	1.452	0.231	1.683	1.667	0.12803	no	no
		M4	16	38	2.571	1.418	0.125	1.543	0.916	0.56405	no	no
1980-85		M1	13	41	2.798	0.289	1.737	2.025	0.821	0.63533	no	no
1985-93		M2	13	41	2.875	0.261	1.656	1.917	1.077	0.41537	no	no
1980-93		M3	10	44	3.830	0.391	2.108	2.499	1.811	0.09627	no	no
		M4	13	41	2.679	0.262	1.687	1.949	0.807	0.64852	no	no
1980-85		M1	16	38	2.685	0.061	0.937	0.998	2.324	0.03369	yes	no
1985-93		M2	16	38	2.776	0.042	1.356	1.397	1.356	0.24962	no	no
1980-93		M3	15	39	3.437	0.115	1.864	1.980	1.178	0.35019	no	no
		M4	16	38	2.571	0.028	1.391	1.419	1.117	0.39746	no	no
1964-75		M1	8	32	2.526	0.166	1.316	1.481	2.115	0.07457	no	no
1976-84	Dtwt,mtrp,kutrp,service	M2	9	31	2.389	0.285	1.147	1.432	1.633	0.16688	no	no
1964-84		M3	4	36	3.429	0.583	2.147	2.730	2.049	0.11101	no	no
	Dtwt, kutrp, service	M4	6	34	2.507	0.668	1.271	1.939	1.367	0.26222	no	no
1976-93		M1	10	54	4.310	0.812	2.296	3.108	1.703	0.11035	no	no
1976-84		M2	12	52	4.429	0.860	2.103	2.963	1.649	0.11676	no	no
1985-93		M3	6	58	6.154	1.103	3.295	4.398	3.459	0.00597	yes	yes
		M4	9	55	4.241	0.655	2.281	2.936	2.273	0.03347	yes	no
1976-93		M1	16	48	3.579	0.667	0.937	1.604	2.463	0.01463	yes	no
1976-84		M2	16	48	3.373	0.738	1.356	2.093	1.223	0.30416	no	no
1985-93		M3	15	49	4.555	0.748	1.864	2.612	1.686	0.10197	no	no
		M4	16	48	3.096	0.610	1.391	2.001	1.094	0.39920	no	no
1976-79	Dtwt	M1	9	19	1.029	0.079	0.574	0.653	0.639	0.74334	no	no
1980-84	Dtwt, totbw	M2	10	18	1.134	0.000	0.471	0.471	1.125	0.44246	no	no
1976-84	Dtwt	M3	5	23	1.241	0.201	0.682	0.883	1.458	0.25211	no	no
	Dtwt	M4	8	20	0.792	0.063	0.536	0.599	0.484	0.84524	no	no
1976-84		M1	10	33	2.239	0.812	0.502	1.314	1.621	0.16294	no	no
1985-88		M2	12	31	2.353	0.860	0.217	1.077	1.877	0.10642	no	no
1976-88		M3	6	37	3.101	1.103	1.016	2.120	2.393	0.05129	no	no
		M4	9	34	2.493	0.655	0.375	1.030	3.943	0.00313	yes	yes

Table I.15: Tests for structural change across time periods, using Chow forecasting test; North American manufacturers.

		model	k	EDF	SSE_R	EDF_U	n2	SSEU	F	P	5%	1%
1964-75	totbw, Dtwt, service, mtrp, kutrp	M1	11	11	0.781	1	10	0.130	0.499	0.81254	no	no
1976-79	totbw, Dtwt, service, mtrp, kutrp	M2	11	11	0.686	1	10	0.130	0.426	0.84339	no	no
1964-79	totbw, Dtwt, service, mtrp, kutrp	M3	10	12	0.648	2	10	0.179	0.524	0.80145	no	no
	totbw, Dtwt, service, mtrp, kutrp	M4	11	11	0.620	1	10	0.130	0.375	0.86631	no	no
1964-75		M1	16	24	1.555	12	12	0.667	1.331	0.31393	no	no
1976-84		M2	16	24	1.398	12	12	0.738	0.895	0.57489	no	no
1964-84		M3	15	25	1.662	13	12	0.748	1.324	0.31056	no	no
		M4	16	24	1.403	12	12	0.610	1.300	0.32839	no	no
1976-79		M1	16	12	0.667	2	10	0.061	1.970	0.38340	no	no
1980-84		M2	16	12	0.738	2	10	0.042	3.320	0.25357	no	no
1976-84		M3	15	13	0.748	3	10	0.115	1.645	0.37510	no	no
		M4	16	12	0.610	2	10	0.028	4.178	0.20850	no	no
1985-88		M1	16	20	0.937	5	15	0.080	3.557	0.08375	no	no
1989-93		M2	16	20	1.356	5	15	0.164	2.415	0.16829	no	no
1985-93		M3	15	21	1.864	6	15	0.231	2.822	0.10363	no	no
		M4	16	20	1.391	5	15	0.125	3.383	0.09213	no	no
1976-79		M1	16	27	2.053	17	10	1.244	1.105	0.41121	no	no
1980-88		M2	16	27	2.111	17	10	1.503	0.688	0.72222	no	no
1976-88		M3	15	28	2.078	18	10	1.452	0.777	0.65001	no	no
		M4	16	27	1.946	17	10	1.418	0.633	0.76715	no	no
1976-84		M1	16	27	2.053	12	15	0.667	1.662	0.19019	no	no
1985-88		M2	16	27	2.111	12	15	0.738	1.489	0.24650	no	no
1976-88		M3	15	28	2.078	13	15	0.748	1.542	0.21954	no	no
		M4	16	27	1.946	12	15	0.610	1.752	0.16645	no	no
1972-75		M1	10	24	1.326	18	6	0.812	1.902	0.13571	no	no
1976-84		M2	12	22	1.297	16	6	0.860	1.355	0.29078	no	no
1972-84		M3	6	28	1.713	22	6	1.103	2.026	0.10505	no	no
		M4	9	25	1.470	19	6	0.655	3.943	0.00995	yes	yes
1972-75		M1	16	18	1.013	12	6	0.667	1.038	0.44803	no	no
1976-84		M2	16	18	1.031	12	6	0.738	0.795	0.59139	no	no
1972-84		M3	15	19	1.119	13	6	0.748	1.077	0.42437	no	no
		M4	16	18	0.966	12	6	0.610	1.168	0.38408	no	no
1980-84		M1	16	17	1.244	2	15	0.061	2.564	0.31625	no	no
1985-88		M2	16	17	1.503	2	15	0.042	4.647	0.19118	no	no
1980-88		M3	15	18	1.452	3	15	0.115	2.317	0.26652	no	no
		M4	16	17	1.418	2	15	0.028	6.652	0.13830	no	no

Table I.16: Tests for structural change across time periods; European manufacturers

Variables	model	k	EDF	SSE_R	SSE_{U1}	SSE_{U2}	SSE_U	F	P	5%	1%
1964-84	M1	9	15	3.067	0.536	0.186	0.721	2.169	0.17914	no	no
1982-93	M2	8	16	4.211	0.522	0.188	0.711	4.924	0.01845	yes	no
1964-93	M3	8	16	4.238	0.468	0.185	0.653	5.493	0.01330	yes	no
	M4	8	16	3.914	0.771	0.185	0.956	3.094	0.06536	no	no
	model	**k**	**EDF**	**SSE_R**	**EDF_U**	**n2**	**SSEU**	**F**	**P**	**5%**	**1%**
1964-79*	M1	11	13	2.554	10	3	1.146	4.094	0.03896	yes	no
1980-93	M2	13	11	2.288	8	3	1.611	1.120	0.39688	no	no
1964-93	M3	13	11	2.319	8	3	1.555	1.311	0.33642	no	no
	M4	14	10	1.973	7	3	1.449	0.845	0.51157	no	no
1964-79*	M1	13	11	1.795	8	3	1.106	1.663	0.25109	no	no
1980-93	M2	13	11	2.420	8	3	1.606	1.351	0.32504	no	no
1964-93	M3	13	11	2.514	8	3	1.542	1.682	0.24730	no	no
	M4	13	11	2.091	8	3	1.685	0.643	0.60883	no	no
1976-84*	M1	10	12	1.972	3	9	0.107	5.831	0.08702	no	no
1982-93	M2	10	12	2.094	3	9	0.132	4.950	0.10759	no	no
1976-93	M3	10	12	2.002	3	9	0.127	4.911	0.10869	no	no
	M4	10	12	2.103	3	9	0.133	4.922	0.10837	no	no
1980-84*	M1	10	11	1.713	3	8	0.107	5.649	0.09102	no	no
1982-93	M2	9	12	2.254	4	8	0.138	7.673	0.03306	yes	no
1980-93	M3	9	12	2.191	4	8	0.132	7.829	0.03190	yes	no
	M4	9	12	2.763	4	8	0.179	7.206	0.03690	yes	no
1980-88*	M1	13	8	1.068	1	7	0.080	1.765	0.52386	no	no
1989-93	M2	13	8	1.606	1	7	0.083	2.615	0.44410	no	no
1980-93	M3	13	8	1.542	1	7	0.084	2.476	0.45471	no	no
	M4	13	8	1.685	1	7	0.084	2.732	0.43576	no	no

* Chow forecasting test

Appendix I.3: Differences in purchasing region

Table I.17: Chow test for structural change between different customers for the years 1964-79 using the variables of the model for international customers.

Variables	model	k	EDF	SSE_R	SSE_{U1}	SSE_{U2}	SSE_U	F	P	5%	1%
US	M1	4	13	1.129	0.328	0.164	0.492	2.909	0.08451	no	no
International	M2	5	12	0.677	0.044	0.280	0.324	1.527	0.29433	no	no
1964-79	M3	4	13	0.670	0.216	0.235	0.451	1.092	0.41647	no	no
	M4	6	11	1.259	0.000	0.183	0.183	4.894	0.05112	no	no
US+Europe	M1	4	15	1.658	0.577	0.164	0.742	3.397	0.04841	yes	no
International	M2	5	14	1.821	0.482	0.280	0.762	2.504	0.10961	no	no
1964-79	M3	4	15	1.624	0.450	0.235	0.686	3.764	0.03641	yes	no
	M4	6	13	1.836	0.320	0.183	0.503	3.088	0.08300	no	no
Others	M1	4	12	0.711	0.164	0.175	0.340	2.186	0.16097	no	no
International	M2	5	11	1.492	0.280	0.077	0.357	3.813	0.06696	no	no
1964-79	M3	4	12	1.251	0.235	0.143	0.378	4.614	0.03170	yes	no
	M4	6	10	0.934	0.183	0.000	0.183	2.733	0.17483	no	no
	model	**k**	**EDF**	**SSE_R**	**EDF_U**	**n2**	**SSE_U**	**F**	**P**	**5%**	**1%**
Europe*	M1	4	8	0.998	6	2	0.164	15.205	0.00448	yes	yes
International	M2	5	7	0.737	5	2	0.280	4.086	0.08878	no	no
1964-79	M3	4	8	1.229	6	2	0.235	12.661	0.00703	yes	yes
	M4	6	6	1.150	4	2	0.183	10.560	0.02536	yes	no

*Chow forecasting test

Table I.18: Chow forecasting tests for structural change between various regions of ownership for the years 1976-84 using the variables of the model for US customers.

Variables	model	k	EDF	SSE_R	EDF_U	n2	SSE_U	F	P	5%	1%
US*	M1	12	10	3.933	2	8	0.011	88.187	0.01126	yes	no
Europe	M2	11	11	3.510	3	8	0.027	48.944	0.00429	yes	yes
1976-84	M3	11	11	2.756	3	8	0.030	33.594	0.00746	yes	yes
	M4	11	11	3.510	3	8	0.027	48.944	0.00429	yes	yes
US*	M1	12	8	0.399	2	6	0.011	11.622	0.08133	no	no
International	M2	11	9	0.393	3	6	0.027	6.871	0.07116	no	no
1976-84	M3	11	9	0.338	3	6	0.030	5.056	0.10578	no	no
	M4	11	9	0.393	3	6	0.027	6.871	0.07116	no	no
US*	M1	12	12	0.554	2	10	0.011	9.772	0.09634	no	no
Others	M2	11	13	0.602	3	10	0.027	6.463	0.07574	no	no
1976-84	M3	11	13	0.565	3	10	0.030	5.271	0.09901	no	no
	M4	11	13	0.602	3	10	0.027	6.463	0.07574	no	no

*Chow forecasting test

Table I.19: Chow tests for structural change between different regions of ownership for the years 1980-93.

Variables	Exceptions	model	k	EDF	SSE_R	SSE_{U1}	SSE_{U2}	SSE_U	F	P	5%	1%
US	D9193	M1	16	23	3.794	0.062	0.183	0.245	6.339	0.00971	yes	yes
Europe	D9193	M2	15	24	2.907	0.068	0.358	0.426	3.497	0.03168	yes	no
1980-93	D9193	M3	15	24	2.914	0.081	0.404	0.485	3.007	0.04997	yes	no
	D9193	M4	15	24	2.907	0.068	0.358	0.426	3.497	0.03168	yes	no
US		M1	12	27	4.281	0.560	0.167	0.727	6.113	0.00076	yes	yes
Europe		M2	15	24	2.660	0.060	0.160	0.220	6.663	0.00347	yes	yes
1980-93		M3	15	24	3.384	0.068	0.117	0.186	10.334	0.00064	yes	yes
		M4	15	24	2.660	0.060	0.160	0.220	6.663	0.00347	yes	yes
US		M1	17	30	1.499	0.001	0.493	0.495	1.553	0.21297	no	no
Others		M2	16	31	2.307	0.014	0.715	0.729	2.029	0.08926	no	no
1980-93		M3	16	31	2.368	0.024	0.731	0.755	2.002	0.09329	no	no
		M4	16	31	2.307	0.014	0.715	0.729	2.029	0.08926	no	no
US		M1	15	32	2.600	0.031	0.267	0.298	8.754	0.00003	yes	yes
Others		M2	17	30	1.704	0.011	0.322	0.333	3.146	0.02079	yes	no
1980-93		M3	14	33	2.535	0.079	0.412	0.491	5.650	0.00034	yes	yes
		M4	14	33	3.611	0.059	0.373	0.432	9.997	0.00001	yes	yes
US		M1	7	24	3.779	0.125	0.808	0.933	7.404	0.00037	yes	yes
International		M2	6	25	2.880	0.164	1.605	1.769	1.988	0.11796	no	no
1980-93		M3	6	25	6.184	0.251	2.571	2.823	3.771	0.01215	yes	no
		M4	6	25	2.880	0.164	1.605	1.769	1.988	0.11796	no	no
		model	**k**	**EDF**	**SSE_R**	**EDF_U**	**n2**	**SSE_U**	**F**	**P**	**5%**	**1%**
US*		M1	17	14	1.075	2	12	0.001	148.860	0.00669	yes	yes
International		M2	16	15	1.268	3	12	0.014	22.812	0.01282	yes	no
1980-93		M3	16	15	1.159	3	12	0.024	11.661	0.03349	yes	no
		M4	16	15	1.268	3	12	0.014	22.812	0.01282	yes	no
Europe*		M1	12	20	2.170	8	12	0.167	7.998	0.00322	yes	yes
International		M2	15	17	3.524	5	12	0.160	8.776	0.01307	yes	no
1980-93		M3	15	17	3.790	5	12	0.117	13.053	0.00530	yes	yes
		M4	15	17	3.524	5	12	0.160	8.776	0.01307	yes	no
Variables	**Exceptions**	**model**	**k**	**EDF**	**SSE_R**	**SSE_{U1}**	**SSE_{U2}**	**SSE_U**	**F**	**P**	**5%**	**1%**
Europe		M1	7	25	7.947	0.125	4.968	5.093	1.441	0.24994	no	no
International		M2	6	26	7.651	0.164	5.071	5.235	1.538	0.21693	no	no
1980-93		M3	6	26	9.358	0.251	5.563	5.814	2.032	0.10862	no	no
		M4	6	26	7.651	0.164	5.071	5.235	1.538	0.21693	no	no
Europe		M1	12	36	3.196	0.167	0.804	0.971	4.583	0.00075	yes	yes
Others		M2	15	37	5.115	0.282	0.685	0.968	10.131	0.00000	yes	yes
1980-93		M3	15	33	3.566	0.117	0.545	0.662	5.266	0.00061	yes	yes
		M4	15	37	5.115	0.282	0.685	0.968	10.131	0.00000	yes	yes
Europe	D9193	M1	14	34	3.209	0.265	0.267	0.533	7.178	0.00005	yes	yes
Others	D9193	M2	16	32	4.151	0.286	0.327	0.613	5.768	0.00055	yes	yes
1980-93	D9193	M3	13	35	3.578	1.349	0.493	1.842	1.595	0.16183	no	no
	D9193	M4	13	35	5.864	0.716	0.429	1.146	6.970	0.00004	yes	yes
Others		M1	7	33	3.478	0.125	1.525	1.650	4.116	0.00364	yes	yes
International		M2	6	34	2.208	0.164	1.121	1.285	3.351	0.01291	yes	no
1980-93		M3	6	34	3.898	0.251	1.527	1.779	5.559	0.00067	yes	yes
		M4	6	34	2.208	0.164	1.121	1.285	3.351	0.01291	yes	no
		model	**k**	**EDF**	**SSE_R**	**EDF_U**	**n2**	**SSE_U**	**F**	**P**	**5%**	**1%**
Others*		M1	15	25	1.591	13	12	0.267	5.365	0.00257	yes	yes
International		M2	17	23	1.598	11	12	0.322	3.634	0.02035	yes	no
1980-93		M3	14	26	1.790	14	12	0.412	3.898	0.00894	yes	yes
		M4	14	26	1.843	14	12	0.373	4.597	0.00419	yes	yes

*Chow forecasting test

Table I.20: Chow tests for structural change between different regions of ownership for the years 1964-93.

Variables	Exceptions	model	k	EDF	SSE_R	SSE_{U1}	SSE_{U2}	SSE_U	F	P	5%	1%
US	D7275	M1	15	33	6.405	0.372	0.578	0.950	6.888	0.00011	yes	yes
Europe	D7275	M2	14	34	8.475	0.402	1.275	1.676	5.793	0.00023	yes	yes
1964-93	D7275	M3	16	32	6.316	0.077	0.286	0.363	16.402	0.00000	yes	yes
	D7275	M4	14	34	8.475	0.402	1.275	1.676	5.793	0.00023	yes	yes
US		M1	16	32	5.550	0.432	0.102	0.535	9.384	0.00003	yes	yes
Europe		M2	18	32	6.448	0.258	0.121	0.379	16.034	0.00000	yes	yes
1964-93		M3	16	31	5.249	0.217	0.100	0.317	12.822	0.00001	yes	yes
		M4	17	30	3.641	0.471	0.070	0.541	3.817	0.01105	yes	no
US		M1	16	32	4.322	0.146	0.530	0.676	5.397	0.00081	yes	yes
International		M2	15	33	4.659	0.125	0.916	1.042	4.166	0.00251	yes	yes
1964-93		M3	17	31	4.185	0.077	0.660	0.736	3.857	0.00715	yes	yes
		M4	15	33	4.659	0.125	0.916	1.042	4.166	0.00251	yes	yes
US		M1	10	38	4.424	1.721	0.503	2.225	2.768	0.01639	yes	no
International		M2	10	38	4.527	1.940	0.559	2.499	2.272	0.04259	yes	no
1964-93		M3	12	36	5.008	1.589	0.506	2.095	2.780	0.01592	yes	no
		M4	8	40	5.623	1.862	0.550	2.412	5.326	0.00027	yes	yes
US	D7275	M1	15	44	4.080	0.146	0.434	0.580	10.571	0.00000	yes	yes
Others		M2	14	45	4.827	0.125	0.880	1.006	7.600	0.00000	yes	yes
1964-93		M3	16	43	3.538	0.077	0.579	0.655	6.725	0.00001	yes	yes
		M4	14	45	4.827	0.125	0.880	1.006	7.600	0.00000	yes	yes
US		M1	16	44	3.378	0.471	0.407	0.877	4.988	0.00011	yes	yes
Others		M2	14	45	4.098	1.529	0.613	2.142	1.826	0.07825	no	no
1964-93		M3	15	45	5.405	0.899	0.593	1.492	5.246	0.00006	yes	yes
		M4	20	40	2.716	0.103	0.474	0.577	3.709	0.00254	yes	yes
Europe		M1	16	28	6.338	0.509	0.102	0.611	7.026	0.00076	yes	yes
International		M2	18	28	4.579	0.418	0.121	0.539	5.626	0.00217	yes	yes
1964-93		M3	16	27	5.203	0.379	0.100	0.479	5.802	0.00371	yes	yes
		M4	17	27	4.982	0.369	0.236	0.605	4.255	0.01217	yes	no
Europe		M1	10	34	4.912	1.568	0.503	2.071	3.292	0.00812	yes	yes
International		M2	10	34	4.670	2.530	0.559	3.089	1.228	0.32318	no	no
1964-93		M3	12	32	7.789	2.393	0.506	2.899	2.811	0.01988	yes	no
		M4	8	36	7.349	2.156	0.550	2.706	6.005	0.00016	yes	yes
Europe		M1	16	40	6.526	0.902	0.102	1.004	8.246	0.00000	yes	yes
Others		M2	18	40	6.876	0.738	0.121	0.859	10.506	0.00000	yes	yes
1964-93		M3	16	39	4.708	0.744	0.100	0.844	5.929	0.00008	yes	yes
		M4	17	38	5.851	0.755	0.070	0.825	6.772	0.00005	yes	yes
Europe	D9193	M1	15	41	3.455	0.630	0.418	1.048	3.981	0.00101	yes	yes
Others	D9193, kutrp	M2	12	43	5.220	2.396	0.649	3.045	1.649	0.12625	no	no
1964-93	D9193	M3	14	42	4.964	1.147	0.599	1.746	3.688	0.00160	yes	yes
	D9193, kutrp	M4	18	38	4.366	0.386	0.575	0.961	3.937	0.00199	yes	yes
Others		M1	10	46	4.292	0.503	1.395	1.899	4.537	0.00035	yes	yes
International		M2	10	46	4.389	0.559	1.315	1.875	4.828	0.00021	yes	yes
1964-93		M3	12	44	4.955	0.506	1.229	1.735	4.949	0.00014	yes	yes
		M4	8	48	5.569	0.550	1.680	2.229	7.490	0.00000	yes	yes
Others		M1	16	40	3.043	0.572	0.407	0.979	3.162	0.00539	yes	yes
International	kutrp	M2	13	42	5.190	1.530	0.647	2.177	2.768	0.01059	yes	no
1964-93		M3	15	41	4.963	1.114	0.593	1.706	3.308	0.00366	yes	yes
	kutrp	M4	19	37	4.219	0.275	0.575	0.850	3.755	0.00351	yes	yes

Table I.21: Tests for structural change across time periods, using Chow forecasting test; US customers.

	Exceptions	model	k	EDF	SSE_R	EDF_U	n2	SSEU	F	P	5%	1%
1964-75		M1	10	8	0.304	4	4	0.022	12.578	0.01547	yes	no
1976-84		M2	9	9	0.659	5	4	0.129	5.147	0.05083	no	no
1964-84		M3	9	9	0.488	5	4	0.123	3.715	0.09128	no	no
		M4	9	9	0.659	5	4	0.129	5.147	0.05083	yes	no
1976-84		M1	10	12	1.075	4	8	0.022	23.510	0.00416	yes	yes
1985-93		M2	9	13	1.902	5	8	0.129	8.604	0.01486	yes	no
1976-93		M3	9	13	1.459	5	8	0.123	6.793	0.02472	yes	no
		M4	9	13	1.902	5	8	0.129	8.604	0.01486	yes	no
1976-80	mtrp	M1	9	5	0.407	2	3	0.011	24.280	0.03982	yes	no
1980-84	mtrp	M2	8	6	0.343	3	3	0.066	4.201	0.13455	no	no
1976-84	mtrp	M3	8	6	0.438	3	3	0.054	7.173	0.06993	no	no
	mtrp	M4	8	6	0.343	3	3	0.066	4.201	0.13455	no	no
1976-84		M1	10	7	0.277	4	3	0.022	15.153	0.01193	yes	no
1984-88		M2	9	8	0.458	5	3	0.129	4.261	0.07628	no	no
1976-88		M3	9	8	0.349	5	3	0.123	3.060	0.12995	no	no
		M4	9	8	0.458	5	3	0.129	4.261	0.07628	no	no
1964-79		M1	12	14	1.222	7	7	0.638	0.918	0.54373	no	no
1980-93		M2	11	15	1.928	8	7	0.839	1.482	0.29557	no	no
1964-93		M3	11	15	1.679	8	7	0.693	1.626	0.25475	no	no
		M4	11	15	1.928	8	7	0.839	1.482	0.29557	no	no
1964-79		M1	9	17	1.485	10	7	0.643	1.872	0.17782	no	no
1980-93		M2	8	18	2.032	11	7	1.302	0.882	0.55045	no	no
1964-93		M3	10	16	1.797	9	7	0.849	1.434	0.30062	no	no
		M4	8	18	2.032	11	7	1.302	0.882	0.55045	no	no
1980-88		M1	12	7	0.638	2	5	0.117	1.777	0.39798	no	no
1989-93		M2	11	8	0.839	3	5	0.142	2.949	0.20122	no	no
1980-93		M3	11	8	0.693	3	5	0.129	2.613	0.22953	no	no
		M4	11	8	0.839	3	5	0.142	2.949	0.20122	no	no
1980-84	mtrp, ctrp	M1	10	9	0.720	1	8	0.063	1.301	0.59375	no	no
1985-93	mtrp	M2	10	9	1.009	1	8	0.001	236.151	0.05029	no	no
1980-93	mtrp	M3	10	9	0.912	1	8	0.003	43.357	0.11695	no	no
	mtrp	M4	10	9	1.009	1	8	0.001	236.151	0.05029	no	no
1976-79		M1	12	10	1.049	7	3	0.638	1.505	0.29457	no	no
1980-93		M2	11	11	1.778	8	3	0.839	2.983	0.09617	no	no
1976-93		M3	11	11	1.403	8	3	0.693	2.733	0.11363	no	no
		M4	11	11	1.778	8	3	0.839	2.983	0.09617	no	no

Table I.22: Tests for structural change across time periods, using Chow forecasting test; European customers.

	Exceptions	model	k	EDF	SSE_R	EDF_U	n2	SSEU	F	P	5%	1%
1964-79		M1	8	14	2.372	12	2	0.861	10.525	0.00229	yes	yes
1980-93		M2	11	11	0.494	9	2	0.282	3.373	0.08070	no	no
1964-93		M3	11	11	2.443	9	2	2.085	0.774	0.48966	no	no
		M4	11	11	0.494	9	2	0.282	3.373	0.08070	no	no
1980-84		M1	8	12	0.861	5	7	0.111	4.811	0.05133	no	no
1985-93		M2	11	9	0.282	2	7	0.111	0.440	0.82642	no	no
1980-93		M3	11	9	2.085	2	7	0.109	5.168	0.17165	no	no
		M4	11	9	0.282	2	7	0.111	0.440	0.82642	no	no
1980-88		M1	8	12	0.861	5	7	0.378	0.913	0.56085	no	no
1989-93	mtrp	M2	10	10	0.511	3	7	0.154	0.993	0.55558	no	no
1980-93		M3	11	9	2.085	2	7	1.500	0.111	0.98829	no	no
	mtrp	M4	10	10	0.511	3	7	0.154	0.993	0.55558	no	no
1964-79		M1	11	11	3.256	9	2	1.637	4.452	0.04526	yes	no
1980-93		M2	13	9	1.255	7	2	0.798	2.000	0.20558	no	no
1964-93		M3	11	11	2.109	9	2	1.994	0.258	0.77819	no	no
		M4	12	10	1.010	8	2	0.772	1.230	0.34205	no	no
1964-84		M1	11	11	3.256	2	9	0.106	6.609	0.13828	no	no
1985-93	lifetime	M2	12	10	1.264	1	9	0.067	1.992	0.50348	no	no
1964-93		M3	11	11	2.109	2	9	0.105	4.227	0.20591	no	no
		M4	12	10	1.010	1	9	0.067	1.570	0.55468	no	no
1976-84		M1	11	10	1.675	2	8	0.106	3.702	0.23001	no	no
1982-93		M2	11	10	1.740	2	8	0.105	3.879	0.22106	no	no
1976-93		M3	10	11	2.627	3	8	0.155	5.964	0.08479	no	no
		M4	9	12	2.280	4	8	0.191	5.464	0.05922	no	no
1980-84		M1	11	9	1.414	2	7	0.106	3.528	0.23858	no	no
1982-93		M2	11	9	1.458	2	7	0.105	3.669	0.23087	no	no
1980-93		M3	10	10	2.252	3	7	0.155	5.781	0.08867	no	no
		M4	9	11	1.792	4	7	0.191	4.786	0.07460	no	no
1980-88		M1	10	10	1.424	3	7	0.566	0.650	0.71328	no	no
1989-93		M2	10	10	1.547	3	7	0.858	0.344	0.88919	no	no
1982-93		M3	9	11	2.296	4	7	1.703	0.199	0.96851	no	no
		M4	4	16	4.817	9	7	4.096	0.227	0.96846	no	no

Table I.23: Tests for structural change across time periods; International customers.

Variables	Exceptions	model	k	EDF	SSE_R	SSE_{U1}	SSE_{U2}	SSE_U	F	P	5%	1%
1964-79		M1	4	18	2.240	0.164	1.209	1.374	2.208	0.12080	no	no
1980-93		M2	5	17	1.852	0.280	0.236	0.516	6.222	0.00454	yes	yes
1964-93		M3	4	18	1.913	0.235	0.876	1.112	2.525	0.08783	no	no
		M4	6	16	2.116	0.183	1.070	1.253	1.148	0.40303	no	no
1964-79		M1	7	15	1.165	0.426	0.184	0.610	1.038	0.47385	no	no
1980-93	Dtwt	M2	5	17	3.559	0.586	1.070	1.656	2.757	0.06964	no	no
1964-93	kutrp	M3	5	17	5.813	0.441	1.504	1.945	4.773	0.01241	yes	no
	Dtwt	M4	5	17	3.559	0.586	1.070	1.656	2.757	0.06964	no	no
1964-79	Dtwt, kutrp	M1	8	14	1.443	0.133	0.254	0.387	2.044	0.19962	no	no
1980-93	eolpower	M2	9	13	0.820	0.130	0.180	0.310	0.731	0.68113	no	no
1964-93	kutrp, hmpower, service, mtrp	M3	8	14	2.021	0.270	0.134	0.404	3.005	0.09854	no	no
	Dtwt	M4	7	15	1.855	0.281	0.189	0.471	3.362	0.05539	no	no
1964-79		M1	4	10	0.786	0.147	0.186	0.333	2.035	0.20833	no	no
1976-84		M2	5	9	0.592	0.211	0.080	0.291	0.829	0.58841	no	no
1964-84		M3	4	10	0.900	0.223	0.178	0.401	1.870	0.23495	no	no
	service	M4	5	9	1.667	0.207	0.080	0.287	3.854	0.10780	no	no
		model	**k**	**EDF**	**SSE_R**	**EDF_U**	**n2**	**SSEU**	**F**	**P**	**5%**	**1%**
1964-79*		M1	5	9	0.697	5	4	0.145	4.746	0.05910	no	no
1980-84		M2	5	9	0.592	5	4	0.280	1.394	0.35615	no	no
1964-84		M3	5	9	0.761	5	4	0.233	2.835	0.14167	no	no
		M4	6	8	0.834	4	4	0.183	3.557	0.12333	no	no
1964-75*		M1	4	6	0.164	4	2	0.147	0.237	0.79928	no	no
1976-79		M2	5	5	0.280	3	2	0.211	0.488	0.65563	no	no
1964-79		M3	4	6	0.235	4	2	0.223	0.112	0.89649	no	no
		M4	6	4	0.183	2	2	0.148	0.241	0.80596	no	no
1976-84*		M1	7	7	0.184	5	2	0.125	1.179	0.38068	no	no
1985-93		M2	6	8	0.300	6	2	0.164	2.500	0.16227	no	no
1976-93		M3	6	8	0.422	6	2	0.251	2.042	0.21070	no	no
		M4	6	8	0.300	6	2	0.164	2.500	0.16227	no	no
1980-84*	service	M1	6	6	0.206	2	4	0.018	5.354	0.16352	no	no
1984-93		M2	6	6	0.164	2	4	0.018	4.165	0.20288	no	no
1980-93	service, kutrp	M3	4	8	1.492	4	4	0.220	5.782	0.05881	no	no
		M4	6	6	0.164	2	4	0.018	4.165	0.20288	no	no

* Chow forecasting test

Table I.24: Chow tests for structural change across time periods; Other customers.

Variables	Exceptions	model	k	EDF	SSE_R	SSE_{U1}	SSE_{U2}	SSE_U	F	P	5%	1%
1980-88		M1	10	18	0.441	0.168	0.077	0.244	0.644	0.74698	no	no
1989-93		M2	12	16	0.551	0.098	0.000	0.098	1.530	0.36448	no	no
1980-93		M3	9	19	0.587	0.058	0.157	0.214	1.934	0.15931	no	no
		M4	9	19	0.575	0.185	0.067	0.252	1.426	0.29339	no	no
1964-84	Dtwt	M1	8	26	0.836	0.056	0.594	0.650	0.643	0.73231	no	no
1985-93	Dtwt	M2	7	27	0.964	0.162	0.723	0.885	0.257	0.96381	no	no
1964-93	Dtwt	M3	8	26	0.950	0.063	0.530	0.593	1.356	0.27987	no	no
	Dtwt, lifetime	M4	11	23	0.947	0.000	0.692	0.692	0.402	0.92912	no	no
		model	**k**	**EDF**	**SSE_R**	**EDF_U**	**n2**	**SSEU**	**F**	**P**	**5%**	**1%**
1964-79*		M1	10	24	0.748	18	6	0.441	2.092	0.10519	no	no
1980-93		M2	12	22	0.898	16	6	0.551	1.683	0.18923	no	no
1964-93		M3	9	25	0.969	19	6	0.587	2.055	0.10767	no	no
		M4	9	25	0.949	19	6	0.575	2.063	0.10652	no	no
1980-84*		M1	10	18	0.441	13	5	0.383	0.393	0.84476	no	no
1985-93		M2	12	16	0.551	11	5	0.427	0.634	0.67865	no	no
1980-93		M3	9	19	0.587	14	5	0.475	0.660	0.65967	no	no
		M4	9	19	0.575	14	5	0.489	0.493	0.77644	no	no
1964-79*		M1	9	25	0.627	19	6	0.466	1.096	0.40044	no	no
1980-93		M2	8	26	0.847	20	6	0.675	0.849	0.54799	no	no
1964-93		M3	8	26	0.852	20	6	0.643	1.082	0.40622	no	no
		M4	13	21	0.797	15	6	0.542	1.175	0.36999	no	no
1976-84*		M1	11	22	0.806	12	10	0.531	0.622	0.77011	no	no
1982-93		M2	12	21	1.047	11	10	0.630	0.728	0.68754	no	no
1976-93		M3	11	22	0.885	12	10	0.434	1.246	0.35394	no	no
		M4	15	18	0.780	8	10	0.416	0.702	0.70526	no	no
1980-84*		M1	11	17	0.592	12	5	0.531	0.274	0.91885	no	no
1982-93		M2	12	16	0.786	11	5	0.630	0.546	0.73890	no	no
1980-93		M3	9	19	0.587	14	5	0.475	0.660	0.65967	no	no
		M4	15	13	0.541	8	5	0.416	0.483	0.78056	no	no

* Chow forecasting test

Appendix J : Learning coefficients

Table J.1: Learning curve estimates, equation (4.8).

Equation	exp(β)		Std Err	T-Ratio	Prob>|T|	Experience	γ		Std Err	T-Ratio	Prob>|T|	SSE	MSE	R^2	DW
G4829326	0.9848		0.0264	37.27	0.0001 ***	R4CCUMI	0.1571		0.1386	1.13	0.2690	0.1776	0.0081	0.0527	0.952
G4829320	0.9865		0.0254	38.91	0.0001 ***	R4CCUMI	0.1416		0.1333	1.06	0.2996	0.1627	0.0074	0.0466	0.936
G4829315	0.9879		0.0246	40.19	0.0001 ***	R4CCUMI	0.1284		0.1295	0.99	0.3323	0.1524	0.0069	0.0409	0.923
G4647926	0.9866		0.0164	60.04	0.0001 ***	R4CCUMI	0.0834		0.0877	0.95	0.3518	0.0671	0.0031	0.0387	1.270
G4647920	0.9885		0.0158	62.61	0.0001 ***	R4CCUMI	0.0675		0.0844	0.80	0.4323	0.0617	0.0028	0.0277	1.195
G4647915	0.9902		0.0155	63.89	0.0001 ***	R4CCUMI	0.0541		0.0830	0.65	0.5209	0.0592	0.0027	0.0187	1.127
G4326	0.9817		0.0251	39.13	0.0001 ***	R43CCUMI	0.1491		0.1353	1.10	0.2825	0.1702	0.0077	0.0502	1.210
G4320	0.9835		0.0243	40.47	0.0001 ***	R43CCUMI	0.1321		0.1314	1.01	0.3256	0.1588	0.0072	0.0423	1.177
G4315	0.9850		0.0238	41.44	0.0001 ***	R43CCUMI	0.1179		0.1289	0.91	0.3703	0.1513	0.0069	0.0354	1.147
N4829326	1.0277		0.0527	19.51	0.0001 ***	R4CCUMI	0.2828		0.2563	1.10	0.2818	0.7341	0.0334	0.0481	0.749
N4829320	1.0301		0.0506	20.37	0.0001 ***	R4CCUMI	0.2561		0.2471	1.04	0.3112	0.6708	0.0305	0.0427	0.735
N4829315	1.0324		0.0490	21.06	0.0001 ***	R4CCUMI	0.2331		0.2405	0.97	0.3428	0.6259	0.0285	0.0378	0.726
N4647926	1.0263		0.0316	32.49	0.0001 ***	R4CCUMI	0.1545		0.1591	0.97	0.3419	0.2536	0.0115	0.0394	0.966
N4647920	1.0295		0.0302	34.12	0.0001 ***	R4CCUMI	0.1267		0.1525	0.83	0.4150	0.2294	0.0104	0.0292	0.912
N4647915	1.0323		0.0294	35.09	0.0001 ***	R4CCUMI	0.1030		0.1492	0.69	0.4971	0.2166	0.0098	0.0205	0.870
N4326	1.0198		0.0473	21.55	0.0001 ***	R43CCUMI	0.2784		0.2371	1.17	0.2530	0.6289	0.0286	0.0545	1.025
N4320	1.0226		0.0458	22.34	0.0001 ***	R43CCUMI	0.2492		0.2305	1.08	0.2914	0.5829	0.0265	0.0471	1.001
N4315	1.0250		0.0447	22.94	0.0001 ***	R43CCUMI	0.2249		0.2261	0.99	0.3307	0.5518	0.0251	0.0403	0.982
M4829326	1.0114	1.8094	0.0288	35.16	0.0001 ***	R4CCUMI	0.1628	0.2913	0.1467	1.11	0.2789	0.2109	0.0096	0.0504	0.758
M4829320	1.0131	1.8123	0.0276	36.71	0.0001 ***	R4CCUMI	0.1475	0.2638	0.1410	1.05	0.3071	0.1932	0.0088	0.0450	0.741
M4829315	1.0146	1.8150	0.0267	37.95	0.0001 ***	R4CCUMI	0.1344	0.2404	0.1369	0.98	0.3370	0.1806	0.0082	0.0400	0.730
M4647926	1.0130	1.8121	0.0175	57.93	0.0001 ***	R4CCUMI	0.0893	0.1597	0.0907	0.98	0.3358	0.0762	0.0035	0.0411	0.965
M4647920	1.0149	1.8155	0.0166	61.00	0.0001 ***	R4CCUMI	0.0736	0.1316	0.0865	0.85	0.4040	0.0686	0.0031	0.0311	0.908
M4647915	1.0165	1.8185	0.0162	62.90	0.0001 ***	R4CCUMI	0.0603	0.1080	0.0842	0.72	0.4808	0.0645	0.0029	0.0224	0.865
M4326	1.0070	1.8014	0.0265	37.96	0.0001 ***	R43CCUMI	0.1635	0.2925	0.1389	1.18	0.2517	0.1910	0.0087	0.0567	1.028
M4320	1.0088	1.8046	0.0256	39.37	0.0001 ***	R43CCUMI	0.1468	0.2626	0.1346	1.09	0.2871	0.1774	0.0081	0.0493	1.002
M4315	1.0103	1.8073	0.0250	40.42	0.0001 ***	R43CCUMI	0.1327	0.2374	0.1316	1.01	0.3240	0.1681	0.0076	0.0426	0.982

Appendix K : Demand shift results

Table K.1: International outgoing communication capacity traffic regression; first method, equation (5.6).

Group	Country	α	Std Err	θ_1	Std Err	θ_2	Std Err	θ_3	Std Err	θ_4	Std Err	D8593	Std Err	SSE	MSE	R^2	Adj R^2
1	CAN	5.062	0.399	1.030	0.533	-1.425	0.696	1.178	0.747	-0.828	0.594	-2.002	1.957	1.6671	0.1389	0.8927	0.8479
1	DEU	5.922	0.214	0.312	0.077	0.102	0.091	0.018	0.102	0.298	0.091	1.220	0.161	0.5332	0.0533	0.9413	0.9120
1	ESP	4.972	0.199	0.483	0.132	0.046	0.119	-0.125	0.106	-0.078	0.145	1.607	0.498	1.2268	0.0944	0.9188	0.8876
1	FRA	5.643	0.254	-0.024	0.153	-0.449	0.216	0.795	0.275	0.048	0.135	2.017	0.301	1.5811	0.1437	0.8637	0.8017
1	GBR	4.365	0.447	0.320	0.179	-0.042	0.212	0.446	0.289	-0.444	0.129	2.079	0.493	1.8450	0.1845	0.8558	0.7837
1	ITA	4.664	0.203	0.737	0.202	0.052	0.147	0.059	0.130	0.007	0.172	2.442	0.745	2.6160	0.1137	0.9356	0.9216
1	JPN	3.130	0.141	0.482	0.046	-0.081	0.046	0.063	0.084	0.000	0.073	2.017	0.114	0.4507	0.0347	0.9825	0.9758
1	LUX	3.107	2.387	0.291	0.290	0.577	0.476	-0.291	0.127	8.217	5.176	4.050	1.694	2.2225	0.1235	0.8305	0.7835
1	NOR	4.993	0.341	0.594	0.154	0.047	0.119	-0.228	0.210	-0.203	0.177	1.701	0.274	3.2632	0.1419	0.8938	0.8707
1	SWE	4.139	0.772	0.461	0.337	0.283	0.269	0.014	0.422	-0.030	0.160	2.641	0.969	6.9985	0.5832	0.7222	0.6064
1	USA	3.019	0.557	0.745	0.135	0.026	0.197	-0.057	0.082	-0.123	0.393	2.535	0.213	1.0481	0.0806	0.9627	0.9483
2	AUS	2.138	0.286	0.351	0.126	-0.172	0.180	-0.675	0.195	-0.133	0.070	3.699	0.452	1.2751	0.0981	0.9489	0.9292
2	BRA	3.000	0.315	0.227	0.077	-0.130	0.147	-0.103	0.165	-0.269	0.202	2.623	0.554	0.9556	0.0735	0.9263	0.8979
2	HKG	1.283	0.412	1.368	0.272	0.053	0.231	0.673	0.253	-0.190	0.117	4.065	0.407	1.4398	0.1200	0.9620	0.9461
2	IDN	0.697	1.012	1.002	0.331	1.163	0.335	0.157	0.354	0.253	0.176	5.378	1.531	2.2368	0.1721	0.9080	0.8727
2	IND	0.134	0.589	0.506	0.465	0.785	0.226	0.257	0.277	-0.262	0.446	3.692	1.605	3.1315	0.2409	0.9246	0.8956
2	KOR	3.323	0.289	0.152	0.037	-0.533	0.311	0.332	0.193	-0.256	0.154	0.812	0.461	0.2589	0.0518	0.9663	0.9327
2	MEX	1.142	0.695	0.976	0.196	-2.361	1.524	1.482	1.432	-4.369	2.120	4.333	0.888	0.1570	0.0314	0.9565	0.9130
2	MYS	0.947	0.279	1.056	0.201	-0.630	0.430	-0.115	0.216	-0.284	0.246	1.803	1.021	1.3101	0.1092	0.9595	0.9427
2	SAU	3.706	2.621	1.805	0.547	0.862	0.935	0.951	1.522	0.154	0.312	6.417	1.452	11.0996	0.8538	0.7750	0.6885
2	THA	-1.253	1.129	1.306	0.374	2.688	1.242	-2.538	1.079	-0.565	0.458	6.290	1.292	0.8175	0.1635	0.9168	0.8335
2	TUR	2.685	0.278	0.956	0.109	-0.519	0.244	-0.295	0.110	0.112	0.184	2.863	0.191	3.7335	0.1623	0.9624	0.9542
3	BDI	-1.276	0.588	1.238	0.826	0.091	1.250	-0.457	1.306	0.513	0.900	3.550	1.333	6.3502	0.9072	0.6664	0.4282
3	BEN	-0.197	0.455	0.891	0.152	-1.465	0.767	-1.192	0.409	-0.804	0.317	0.912	0.308	3.6492	0.1825	0.7955	0.7443
3	BFA	-2.106	0.770	0.948	0.617	-0.276	0.367	-0.859	0.466	0.797	0.354	2.320	1.140	1.8958	0.2370	0.7914	0.6610
3	BWA	2.896	0.385	0.959	0.111	-0.931	0.400	-1.068	0.332	-0.768	0.227	0.418	0.525	0.2071	0.0296	0.9684	0.9459
3	CAF	0.167	0.028	0.283	0.022	-0.321	0.104	-0.360	0.053	-0.222	0.073	0.513	0.066	0.1019	0.0044	0.9808	0.9766
3	CIV	0.012	0.375	0.819	0.178	-0.166	0.163	-0.338	0.256	-0.145	0.198	1.508	0.322	1.3390	0.0893	0.9213	0.8951
3	COG	0.256	0.597	3.990	1.326	-2.178	1.472	-5.228	1.932	-3.179	1.353	4.957	1.687	4.7817	0.4347	0.7290	0.6058
3	COM	-1.269	2.276	0.459	0.212	0.334	0.167	0.048	0.431	0.114	0.481	2.637	2.158	0.5312	0.0885	0.9251	0.8627
3	DZA	-0.674	8.228	0.856	1.877	-0.205	0.889	-0.640	1.125	0.320	0.520	1.395	0.667	5.5904	0.6988	0.6738	0.4699
3	ETH	-4.082	2.214	1.903	0.735	1.041	0.273	-0.344	0.385	-0.362	0.460	2.977	0.956	0.4429	0.0738	0.9274	0.8669

Table K.1: Continued.

Group	Country	α	Std Err	θ_1	Std Err	θ_2	Std Err	θ_3	Std Err	θ_4	Std Err	D8593	Std Err	SSE	MSE	R^2	Adj R^2
3	GAB	1.134	0.283	0.801	0.230	0.021	0.089	-0.226	0.177	0.174	0.208	1.780	0.306	2.6273	0.2021	0.8458	0.7864
3	GHA	-3.570	2.447	1.516	1.044	0.169	1.573	-0.405	1.832	0.619	1.050	3.383	1.636	4.7553	0.5944	0.7045	0.5198
3	GIN	-0.561	0.764	1.357	0.503	-0.627	0.838	-1.019	0.658	-0.780	0.386	4.482	0.953	0.6439	0.1073	0.9269	0.8660
3	KEN	3.064	2.029	-0.795	0.725	-0.612	0.792	-2.033	0.765	-1.456	0.806	-0.227	1.198	1.7474	0.2184	0.8473	0.7518
3	LBR	-0.332	0.247	0.232	0.312	-1.403	0.685	-1.158	0.356	0.000	.	1.070	0.650	1.3083	0.1635	0.8649	0.7805
3	LSO	-27.011	16.574	-1.484	1.661	-0.049	0.914	-10.257	5.720	-0.447	1.028	11.145	5.551	2.6830	0.4472	0.8537	0.7318
3	MAR	-4.216	2.361	2.073	0.658	-0.643	0.357	-1.275	0.605	0.923	2.191	4.885	2.139	4.6835	0.3122	0.6846	0.5794
3	MDG	0.239	0.181	0.437	0.045	0.040	0.475	-0.524	0.125	0.353	0.496	0.896	0.403	0.3452	0.0150	0.9271	0.9113
3	MRT	-0.717	0.532	0.623	0.417	0.850	0.806	0.240	0.578	-13.653	4.666	3.286	0.748	1.2880	0.1610	0.9047	0.8452
3	MUS	-0.087	0.342	0.976	0.286	-0.236	0.460	-0.728	0.319	0.232	0.512	1.752	0.476	0.6225	0.0889	0.9524	0.9184
3	NER	6.420	0.112	-0.441	0.148	-1.084	0.132	0.464	0.279	0.070	0.447	-2.288	0.309	3.9048	0.1775	0.9105	0.8902
3	NGA	2.644	7.801	-0.050	1.736	0.250	0.646	-0.141	1.185	-0.157	0.231	1.630	1.153	3.5520	0.3947	0.6858	0.5113
3	RWA	-2.239	0.186	1.625	0.319	0.556	0.606	-0.725	0.428	-0.418	0.592	4.827	0.186	0.6858	0.0572	0.9890	0.9844
3	SEN	0.247	0.292	0.570	0.112	-0.023	0.159	-0.009	0.046	-1.161	0.978	1.576	0.231	1.6250	0.1083	0.9023	0.8698
3	SLE	-1.717	0.891	0.946	0.796	0.892	0.963	0.131	0.909	1.550	1.664	2.924	1.159	3.1848	0.2654	0.7068	0.5847
3	SWZ	2.153	0.279	0.712	0.135	-0.170	0.161	-0.511	0.238	0.011	0.256	1.369	0.207	2.3678	0.1315	0.8726	0.8372
3	TCD	-1.003	0.062	0.298	0.045	0.252	0.035	-0.185	0.058	0.232	0.298	1.581	0.114	0.0311	0.0062	0.9926	0.9851
3	TGO	-2.875	1.397	2.447	1.461	0.290	0.124	-1.431	0.766	0.011	0.056	6.786	3.017	2.1681	0.4336	0.8487	0.6974
3	TUN	1.707	0.574	0.239	0.227	0.065	0.059	0.199	0.165	-0.046	0.329	1.135	0.200	1.5966	0.1228	0.8386	0.7766
3	TZA	1.442	1.039	-0.162	0.126	-0.085	0.059	-0.062	0.346	-1.091	0.207	-0.069	0.440	0.0545	0.0024	0.9398	0.9267
3	ZAF	4.230	0.707	-0.067	0.264	0.200	0.137	0.380	0.376	-0.148	0.325	1.356	0.649	3.6006	0.4001	0.6625	0.4750
3	ZMB	-2.250	1.681	1.914	1.031	-1.668	1.490	-2.259	1.376	0.184	0.400	1.485	1.013	8.2245	0.6327	0.5778	0.4154
3	ZWE	-4.649	0.920	2.810	0.417	-0.570	0.249	-0.918	0.184	-1.242	0.967	3.186	0.387	1.7605	0.1600	0.9046	0.8612
4	ARE	3.266	0.849	0.378	0.329	0.112	0.122	0.006	0.124	0.169	0.151	1.449	0.805	0.8320	0.0832	0.9015	0.8522
4	BHR	0.223	3.135	1.254	1.364	0.306	0.557	-0.434	0.456	0.273	0.999	4.448	4.702	19.0027	1.5836	0.5246	0.3265
4	BRN	-1.459	0.459	-2.327	0.447	0.999	0.240	0.325	0.141	0.944	0.341	-4.391	1.173	1.4850	0.1350	0.9207	0.8847
4	DJI	1.181	0.621	0.944	0.472	-0.062	0.486	0.132	0.333	-0.018	0.683	3.945	1.609	3.0709	0.2792	0.7313	0.6092
4	EGY	2.068	1.079	0.179	0.349	0.059	0.299	0.065	0.240	0.150	0.234	1.040	0.361	0.9474	0.1353	0.8605	0.7608
4	IRN	2.209	0.796	0.364	0.885	0.195	0.792	0.230	0.083	0.423	0.255	1.276	6.234	0.2063	0.0413	0.9453	0.8907
4	ISR	2.253	0.375	0.323	0.140	0.314	0.142	-0.290	0.147	-0.001	0.054	0.830	0.410	1.3499	0.1125	0.8972	0.8544
4	JOR	0.219	0.671	0.933	0.368	-0.149	0.252	-0.760	0.422	0.179	0.159	2.612	0.447	0.3791	0.0542	0.9598	0.9312
4	KWT	3.838	1.333	-0.084	0.495	0.400	0.310	-0.048	0.334	0.057	0.158	0.660	1.548	3.3714	0.3065	0.6843	0.5408

Table K.1: Continued.

Group	Country	α	Std Err	θ_1	Std Err	θ_2	Std Err	θ_3	Std Err	θ_4	Std Err	D8593	Std Err	SSE	MSE	R^2	Adj R^2
4	OMN	0.387	0.763	0.798	0.208	0.518	0.562	0.751	0.247	-0.152	0.470	2.768	1.135	0.1927	0.0275	0.9774	0.9612
4	QAT	2.570	0.264	0.434	0.283	0.634	0.289	0.184	0.080	-0.115	1.379	1.191	0.479	1.1196	0.0933	0.8849	0.8370
4	SYR	0.933	0.406	0.657	0.185	-0.052	0.241	-0.031	0.152	-14.985	9.006	1.444	0.680	1.7868	0.0993	0.9060	0.8799
4	YEM	2.158	0.799	-0.783	0.775	0.767	0.564	0.387	0.223	0.633	0.305	1.320	0.513	0.5153	0.0736	0.9452	0.9061
5	BGD	-8.027	4.469	1.863	0.954	-2.752	2.477	-0.905	1.149	1.023	0.955	2.721	1.345	4.3554	0.3960	0.8797	0.8250
5	CYP	0.937	0.763	0.923	0.557	-0.494	0.556	0.164	0.235	-0.113	0.389	1.523	0.326	3.0243	0.2326	0.8216	0.7530
5	LAO	-1.560	0.722	0.102	0.212	0.317	0.198	0.767	0.269	0.887	0.193	0.748	0.480	0.0740	0.0148	0.9821	0.9641
5	LKA	-4.354	1.833	1.182	0.378	0.235	0.285	-0.863	0.310	-1.181	0.345	4.478	0.948	0.3561	0.0593	0.9364	0.8834
5	MAC	2.505	0.853	0.240	0.325	-0.600	1.161	-0.207	0.847	0.072	0.199	0.342	2.344	0.8475	0.1413	0.9093	0.8336
5	MDV	14.055	5.004	0.106	1.626	-13.499	5.531	-5.229	1.358	-0.194	0.103	-14.628	9.551	0.1749	0.0437	0.9721	0.9371
5	MMR	-3.463	1.329	0.838	0.335	-1.374	0.848	-1.146	0.381	0.806	0.401	0.545	1.043	0.4500	0.0643	0.9361	0.8904
5	MNG	-339.584	101.576	-81.489	23.585	-224.367	68.159	-17.310	6.260	0.290	0.324	0.000	.	0.8056	0.2685	0.8560	0.6640
5	NPL	-4.582	1.193	4.725	1.140	0.192	1.326	-3.307	0.967	0.017	0.098	6.898	0.540	0.3574	0.0596	0.9820	0.9670
5	PAK	-4.790	2.557	2.042	0.754	-0.142	0.381	-1.857	0.840	0.211	0.211	1.070	0.756	0.2556	0.0511	0.9625	0.9250
5	PHL	1.098	0.727	0.244	0.201	0.470	0.247	-0.096	0.138	-0.133	0.171	3.086	0.434	1.2082	0.0929	0.9369	0.9127
5	SGP	1.512	0.659	0.474	0.182	-0.071	0.086	0.120	0.038	-0.024	0.135	2.495	0.364	0.3251	0.0250	0.9774	0.9687
5	SYC	3.865	14.714	3.051	4.569	-5.172	9.271	-5.873	3.668	0.298	0.269	6.071	5.574	92.3437	7.6953	0.7574	0.6563
5	VNM	170.819	141.391	-18.637	14.537	41.137	32.889	-46.398	41.324	-0.490	0.105	-277.632	237.962	0.8698	0.2175	0.8979	0.7702
6	FJI	-2.463	0.658	0.638	0.240	0.079	0.711	1.173	0.294	0.877	0.337	4.333	0.465	0.4621	0.0660	0.9685	0.9460
6	KIR	-1.787	1.155	1.373	0.338	1.630	0.753	-0.190	0.309	0.806	1.217	3.994	0.888	0.1589	0.0265	0.9811	0.9653
6	NCL	1.809	0.546	0.923	0.286	-0.283	0.274	-0.269	0.315	-0.407	0.264	1.443	0.505	2.0241	0.1687	0.7716	0.6764
6	NZL	2.864	0.874	-0.151	0.381	0.334	0.268	-0.196	0.260	2.099	0.574	2.106	0.338	4.9534	0.3810	0.8252	0.7579
6	PNG	3.049	1.246	0.328	0.451	-0.363	0.667	-0.612	0.328	0.213	0.267	-2.276	2.857	2.6866	0.2442	0.7320	0.6101
6	PYF	1.593	0.379	1.009	0.240	-0.125	0.225	0.344	0.525	-1.049	0.328	1.352	0.547	2.2758	0.1897	0.8438	0.7786
6	SLB	9.427	8.519	3.564	1.883	1.342	2.571	-3.365	3.726	0.061	0.066	1.693	5.394	0.5829	0.1166	0.9222	0.8444
6	VUT	-2.381	0.822	0.108	0.405	0.033	0.632	0.370	0.320	8.477	8.476	3.206	0.769	0.1255	0.0251	0.9852	0.9704
7	AUT	4.310	0.104	0.264	0.070	0.087	0.105	0.186	0.085	0.097	0.103	1.405	0.272	0.7974	0.0443	0.9433	0.9276
7	BEL	4.019	1.229	0.173	0.276	0.279	0.431	0.201	0.295	-0.047	0.351	1.766	0.676	16.6434	1.2803	0.4111	0.1846
7	CHE	4.990	0.175	0.260	0.083	-0.028	0.140	0.090	0.116	0.027	0.067	1.372	0.501	0.7729	0.0429	0.9377	0.9204
7	DNK	4.249	0.489	0.081	0.293	0.837	0.444	0.541	0.227	0.269	0.317	2.428	0.745	6.5175	0.5014	0.7533	0.6584
7	FIN	3.592	0.121	0.248	0.051	-0.103	0.105	-0.013	0.166	0.086	0.098	0.719	0.348	0.5730	0.0441	0.9219	0.8919

Table K.1: Continued.

Group	Country	α	Std Err	θ_1	Std Err	θ_2	Std Err	θ_3	Std Err	θ_4	Std Err	D8593	Std Err	SSE	MSE	R^2	Adj R^2
7	GRC	2.811	0.254	0.583	0.181	0.239	0.233	0.560	0.235	-0.046	0.183	3.160	0.734	2.5647	0.1832	0.8610	0.8114
7	IRL	2.900	0.190	0.205	0.189	-0.129	0.246	0.315	0.117	0.094	0.342	1.260	0.391	1.4162	0.1416	0.9091	0.8637
7	ISL	4.168	1.499	0.031	0.384	-0.634	0.438	-0.548	0.405	-0.123	0.557	-4.077	4.195	0.9688	0.1211	0.8682	0.7858
7	MLT	5.210	1.920	0.608	0.692	-0.750	1.039	-0.550	0.789	-0.339	0.249	-0.586	4.964	2.2565	0.2507	0.7894	0.6724
7	NLD	2.237	1.014	0.794	0.243	0.488	0.549	0.468	0.283	-1.576	1.632	1.524	0.826	4.3583	0.3632	0.7528	0.6498
7	PRT	2.118	0.518	-0.043	0.231	-0.776	0.478	0.316	0.159	-0.449	0.200	2.939	0.723	2.5609	0.1970	0.8688	0.8184
8	HUN	2.593	0.215	0.495	0.174	-0.081	0.171	0.157	0.222	0.125	0.218	2.603	0.646	1.1455	0.0881	0.9447	0.9234
8	POL	0.804	0.426	0.257	0.108	-0.832	0.184	0.407	0.143	-2.496	1.664	5.929	0.840	0.3134	0.0392	0.9630	0.9399
8	ROM	0.722	1.520	0.274	0.625	-0.485	0.975	1.255	0.615	0.469	0.121	3.940	3.208	5.7584	0.5235	0.7052	0.5713
8	YUG	4.155	0.619	0.195	0.254	-0.147	0.519	0.646	0.311	0.126	0.170	1.705	0.728	3.3228	0.2556	0.7760	0.6898
9	ARG	2.300	0.550	0.286	0.175	0.181	0.083	-0.031	0.146	0.151	0.148	0.758	0.275	1.1370	0.0875	0.9159	0.8835
9	BOL	0.053	1.032	-0.078	0.465	0.160	0.212	0.902	0.251	-0.205	0.778	2.514	0.958	0.5378	0.0672	0.9261	0.8799
9	CHL	0.081	0.626	0.773	0.280	-0.007	0.133	0.221	0.107	-1.121	0.698	1.268	0.270	0.2118	0.0265	0.9721	0.9547
9	COL	0.859	0.432	0.629	0.116	0.279	0.138	-0.408	0.202	-0.097	0.129	1.758	0.198	1.9787	0.1099	0.9582	0.9466
9	ECU	0.759	1.147	0.786	0.499	-0.314	0.232	0.168	0.096	-1.484	0.450	0.702	0.381	0.4702	0.0523	0.9446	0.9138
9	PER	0.395	0.594	0.417	0.277	0.267	0.091	-0.323	0.340	0.034	0.140	1.473	0.263	0.8393	0.0646	0.9387	0.9151
9	PRY	0.058	0.453	1.493	0.459	-0.772	0.350	0.137	0.339	-0.555	0.452	2.639	0.693	2.9850	0.2296	0.8223	0.7539
9	SUR	0.480	0.284	-0.014	0.147	0.188	0.133	0.446	0.244	-0.369	0.340	0.906	0.321	0.2747	0.0393	0.9548	0.9225
9	URY	0.557	0.796	0.719	0.512	0.246	0.298	-0.151	0.253	0.000	0.000	1.838	0.435	2.5202	0.2800	0.8374	0.7471
9	VEN	0.638	0.298	1.126	0.138	-0.006	0.115	0.046	0.204	-0.232	0.196	0.381	0.331	2.3115	0.1284	0.9146	0.8909
10	BHS	2.310	1.194	0.221	0.405	0.001	0.160	0.018	0.511	0.156	0.236	1.373	2.899	8.5087	0.6078	0.6665	0.5474
10	BMU	1.398	1.245	0.183	0.598	0.309	0.159	0.288	0.177	-0.023	0.297	1.884	1.572	3.7487	0.3408	0.7960	0.7033
10	BRB	3.205	2.660	0.807	0.519	0.166	0.386	0.327	0.212	-0.370	0.722	1.299	1.965	0.7757	0.1551	0.8504	0.7008
10	CRI	0.870	1.418	0.595	1.190	0.044	0.554	-0.105	0.861	-0.109	0.471	1.851	1.339	16.2758	1.6276	0.4219	0.1329
10	GTM	-1.157	1.905	1.632	0.905	-0.228	0.424	0.075	0.494	-1.020	0.552	2.960	1.395	4.4115	0.3676	0.6248	0.4685
10	HND	0.478	0.283	0.927	0.205	0.039	0.184	0.534	0.252	-1.103	0.378	3.367	0.445	0.3576	0.0447	0.9621	0.9383
10	JAM	3.492	0.239	0.227	0.099	0.262	0.079	-0.439	0.224	-0.020	0.045	0.198	0.386	1.9899	0.0865	0.7824	0.7351
10	LCA	1.989	1.049	0.419	0.287	-1.343	0.869	0.319	0.720	0.000	0.000	1.214	1.126	1.5358	0.1707	0.8359	0.7447
10	NIC	-2.045	1.694	3.605	1.660	-1.049	1.144	0.567	2.199	0.079	0.360	5.586	1.652	82.6141	6.8845	0.5464	0.3574
10	PAN	1.839	0.249	0.286	0.291	0.393	0.202	0.282	0.109	-1.081	0.897	1.956	0.294	2.4627	0.1642	0.8311	0.7749
10	SLV	-0.969	0.940	1.912	0.493	0.907	0.406	-2.013	0.789	0.351	1.052	6.214	1.305	3.3147	0.2550	0.8350	0.7715
10	TTO	0.693	0.388	0.636	0.342	0.538	0.206	-0.955	0.373	0.635	0.642	3.325	0.544	4.2218	0.2639	0.7880	0.7218

Table K.2: International outgoing communication capacity traffic regression; second method, equation (5.7).

Group	Country	α	S. Err	θ_1'	S. Err	θ_2'	S. Err	θ_3'	S. Err	θ_4'	S. Err	θ_1''	S. Err	θ_2''	S. Err	θ_3''	S. Err	θ_4''	S. Err	SSE	MSE	R^2	AdjR^2
1	CAN	3.234	0.315	6.969	0.557	-1.945	0.327	-0.182	0.651	3.514	1.252	-0.012	0.124	0.677	0.691	-0.726	1.204	0.370	0.150	0.0986	0.0110	0.9937	0.9880
1	DEU	-2.447	2.843	13.116	1.795	-5.612	0.763	0.523	0.722	11.309	1.534	-1.727	0.350	-0.543	0.242	1.134	0.178	-3.069	0.477	0.1826	0.0261	0.9799	0.9569
1	ESP	4.569	0.252	3.542	0.496	-1.314	0.238	-0.665	0.204	0.243	0.301	0.187	0.134	-0.154	0.563	1.137	1.466	0.063	0.477	0.3550	0.0355	0.9765	0.9577
1	FRA	0.887	1.219	6.238	0.567	-2.971	0.256	-0.869	0.414	1.080	1.058	0.101	0.092	-0.196	0.181	0.354	0.286	0.148	0.163	0.1858	0.0232	0.9840	0.9680
1	GBR	-16.446	8.285	22.919	8.655	-7.078	3.226	-3.885	1.601	3.204	1.218	-2.363	1.025	0.896	0.777	-2.296	1.377	2.181	0.873	1.5474	0.2211	0.8791	0.7409
1	ITA	3.340	0.232	3.080	0.254	-1.228	0.162	-0.457	0.109	0.440	0.238	-0.784	0.102	-0.999	0.227	-1.610	0.302	-2.299	0.369	0.5227	0.0261	0.9871	0.9820
1	JPN	-5.116	3.684	3.844	1.212	-1.367	0.591	-0.612	0.270	0.819	0.593	0.344	0.184	-0.339	0.212	0.549	0.319	-0.127	0.185	0.7048	0.0705	0.9726	0.9508
1	LUX	21.307	0.963	3.479	0.176	-1.544	0.125	-0.406	0.062	-33.909	32.947	-0.168	0.266	0.133	0.346	-0.719	1.940	-0.298	1.594	0.1244	0.0083	0.9905	0.9855
1	NOR	-3.981	0.997	1.933	0.195	-1.458	0.231	5.224	0.588	-4.062	1.208	0.273	0.116	-0.005	0.214	-0.306	0.264	0.254	0.182	0.6414	0.0321	0.9791	0.9708
1	SWE	31.078	15.895	26.598	15.232	-10.29	6.613	-4.559	2.335	-0.042	0.248	-1.094	0.948	2.277	2.615	0.861	1.483	4.713	4.584	5.7346	0.6372	0.7724	0.5700
1	USA	-15.496	2.683	7.763	0.983	-2.744	0.544	-1.354	0.172	-1.319	0.804	0.085	0.298	0.235	0.489	-0.072	1.761	0.049	1.058	0.2708	0.0271	0.9904	0.9827
2	AUS	-1.595	2.042	3.718	1.410	-4.785	1.358	-2.813	0.857	-14.088	3.556	-0.384	0.359	-1.475	0.757	0.515	0.334	-0.286	0.397	1.5382	0.1538	0.9383	0.8890
2	BRA	1.989	0.648	0.682	0.197	0.106	0.210	-0.024	0.226	-0.378	0.219	-1.406	0.485	-7.913	4.371	0.094	0.315	-0.343	0.344	1.0192	0.1019	0.9214	0.8585
2	HKG	-3.030	1.877	3.688	0.544	-1.964	0.636	0.308	0.339	0.327	0.665	-0.291	0.238	-0.370	0.302	-0.063	0.155	0.177	0.264	0.1658	0.0184	0.9956	0.9917
2	IDN	-1.341	0.498	1.395	0.148	1.678	0.177	1.339	0.197	-0.796	0.146	-1.295	0.887	-46.72	32.064	-5.404	3.777	-1.920	1.667	0.3181	0.0318	0.9869	0.9765
2	IND	-3.435	0.893	1.774	0.312	1.676	0.297	1.392	0.306	-0.636	0.142	-3.170	3.188	-22.30	23.387	0.000	.	0.000	.	0.9362	0.0780	0.9775	0.9662
2	KOR	3.168	0.651	0.159	0.405	-0.795	0.395	-0.122	0.168	-0.052	0.198	-0.034	0.218	-0.808	0.253	0.082	0.504	-0.357	0.521	0.0222	0.0111	0.9971	0.9856
2	MEX	-0.194	0.804	2.570	0.433	-1.105	0.539	0.454	0.312	-4.714	1.281	-1.201	0.185	-1.317	0.308	1.306	0.204	0.615	0.223	0.0036	0.0018	0.9990	0.9950
2	MYS	0.111	2.221	1.744	0.127	2.277	0.755	1.694	0.546	-0.461	0.273	-0.440	0.151	-2.500	0.381	0.804	0.187	-0.634	0.118	0.1409	0.0157	0.9956	0.9918
2	SAU	2.610	1.552	2.714	0.440	-0.483	0.457	-1.658	1.097	0.242	0.440	2.203	1.125	18.486	20.090	0.408	2.982	-0.008	0.950	3.9382	0.3938	0.9202	0.8563
2	THA	2.395	0.195	1.084	0.233	1.007	0.349	1.201	0.181	-6.244	1.264	-0.815	0.138	-2.017	0.547	0.575	0.048	-0.676	0.484	0.0011	0.0006	0.9999	0.9994
2	TUR	2.960	0.442	1.158	0.110	-0.504	0.373	0.043	0.337	0.434	0.149	-0.027	0.202	0.179	0.139	-0.297	0.266	0.225	0.171	2.5258	0.1263	0.9746	0.9644
3	BDI	-0.708	3.131	3.015	3.714	1.217	6.991	-7.170	22.865	-2.090	7.441	-1.460	6.729	1.485	4.212	1.615	6.386	0.000	.	5.3411	1.0682	0.7194	0.3267
3	BEN	0.505	0.519	0.903	0.256	-0.238	0.223	-0.976	0.889	0.317	0.388	0.044	0.645	-0.216	1.521	0.000	.	0.000	.	3.1950	0.1682	0.8209	0.7644
3	BFA	-6.425	2.025	7.367	2.603	-2.344	0.768	-8.078	2.953	0.980	0.739	-4.855	3.482	3.048	2.825	8.566	5.610	0.000	.	0.8397	0.1400	0.9076	0.7998
3	BWA	5.625	0.368	2.154	0.179	-0.268	0.100	-3.000	0.517	0.000	0.185	1.670	0.162	-3.189	0.683	-0.023	0.072	0.000	.	0.0255	0.0051	0.9961	0.9907
3	CAF	0.319	0.030	0.277	0.040	-0.058	0.035	-0.348	0.150	0.057	0.051	-0.110	0.038	0.346	0.108	0.000	.	0.000	.	0.0851	0.0039	0.9840	0.9796
3	CIV	-1.176	0.856	1.921	0.550	-0.238	0.135	-1.774	0.963	0.452	0.217	-0.106	0.135	-0.363	0.233	0.100	0.439	0.000	.	0.5690	0.0438	0.9666	0.9486
3	COG	3.116	0.900	5.503	1.267	-1.091	1.162	-7.669	2.941	0.690	1.453	0.700	0.704	-3.041	2.004	0.000	.	0.000	.	2.9805	0.2981	0.8311	0.7297
3	COM	3.581	16.541	0.562	0.586	-0.409	0.764	-0.687	2.863	-0.129	1.373	1.218	1.183	-0.275	0.822	-0.629	1.555	1.274	3.932	0.3457	0.1152	0.9513	0.8213
3	DZA	-25.942	12.867	9.735	3.911	-2.651	0.961	-10.08	3.929	2.871	1.312	0.320	1.457	1.693	2.470	-0.526	1.022	4.179	5.647	1.2545	0.2509	0.9268	0.8097
3	ETH	-13.559	3.554	5.377	1.345	-1.413	0.310	-5.388	1.929	0.906	0.283	0.868	0.357	-0.778	0.309	-0.028	0.284	0.000	.	0.1182	0.0296	0.9806	0.9467

Table K.2: Continued.

Group	Country	α	S. Err	θ_1'	S. Err	θ_2'	S. Err	θ_3'	S. Err	θ_4'	S. Err	θ_1''	S. Err	θ_2''	S. Err	θ_3''	S. Err	θ_4''	S. Err	SSE	MSE	R^2	AdjR^2
3	GAB	2.902	0.394	1.072	0.193	-0.380	0.229	-1.265	1.032	0.153	0.453	-0.006	0.460	0.014	0.376	-0.437	0.971	0.001	1.621	0.7038	0.0704	0.9587	0.9256
3	GHA	-21.421	5.989	13.141	3.673	-3.044	1.454	-14.85	5.993	1.820	2.421	1.683	1.076	3.535	4.923	-1.254	0.888	8.746	14.842	1.4410	0.2882	0.9105	0.7672
3	GIN	-0.129	1.265	4.246	0.981	-1.041	0.263	-3.778	1.855	0.723	0.477	-0.636	0.303	-0.278	0.459	0.000	.	0.000	.	0.2517	0.0503	0.9714	0.9371
3	KEN	-5.054	2.512	2.806	1.127	-1.164	0.428	-5.256	1.320	1.112	0.560	-0.863	0.577	-0.250	0.493	0.118	0.333	0.000	.	0.4675	0.0779	0.9591	0.9115
3	LBR	1.635	0.686	6.367	2.728	-1.503	0.518	-7.833	3.517	0.000	.	0.199	0.608	0.000	.	0.000	.	0.000	.	1.2102	0.1513	0.8750	0.7969
3	LSO	-234.33	217.34	-23.03	24.731	-89.22	80.192	-49.22	51.175	14.284	2.426	1.111	3.155	4.359	6.431	-1.134	1.532	6.361	14.519	1.7681	0.5894	0.9036	0.6465
3	MAR	-9.464	1.121	4.795	0.423	-1.178	0.265	-4.920	0.970	5.261	3.388	0.124	0.942	0.788	1.552	-0.119	0.336	0.703	3.231	0.6003	0.0500	0.9596	0.9326
3	MDG	0.489	0.187	0.487	0.054	-0.212	0.093	-0.437	0.204	0.774	0.315	0.057	0.160	0.000	.	0.000	.	0.000	.	0.2799	0.0122	0.9409	0.9281
3	MRT	1.043	0.978	0.862	0.730	-0.557	0.164	0.294	1.213	-29.366	16.753	-0.150	0.765	0.000	.	0.000	.	0.000	.	0.9776	0.1222	0.9277	0.8825
3	MUS	2.045	0.325	2.516	0.473	-0.185	0.182	-4.667	0.765	0.590	0.316	-1.120	0.184	-1.866	0.217	0.836	0.119	-3.159	0.391	0.0195	0.0049	0.9985	0.9955
3	NER	6.453	0.121	-0.816	0.128	0.107	0.100	1.236	0.568	2.854	1.173	-16.68	1.624	-9.261	0.788	30.219	2.869	22.734	2.139	0.3555	0.0187	0.9919	0.9884
3	NGA	-10.753	6.780	3.603	1.901	-0.321	0.876	-7.468	5.661	0.044	0.195	-0.271	0.617	2.127	1.757	0.399	1.382	0.000	.	1.3077	0.1868	0.8843	0.7687
3	RWA	-1.385	0.320	2.967	0.429	-0.847	0.131	-2.564	0.691	2.612	1.148	-0.198	0.351	1.174	0.934	0.000	.	0.000	.	0.5961	0.0542	0.9904	0.9852
3	SEN	-0.978	0.816	2.284	0.713	-0.007	0.181	-2.923	1.252	-2.513	0.784	1.398	2.232	0.581	0.763	3.077	4.364	6.322	9.039	1.1439	0.0953	0.9312	0.8854
3	SLE	-2.021	0.217	5.776	0.642	-1.044	0.309	-7.762	1.318	21.657	53.608	0.190	0.222	-1.676	0.846	0.000	.	0.000	.	0.4336	0.0394	0.9601	0.9383
3	SWZ	2.302	0.780	0.537	0.343	-0.627	0.266	0.505	0.886	2.775	2.379	-7.859	18.511	-70.90	173.58	16.966	41.626	0.000	.	2.0276	0.1267	0.8909	0.8431
3	TCD	0.045	0.193	0.539	0.057	-0.836	0.137	1.301	0.435	-1.156	0.259	-0.453	0.075	0.774	0.133	0.274	0.084	-0.005	0.076	0.0026	0.0013	0.9994	0.9969
3	TGO	-6.568	1.295	-3.831	4.916	1.464	1.282	7.399	4.991	0.808	0.157	0.531	0.169	10.157	3.508	-1.091	0.803	-6.261	3.205	0.0466	0.0233	0.9967	0.9837
3	TUN	-3.009	0.412	3.660	0.264	-0.818	0.114	-4.200	0.450	-0.382	0.454	-0.130	0.063	0.115	0.065	-0.017	0.070	-0.052	0.134	0.1459	0.0146	0.9853	0.9735
3	TZA	7.892	0.495	-0.091	0.490	2.364	0.406	1.083	0.230	-0.347	0.126	0.001	0.018	0.027	0.050	0.000	.	0.000	.	0.0066	0.0003	0.9927	0.9907
3	ZAF	-23.576	4.328	7.197	1.253	-2.406	0.467	-5.710	2.425	-0.533	0.388	-1.316	0.285	-1.319	0.292	3.347	0.361	-6.288	1.384	0.3093	0.0516	0.9710	0.9323
3	ZMB	-3.988	1.358	4.886	1.299	-0.478	0.626	-7.542	2.613	2.144	0.675	0.228	0.663	-1.607	2.071	0.000	.	0.000	.	4.5277	0.3773	0.7676	0.6513
3	ZWE	-3.664	2.593	3.173	1.898	-0.895	0.460	-0.284	3.305	-0.611	1.147	0.191	0.864	-0.101	0.764	-0.007	0.445	0.420	2.643	1.4563	0.1820	0.9211	0.8421
4	ARE	2.998	1.155	0.288	0.961	-0.430	0.391	-0.436	0.480	-0.073	0.517	0.582	0.229	-0.473	1.236	-1.239	1.905	-8.759	6.917	0.8619	0.1231	0.8979	0.7813
4	BHR	-8.381	2.223	7.013	2.387	-0.179	1.211	-1.423	1.612	-2.842	1.516	-0.363	0.784	1.822	2.405	-5.316	8.939	2.231	3.183	3.6326	0.4036	0.9091	0.8283
4	BRN	14.689	11.365	12.959	5.848	-0.600	4.036	-0.422	4.540	-5.535	1.184	0.709	0.370	-3.062	1.430	1.032	1.550	0.000	.	0.3234	0.0359	0.9827	0.9693
4	DJI	16.083	1.596	10.713	1.077	5.364	0.562	6.930	0.835	-7.381	0.829	1.691	0.881	-43.92	24.713	1216.9	648.76	-229.3	123.56	0.2143	0.0268	0.9813	0.9625
4	EGY	-11.384	1.723	5.021	0.618	0.051	0.878	-1.239	1.633	-2.569	0.440	0.044	0.137	0.022	0.245	-0.509	1.513	0.083	0.076	0.0600	0.0150	0.9912	0.9735
4	IRN	-67.292	13.278	1.007	1.139	17.789	3.346	-11.22	2.513	2.802	1.046	0.046	0.106	-1.808	0.791	2.521	1.978	0.000	.	0.0175	0.0058	0.9954	0.9846
4	ISR	-1.658	3.533	2.375	1.735	1.048	0.935	1.282	1.172	-1.442	1.052	0.642	0.260	1.976	0.603	-3.189	1.237	-1.089	0.522	0.9720	0.1080	0.9260	0.8603
4	JOR	0.726	0.268	1.015	0.275	0.112	0.190	0.242	0.207	-0.492	0.186	-1.307	0.177	3.446	0.582	-2.021	0.356	0.000	.	0.1408	0.0282	0.9851	0.9642
4	KWT	4.101	2.116	-1.046	2.669	-0.433	1.566	-0.787	1.636	0.834	1.834	-1.248	0.655	3.563	1.646	-1.054	2.331	0.000	.	3.4170	0.3797	0.6800	0.4311

Table K.2: Continued.

Group	Country	α	S. Err	θ_1'	S. Err	θ_2'	S. Err	θ_3'	S. Err	θ_4'	S. Err	θ_1''	S. Err	θ_2''	S. Err	θ_3''	S. Err	θ_4''	S. Err	SSE	MSE	R^2	AdjR^2
4	OMN	1.549	0.459	1.230	0.535	1.023	0.543	0.472	0.466	1.591	1.001	3.426	5.862	-18.60	35.945	24.185	51.145	0.000	.	0.3228	0.0646	0.9621	0.9090
4	QAT	7.019	1.082	2.797	0.792	3.826	0.729	-0.799	0.797	11.991	4.744	-8.882	8.112	2.497	1.673	39.395	40.783	3.662	2.191	0.7338	0.0815	0.9246	0.8576
4	SYR	-0.931	0.478	1.554	0.222	0.774	0.221	0.747	0.194	-27.012	19.418	-0.221	0.109	0.000	.	0.000	.	0.000	.	0.8543	0.0475	0.9550	0.9426
4	YEM	0.683	2.187	0.347	1.718	0.482	0.780	0.055	0.971	5.557	5.208	1.459	5.861	-5.103	15.840	-1.529	8.179	-35.39	99.080	0.1651	0.0413	0.9825	0.9474
5	BGD	-11.828	10.419	3.831	2.331	-1.483	5.836	-0.555	2.452	-3.243	2.311	-0.951	3.552	1.597	2.187	1.482	22.429	0.000	.	0.8739	0.0971	0.9759	0.9571
5	CYP	-1.760	1.979	2.316	1.725	-1.022	3.238	-0.462	1.226	-1.496	0.941	-0.015	0.388	-0.279	0.334	-0.426	0.325	-0.506	0.346	0.3981	0.0398	0.9765	0.9577
5	LAO	28.685	80.928	-5.686	7.040	22.006	49.395	13.271	40.087	-4.498	5.472	-1.801	1.144	1.424	1.110	-4.886	5.019	-0.181	1.345	0.0552	0.0276	0.9866	0.9332
5	LKA	-78.570	11.172	26.305	3.654	-55.28	8.376	-23.10	3.626	-0.453	0.513	2.084	0.609	2.406	1.717	4.454	1.444	2.571	1.694	0.0112	0.0038	0.9980	0.9926
5	MAC	13.327	7.363	3.573	2.086	0.246	9.619	6.278	6.827	0.606	0.139	0.085	0.264	1.146	0.829	0.430	0.454	0.535	0.624	0.1927	0.0642	0.9794	0.9243
5	MDV	1.155	4.365	4.751	1.181	-0.077	2.888	0.193	1.131	0.122	0.113	-0.156	0.135	0.000	.	0.000	.	0.000	.	0.0578	0.0144	0.9908	0.9792
5	MMR	-12.272	8.315	3.368	2.178	-6.344	6.268	-2.800	2.462	1.946	0.790	-0.679	0.563	0.276	1.026	0.000	.	0.000	.	0.5568	0.0928	0.9209	0.8418
5	MNG	-89.738	54.481	-23.04	26.883	-60.19	42.175	-90.75	64.979	1.821	3.303	0.000	.	0.000	.	0.000	.	0.000	.	1.2048	0.4016	0.7846	0.4975
5	NPL	-5.656	11.565	6.855	11.079	-8.505	22.870	-2.719	8.892	8.250	0.937	5.743	4.943	-6.144	7.277	0.000	.	0.000	.	0.5964	0.1193	0.9700	0.9339
5	PAK	7.606	27.754	-0.686	6.347	11.319	15.486	4.553	7.004	-0.702	0.399	-0.287	1.085	4.926	2.954	-12.57	8.405	8.314	5.177	0.0271	0.0136	0.9960	0.9801
5	PHL	-4.702	0.855	0.369	0.840	5.879	1.866	1.752	0.756	-0.214	0.155	-4.949	1.215	2.429	0.722	-3.096	1.277	-1.946	0.782	0.2496	0.0250	0.9870	0.9766
5	SGP	-11.518	0.942	7.226	0.520	-13.48	1.006	-5.472	0.485	-0.246	0.230	0.033	0.014	-0.002	0.025	0.027	0.025	-0.036	0.012	0.0173	0.0017	0.9988	0.9978
5	SYC	-71.165	88.165	-9.103	19.178	40.716	47.598	13.124	18.896	0.300	0.350	4.317	4.913	-18.76	12.277	0.000	.	0.000	.	53.8350	4.8941	0.8586	0.7814
5	VNM	202.85	62.068	64.475	38.317	47.272	22.484	-83.85	34.012	-0.473	0.156	2.919	4.792	-0.907	1.313	9.247	16.021	0.000	.	0.0349	0.0174	0.9959	0.9816
6	FJI	-60.452	58.358	-23.17	17.535	46.876	45.301	28.318	21.928	-27.327	20.616	4.612	10.577	-6.431	10.085	13.013	7.025	-3.706	4.633	1.6590	0.4148	0.8870	0.6610
6	KIR	-24.255	16.010	-1.924	1.220	17.426	14.047	12.212	12.231	-3.280	1.170	-2.305	0.489	4.159	1.301	0.000	.	0.000	.	0.0755	0.0151	0.9910	0.9802
6	NCL	-8.755	3.270	10.648	3.278	18.882	6.188	26.723	8.744	-0.032	1.139	0.372	0.353	0.167	0.337	-0.377	0.565	1.198	0.843	0.5410	0.0601	0.9390	0.8847
6	NZL	1.166	2.501	3.083	2.802	-6.339	4.813	-2.795	1.884	-1.063	8.455	-1.861	0.908	0.809	1.944	3.836	1.020	-2.723	2.589	3.3541	0.3354	0.8816	0.7869
6	PNG	6.040	2.437	0.983	0.846	-1.829	3.139	-2.456	1.264	-5.482	0.823	0.086	1.251	-0.773	1.980	0.380	2.706	0.000	.	1.3046	0.1450	0.8698	0.7686
6	PYF	-17.120	6.837	22.221	7.751	40.811	14.946	61.423	22.325	-0.695	0.413	0.548	0.536	1.765	0.863	1.427	1.696	-0.381	0.501	0.7234	0.0804	0.9503	0.9062
6	SLB	126.91	285.54	26.009	56.117	27.428	68.991	-37.23	85.005	3.099	0.173	-0.561	1.797	-0.500	2.810	-1.245	4.459	0.000	.	0.2224	0.0742	0.9703	0.9011
6	VUT	22.447	16.285	6.667	4.167	-15.50	11.722	-6.360	4.760	49.498	13.989	-1.311	0.597	0.000	.	0.000	.	0.000	.	0.6103	0.1221	0.9281	0.8561
7	AUT	2.749	0.359	0.666	0.215	0.652	0.328	2.451	0.639	-1.360	0.292	0.186	0.156	0.352	0.562	0.523	0.649	-0.039	0.123	0.3513	0.0234	0.9750	0.9617
7	BEL	-2.313	3.408	5.347	1.965	-2.888	1.922	0.492	4.180	-1.994	2.297	-0.109	0.611	0.059	2.271	0.080	3.464	-0.142	1.252	10.2358	1.0236	0.6378	0.3481
7	CHE	4.344	0.250	3.435	0.488	-2.244	0.433	-0.281	0.472	-0.201	0.159	0.001	0.059	-0.037	0.066	-0.161	0.140	0.047	0.067	0.1252	0.0083	0.9899	0.9845
7	DNK	3.526	0.789	0.802	1.271	0.716	0.820	0.367	0.470	-0.707	0.292	0.025	0.220	0.207	0.451	0.493	1.069	0.515	0.477	3.1201	0.3120	0.8819	0.7874
7	FIN	3.749	0.854	1.096	0.839	0.008	1.114	1.260	3.172	-0.947	1.293	-0.724	1.874	-1.295	3.082	-1.971	3.839	0.411	0.785	1.0283	0.1028	0.8599	0.7478

Table K.2: Continued.

Group	Country	α	S. Err	θ_1'	S. Err	θ_2'	S. Err	θ_3'	S. Err	θ_4'	S. Err	θ_1''	S. Err	θ_2''	S. Err	θ_3''	S. Err	θ_4''	S. Err	SSE	MSE	R^2	AdjR^2
7	GRC	3.163	0.362	0.944	0.540	0.443	0.891	-0.988	0.585	0.182	0.304	0.230	0.449	-0.349	1.043	-0.744	3.835	0.130	0.191	1.1813	0.1074	0.9360	0.8895
7	IRL	6.197	1.237	3.704	2.044	-2.879	1.924	-0.565	0.996	-1.774	0.606	0.118	0.138	1.144	0.461	-0.291	0.369	-0.931	0.521	0.4840	0.0691	0.9690	0.9335
7	ISL	7.350	3.476	1.195	0.777	-1.219	0.523	0.889	0.549	-0.670	0.343	-1.586	3.588	10.348	8.382	0.554	23.235	-3.068	8.072	0.3727	0.0746	0.9493	0.8682
7	MLT	9.423	1.895	2.875	0.461	-4.199	1.104	-3.605	1.681	0.084	0.210	0.628	0.410	4.402	2.372	-3.766	2.323	-7.965	4.593	0.3950	0.0658	0.9631	0.9140
7	NLD	9.527	3.329	0.729	0.853	2.657	1.844	7.437	2.294	0.026	2.634	-0.266	0.242	0.030	0.619	-0.452	0.779	-0.577	0.533	2.0401	0.2267	0.8843	0.7814
7	PRT	-0.667	0.497	2.419	0.321	-2.239	0.292	-2.690	0.342	-0.268	0.361	-0.116	0.129	0.385	0.627	-0.844	1.326	-0.559	0.667	0.8641	0.0864	0.9557	0.9203
8	HUN	-3.193	7.009	1.766	0.983	-2.256	2.185	-3.814	5.481	1.515	2.694	-0.041	0.684	0.708	4.576	-1.090	6.643	-1.156	2.258	1.1821	0.1182	0.9429	0.8973
8	POL	2.390	1.070	0.401	0.528	-0.021	0.210	-0.104	0.414	-1.405	1.650	-1.904	0.324	1.536	0.207	13.646	2.624	1.538	0.767	0.0673	0.0135	0.9921	0.9794
8	ROM	-5.484	2.005	0.580	1.069	-2.168	0.816	-5.936	1.836	6.286	1.971	-4.523	16.596	4.443	9.056	41.717	137.87	14.793	50.950	2.2932	0.2867	0.8826	0.7652
8	YUG	3.427	1.027	1.387	0.888	-0.550	0.647	-0.368	0.285	-0.335	0.362	0.426	1.035	-1.472	2.487	-3.841	8.393	0.000	.	3.0702	0.2791	0.7930	0.6613
9	ARG	-18.719	4.669	4.964	1.046	-2.167	0.502	-6.439	1.421	-0.733	0.230	0.240	0.317	3.222	1.352	-0.074	0.843	1.518	0.908	0.3506	0.0351	0.9741	0.9533
9	BOL	-4.684	0.938	5.512	0.904	-1.598	0.271	-3.169	0.818	-2.047	0.339	-0.003	0.096	1.331	0.466	0.000	.	0.000	.	0.0974	0.0139	0.9866	0.9751
9	CHL	0.349	1.393	2.474	0.714	-1.758	0.632	-4.288	1.371	-0.079	0.652	-0.121	0.294	-1.477	4.495	-0.112	0.566	0.000	.	0.1032	0.0172	0.9864	0.9706
9	COL	1.131	0.421	0.863	0.161	-0.215	0.237	-1.301	0.579	0.259	0.162	-1.147	0.344	-10.20	2.652	7.158	1.950	0.000	.	1.6784	0.1049	0.9645	0.9490
9	ECU	-0.091	1.857	1.277	0.652	-0.109	0.908	0.093	1.730	-1.187	1.141	-0.118	0.431	-1.843	3.758	0.000	.	0.000	.	0.4326	0.0541	0.9490	0.9107
9	PER	-0.585	0.737	1.970	0.413	-0.812	0.298	-2.896	0.560	-1.900	0.241	-0.934	0.328	-0.342	0.537	-2.872	0.907	-1.424	0.462	0.2705	0.0271	0.9802	0.9644
9	PRY	-1.049	1.390	2.379	0.551	-1.200	0.626	-2.678	1.652	0.812	0.271	-0.358	0.351	-0.242	0.586	-0.237	0.786	0.000	.	1.8912	0.1719	0.8874	0.8157
9	SUR	0.554	0.539	-1.144	1.546	0.607	0.980	1.775	2.519	0.360	0.257	-0.630	0.232	0.645	0.815	0.094	0.402	2.301	0.650	0.1538	0.0385	0.9747	0.9240
9	URY	-20.830	9.727	9.217	3.838	-4.241	2.020	-14.69	6.498	0.000	0.000	3.053	1.842	0.289	1.633	8.420	5.593	4.820	3.098	1.2569	0.2095	0.9189	0.8108
9	VEN	0.694	0.412	1.336	0.141	-0.025	0.210	-0.279	0.430	0.878	0.339	0.017	0.405	-0.660	0.699	-0.222	1.115	-0.362	0.609	1.4811	0.0987	0.9453	0.9161
10	BHS	0.883	3.312	1.020	0.664	-0.021	0.275	0.715	1.208	-0.698	0.855	-1.387	1.557	-2.987	3.178	-3.411	3.730	-1.145	1.788	7.2974	0.6634	0.7140	0.5060
10	BMU	14.676	2.952	8.443	2.282	-2.802	0.975	-8.094	3.018	-2.358	0.548	-3.417	7.934	6.258	14.239	-4.533	7.481	0.000	.	1.9908	0.2212	0.8917	0.8074
10	BRB	0.748	1.929	4.881	5.828	-2.212	2.522	-6.468	7.913	-0.530	1.253	-0.266	1.740	-0.219	2.379	-1.333	5.224	-0.634	2.550	0.4528	0.2264	0.9127	0.5634
10	CRI	0.440	3.449	3.453	1.675	-0.429	0.940	-2.820	2.812	-1.232	1.504	-2.080	8.667	-16.09	85.050	-11.72	63.431	0.822	10.334	11.7028	1.6718	0.5843	0.1093
10	GTM	-14.198	4.196	8.204	1.940	-2.132	0.770	-9.035	2.702	-1.572	0.451	1.129	0.852	2.064	1.295	3.774	2.536	2.264	1.804	1.6458	0.1829	0.8600	0.7356
10	HND	2.820	0.511	1.244	0.117	-0.623	0.238	-1.611	0.410	-0.048	0.161	-0.240	0.080	2.457	0.980	0.000	.	0.000	.	0.1751	0.0250	0.9814	0.9655
10	JAM	3.327	0.401	0.622	0.187	0.166	0.126	-0.345	0.399	-0.145	0.174	-0.246	0.236	0.088	0.358	-0.101	0.460	0.152	0.267	1.4614	0.0731	0.8402	0.7763
10	LCA	2.789	1.766	0.826	0.477	-1.056	0.785	-1.158	0.852	0.000	0.000	-0.019	0.448	0.000	.	0.000	.	0.000	.	1.6963	0.1885	0.8187	0.7180
10	NIC	-5.224	3.158	4.761	1.955	-3.245	1.200	-8.329	4.049	0.133	3.008	0.584	1.590	-0.168	3.209	-0.442	2.811	0.000	.	37.9000	3.7900	0.7919	0.6462
10	PAN	-2.343	0.525	4.790	0.435	-1.421	0.164	-3.411	0.454	-5.850	4.507	0.292	0.129	-0.571	0.418	-0.563	0.353	0.000	.	0.4531	0.0349	0.9689	0.9522
10	SLV	-0.536	0.761	3.032	0.457	0.695	0.447	-2.241	0.818	0.559	0.378	0.068	0.258	-1.563	1.244	0.000	.	0.000	.	1.5150	0.1263	0.9246	0.8869
10	TTO	-1.495	0.832	2.807	0.675	-0.840	0.372	-3.144	0.834	2.479	0.472	-1.360	0.907	-5.076	5.818	-3.236	1.256	-3.786	3.857	2.1734	0.1672	0.8909	0.8237

Appendix L : Stock demand calculations

Table L.1: Stock demand regression results (equation 5.11); first traffic demand predicted results (equation 5.6); all countries manufacturing price index, model 3 (table 3.3).

Country	α	S. Err	β	S. Err	γ	S. Err	ε	S. Err	φ	S. Err	ψ	S. Err	DFE	SSE	MSE	R^2	AdjR^2
1 CAN	-110.775	56.885 *	-0.092	0.695	-1.313	2.198	1.243	1.204	2.631	1.450 *	-0.015	0.009	22	11.147	0.507	0.935	0.920
1 DEU	58.818	19.675 ***	-0.294	0.299	-5.724	1.111 ***	0.132	0.659	-1.780	0.509 ***	0.012	0.003 ***	22	3.415	0.155	0.970	0.964
1 ESP	-0.519	17.967	0.901	0.363 **	-4.692	0.801 ***	-0.387	0.538	-0.234	0.462	0.001	0.003	22	1.989	0.090	0.979	0.974
1 FRA	49.136	18.921 **	-0.282	0.208	-5.042	0.992 ***	-0.065	0.604	-1.483	0.479 ***	0.010	0.003 ***	22	2.855	0.130	0.974	0.968
1 GBR	14.155	16.768	-0.309	0.180	-4.290	0.916 ***	-0.102	0.546	-0.612	0.435	0.005	0.002 *	22	2.248	0.102	0.976	0.971
1 ITA	60.077	21.143 ***	-0.484	0.370	-5.905	1.125 ***	0.421	0.706	-1.847	0.545 ***	0.012	0.003 ***	22	3.925	0.178	0.966	0.958
1 JPN	101.346	37.360 **	0.505	0.532	-8.309	2.935 **	0.053	0.833	-2.956	1.002 ***	0.018	0.006 ***	20	4.418	0.221	0.962	0.953
1 LUX	30.946	25.559	0.558	0.246 **	-4.494	2.468 *	-0.555	0.457	-1.128	0.712	0.007	0.004	19	1.250	0.066	0.973	0.965
1 NOR	36.109	15.867 **	-0.106	0.231	-4.821	0.878 ***	0.023	0.508	-1.179	0.411 ***	0.008	0.002 ***	22	2.034	0.092	0.977	0.972
1 SWE	44.637	16.840 **	-0.160	0.185	-4.967	0.929 ***	-0.121	0.534	-1.396	0.435 ***	0.009	0.002 ***	22	2.243	0.102	0.976	0.971
1 USA	-115.094	23.259 ***	-0.040	0.260	-0.403	1.268	-1.088	0.761	2.806	0.603 ***	-0.016	0.004 ***	22	4.545	0.207	0.981	0.976
2 AUS	-15.848	35.139	0.512	0.282 *	-1.761	2.885	0.323	0.744	0.361	0.942	-0.002	0.005	20	3.457	0.173	0.930	0.912
2 BRA	8.463	24.231	0.482	0.488	-4.021	1.127 ***	0.730	0.699	-0.392	0.626	0.003	0.004	22	3.626	0.165	0.960	0.951
2 IDN	-32.194	32.476	-0.128	0.204	-0.921	2.609	0.480	0.744	0.687	0.860	-0.003	0.005	20	3.476	0.174	0.933	0.917
2 IND	-140.668	53.845 **	-0.155	0.326	14.531	5.856 **	0.483	0.882	3.892	1.526 **	-0.020	0.009 **	18	4.522	0.251	0.920	0.898
2 KOR	-79.408	45.779 *	-0.220	0.469	1.851	3.512	0.604	0.906	1.926	1.248	-0.010	0.007	20	5.327	0.266	0.868	0.836
2 MEX	88.941	43.141 *	0.076	0.099	-5.061	2.255 **	-0.165	1.416	-2.497	1.109 **	0.016	0.006 **	21	14.774	0.704	0.894	0.869
2 MYS	-92.179	37.462 **	0.524	0.249 **	5.491	3.626	0.245	0.820	2.537	1.053 **	-0.015	0.006 **	20	4.351	0.218	0.885	0.856
2 SAU	22.405	25.400	0.085	0.080	-3.694	1.234 ***	0.790	0.759	-0.738	0.635	0.005	0.004	22	4.431	0.201	0.948	0.937
2 THA	-109.148	49.193 **	0.072	0.062	7.811	5.611	0.398	0.815	2.924	1.389 **	-0.016	0.008 **	18	3.664	0.204	0.879	0.845
2 TUR	86.308	26.902 ***	0.510	0.220 **	-10.603	2.349 ***	-0.493	0.592	-2.494	0.716 ***	0.014	0.004 ***	20	1.991	0.100	0.961	0.951
3 BFA	-97.215	71.346	0.299	0.150 *	18.550	24.439	-0.362	0.435	3.143	2.778	-0.016	0.014	11	0.435	0.040	0.946	0.921
3 CAF	-90.403	40.605 **	-0.133	1.053	16.066	7.961 *	-0.293	0.498	2.860	1.319 **	-0.015	0.007 *	15	0.870	0.058	0.931	0.908
3 CIV	21.924	19.675	-0.277	0.149 *	-5.890	1.788 ***	-0.460	0.367	-0.821	0.537	0.005	0.003	19	0.765	0.040	0.970	0.962
3 COG	-181.366	75.789 **	0.156	0.170	48.970	25.024 *	-0.183	0.505	6.522	2.920 **	-0.034	0.015 **	11	0.587	0.053	0.927	0.894
3 DZA	-8.358	17.814	0.498	0.171 ***	-1.969	1.223	0.435	0.569	0.134	0.473	-0.001	0.003	22	2.542	0.116	0.972	0.965
3 ETH	-2.941	19.302	0.073	0.103	-4.024	0.976 ***	0.502	0.616	-0.102	0.488	0.001	0.003	22	2.951	0.134	0.960	0.951
3 GAB	-23.420	27.725	0.050	0.180	3.337	3.822	-0.205	0.444	0.675	0.814	-0.003	0.004	17	0.956	0.056	0.942	0.925
3 GHA	-29.018	25.350	0.200	0.136	2.656	3.579	0.047	0.443	0.794	0.747	-0.004	0.004	17	0.852	0.050	0.948	0.933
3 GIN	105.275	90.468	-0.302	0.169	-80.684	40.676 *	-0.808	0.363 *	-6.374	3.972	0.032	0.020	8	0.157	0.020	0.967	0.946
3 KEN	34.228	18.087 *	0.075	0.091	-8.809	1.849 ***	0.077	0.485	-1.202	0.489 **	0.007	0.003 **	21	1.663	0.079	0.970	0.963

Table L.1: Continued.

Country	α	S. Err	β	S. Err	γ	S. Err	ε	S. Err	φ	S. Err	ψ	S. Err	DFE	SSE	MSE	R^2	AdjR^2
3 LBR	-149.695	895.798	-1.074	0.868	711.373	910.648	0.869	1.133	37.650	64.314	-0.170	0.312	3	0.298	0.099	0.963	0.900
3 MAR	16.597	17.581	0.193	0.133	-3.883	0.963 ***	0.120	0.573	-0.615	0.444	0.004	0.003	22	2.477	0.113	0.971	0.965
3 MDG	-79.328	38.263 *	-1.526	1.470	12.134	5.334 **	0.360	0.601	2.364	1.128 *	-0.012	0.006 *	17	1.944	0.114	0.889	0.856
3 MRT	-7.382	25.723	0.340	0.155 **	0.045	3.643	-0.058	0.409	0.209	0.759	-0.001	0.004	17	0.883	0.052	0.959	0.946
3 NER	116.097	99.103	-0.031	0.096	-107.962	45.150 **	-0.336	0.378	-7.810	4.391	0.038	0.022	8	0.200	0.025	0.959	0.934
3 NGA	-19.579	21.038	0.437	0.224 *	-3.879	0.958 ***	0.679	0.607	0.278	0.537	-0.001	0.003	22	2.506	0.114	0.969	0.961
3 SEN	19.333	21.606	-0.404	0.194 *	-5.203	2.253 **	-0.580	0.319 *	-0.750	0.601	0.005	0.003	18	0.534	0.030	0.972	0.965
3 TCD	-211.114	63.713 ***	-1.148	0.397 **	73.938	23.359 ***	-0.232	0.422	8.220	2.513 ***	-0.041	0.013 ***	11	0.408	0.037	0.948	0.925
3 TUN	-5.024	17.303	0.892	0.309 ***	-3.531	0.947 ***	0.152	0.569	-0.086	0.450	0.001	0.003	22	2.522	0.115	0.972	0.966
3 TZA	32.812	17.476 *	1.551	1.470	-8.024	1.231 ***	-0.096	0.502	-1.218	0.479 **	0.007	0.003 **	21	1.631	0.078	0.971	0.964
3 ZAF	-29.233	21.485	0.481	0.306	-3.722	0.942 ***	0.624	0.576	0.535	0.547	-0.003	0.003	22	2.570	0.117	0.965	0.958
3 ZMB	-22.530	29.083	0.090	0.248	0.196	3.607	0.212	0.485	0.550	0.851	-0.003	0.005	18	1.232	0.068	0.925	0.904
4 ARE	-246.224	125.930 *	1.076	0.579 *	46.998	34.914	-0.072	0.768	7.839	4.537	-0.042	0.023 *	12	1.205	0.100	0.955	0.937
4 EGY	-46.276	22.786 *	0.928	0.355 **	-2.319	1.092 **	0.501	0.558	1.017	0.599	-0.006	0.004	22	2.456	0.112	0.971	0.965
4 IRN	8.884	48.672	-0.732	0.426	-3.931	4.082	0.500	0.709	-0.420	1.326	0.003	0.008	20	3.279	0.164	0.928	0.910
4 ISR	-13.700	18.067	-0.128	0.275	-3.935	1.043 ***	0.451	0.613	0.051	0.467	0.000	0.003	22	2.833	0.129	0.962	0.953
4 JOR	-6.039	17.460	0.281	0.133 **	-3.269	0.985 ***	0.601	0.584	-0.059	0.449	0.001	0.003	22	2.681	0.122	0.969	0.961
4 KWT	-63.245	31.838 *	0.599	0.316 *	-1.104	1.260	0.846	0.751	1.294	0.801	-0.007	0.005	22	4.213	0.191	0.953	0.943
4 LBN	0.139	30.631	0.006	0.013	-4.279	1.208 ***	0.390	0.726	-0.343	0.798	0.003	0.005	22	3.192	0.145	0.963	0.954
4 OMN	-253.107	78.629 ***	0.539	0.215 **	43.881	19.994 **	0.353	0.619	7.947	2.732 **	-0.043	0.014 **	13	1.299	0.100	0.958	0.942
4 QAT	-338.174	73.128 ***	0.532	0.370	80.484	20.659 ***	0.324	0.585	11.519	2.643 ***	-0.060	0.014 ***	12	0.851	0.071	0.958	0.940
4 SYR	-0.767	19.814	0.327	0.279	-4.368	1.085 ***	0.757	0.667	-0.236	0.510	0.002	0.003	22	3.411	0.155	0.958	0.949
4 YEM	-59.436	40.582	0.485	0.258 *	-3.190	1.179 **	1.092	0.769	1.207	1.009	-0.007	0.006	22	4.280	0.195	0.950	0.938
5 BGD	-159.783	163.354	0.061	0.424	15.500	50.534	0.817	1.488	4.415	6.083	-0.024	0.031	12	3.259	0.272	0.722	0.606
5 CYP	-86.920	44.601 *	-0.062	0.201	21.468	10.080 *	-0.453	0.451	2.989	1.500 *	-0.015	0.008 *	14	0.781	0.056	0.957	0.941
5 LKA	-176.376	50.648 ***	-0.192	0.116	15.221	5.990 **	0.599	0.766	4.725	1.441 ***	-0.026	0.008 ***	18	3.419	0.190	0.887	0.856
5 PAK	-49.177	28.140 *	-0.316	0.085 ***	-2.050	2.431	-0.468	0.695	1.060	0.762	-0.006	0.004	20	2.696	0.135	0.949	0.936
5 PHL	-94.589	38.064 **	0.465	0.421	2.454	3.114	1.019	0.945	2.386	1.029 **	-0.014	0.006 **	20	5.073	0.254	0.875	0.843
5 SGP	-134.480	47.442 **	-0.244	0.768	10.042	5.487 *	0.656	0.832	3.414	1.351 **	-0.018	0.008 **	18	3.945	0.219	0.870	0.834
5 VNM	-47.892	40.635	0.002	0.004	-0.532	3.757	0.301	0.767	1.080	1.106	-0.006	0.006	19	3.599	0.189	0.882	0.851
6 FJI	-527.792	148.770 ***	0.165	0.198	160.132	45.619 ***	0.062	0.559	19.815	5.535 ***	-0.103	0.029 ***	9	0.543	0.060	0.930	0.891
6 NZL	-237.384	88.847 **	0.879	0.641	8.371	6.479	1.789	1.993	6.136	2.356 **	-0.036	0.014 **	20	21.967	1.098	0.595	0.494

Table L.1: Continued.

Country	α	S. Err	β	S. Err	γ	S. Err	ε	S. Err	φ	S. Err	ψ	S. Err	DFE	SSE	MSE	R^2	AdjR^2
6 PNG	-1803.22	681.113 **	0.242	0.588	931.648	519.170	-0.296	1.279	86.368	40.321 *	-0.436	0.198 *	5	1.527	0.305	0.829	0.658
7 AUT	19.700	18.165	0.335	0.446	-5.085	0.976 ***	0.250	0.608	-0.813	0.469 *	0.005	0.003 *	22	2.912	0.132	0.968	0.961
7 BEL	14.498	15.461	0.638	0.217 ***	-4.483	0.826 ***	0.292	0.517	-0.689	0.399 *	0.004	0.002 *	22	2.087	0.095	0.978	0.973
7 CHE	18.467	18.403	0.937	0.559	-5.113	0.989 ***	-0.289	0.677	-0.826	0.475 *	0.005	0.003 *	22	2.989	0.136	0.969	0.962
7 DNK	18.165	18.118	-0.105	0.205	-4.830	1.001 ***	0.168	0.622	-0.775	0.468	0.005	0.003 *	22	2.829	0.129	0.969	0.962
7 FIN	-103.846	46.721 **	-0.912	0.564	30.667	9.663 ***	-0.819	0.496	3.738	1.528 **	-0.018	0.008 **	15	1.059	0.071	0.967	0.956
7 GRC	-18.490	19.816	-0.561	0.222 **	-3.489	0.963 ***	0.366	0.547	0.175	0.506	0.000	0.003	22	2.358	0.107	0.975	0.969
7 IRL	19.692	24.648	0.020	0.350	-4.866	0.970 ***	0.085	0.583	-0.825	0.647	0.005	0.004	22	2.547	0.116	0.973	0.967
7 ISL	-56.935	33.338	0.365	0.189 *	15.046	7.165 *	-0.656	0.430	1.941	1.089 *	-0.009	0.006	15	0.729	0.049	0.971	0.961
7 MLT	-224.895	489.246	-0.319	0.390	183.665	512.108	-0.292	0.678	13.713	35.762	-0.066	0.173	3	0.109	0.036	0.955	0.881
7 NLD	-6.840	20.287	-0.239	0.108 **	-3.940	0.966 ***	-0.208	0.571	-0.145	0.520	0.002	0.003	22	2.378	0.108	0.975	0.970
7 PRT	0.970	27.038	0.329	0.334	-4.278	1.077 ***	0.306	0.597	-0.308	0.700	0.002	0.004	22	2.440	0.111	0.974	0.968
8 YUG	46.332	25.109 *	0.521	0.202 **	-6.133	3.045 *	-0.323	0.389	-1.428	0.720 *	0.008	0.004 **	18	0.835	0.046	0.971	0.962
9 ARG	5.111	20.538	0.245	0.385	-4.548	1.085 ***	0.322	0.666	-0.313	0.529	0.002	0.003	22	3.484	0.158	0.953	0.942
9 BOL	-82.555	44.851 *	-0.292	0.375	29.032	10.567 **	-0.945	0.524 *	3.255	1.408 **	-0.016	0.008 *	14	0.732	0.052	0.938	0.916
9 CHL	5.591	37.141	-0.342	0.304	-5.297	2.202 **	0.834	1.064	-0.433	0.985	0.003	0.006	22	8.810	0.400	0.900	0.877
9 COL	-15.587	25.085	-0.431	0.307	-3.400	1.286 **	0.308	0.718	0.157	0.633	0.000	0.003	22	4.035	0.183	0.948	0.936
9 ECU	50.987	30.782	0.105	0.143	-7.137	3.529 *	-0.512	0.548	-1.550	0.869 *	0.009	0.005 *	18	1.444	0.080	0.921	0.899
9 PER	27.275	34.587	0.632	0.354 *	-7.593	2.407 ***	0.196	0.876	-0.950	0.929	0.005	0.005	21	5.293	0.252	0.927	0.910
9 PRY	-188.362	83.210 **	-0.020	0.248	55.529	26.465 *	-0.416	0.538	6.959	3.147 **	-0.036	0.016 *	11	0.606	0.055	0.931	0.899
9 URY	161.579	203.260	0.110	0.678	-129.751	125.435	-0.439	0.368	-9.980	10.621	0.049	0.053	6	0.154	0.026	0.936	0.883
9 VEN	7.857	23.649	-0.149	0.275	-4.471	1.005 ***	0.212	0.603	-0.418	0.596	0.003	0.003	22	2.834	0.129	0.961	0.952
10 BHS	-141.545	628.643	-0.227	0.852	139.702	624.071	-1.225	0.884	9.932	44.450	-0.048	0.216	3	0.130	0.043	0.865	0.641
10 BRB	-18.113	26.385	-0.339	0.106 ***	5.072	4.364	-0.612	0.349 *	0.469	0.811	-0.002	0.004	16	0.584	0.037	0.959	0.946
10 CRI	3.775	29.794	-0.104	0.226	0.910	4.057	-0.544	0.493	-0.126	0.875	0.002	0.005	17	1.132	0.067	0.916	0.891
10 GTM	130.714	24.591 ***	-0.115	0.186	-12.818	2.512 ***	-1.405	0.464 ***	-3.750	0.691 ***	0.022	0.004 ***	19	1.302	0.069	0.945	0.930
10 HND	253.611	133.877 *	0.013	0.192	-150.979	70.492 *	-0.663	0.449	-13.103	6.406 *	0.066	0.032 *	8	0.334	0.042	0.925	0.878
10 JAM	49.369	25.686 *	-0.183	0.380	-8.671	2.596 ***	-0.258	0.536	-1.664	0.713 **	0.010	0.004 **	19	1.631	0.086	0.933	0.916
10 NIC	53.165	26.164 *	0.015	0.039	-8.346	2.533 ***	-0.344	0.518	-1.678	0.720 **	0.010	0.004 **	19	1.639	0.086	0.933	0.915
10 PAN	58.787	19.913 ***	0.258	0.241	-8.655	1.296 ***	-0.329	0.482	-1.836	0.520 ***	0.011	0.003 ***	20	1.559	0.078	0.964	0.955
10 SLV	-58.656	74.468	0.108	0.174	23.911	24.287	-0.697	0.508	2.395	2.844	-0.012	0.015	11	0.591	0.054	0.918	0.881
10 TTO	19.150	27.146	-0.400	0.239	-4.353	3.322	-1.147	0.733	-0.768	0.778	0.005	0.004	18	1.257	0.070	0.936	0.918

Table L.2: Stock demand regression results (equation 5.11); first traffic demand predicted results (equation 5.6); US manufacturing price index, model 3 (table 3.12).

Country	α	S. Err	β	S. Err	γ	S. Err	ε	S. Err	φ	S. Err	ψ	S. Err	DFE	SSE	MSE	R^2	AdjR^2
1 CAN	-91.015	53.296	-0.229	0.700	-2.129	2.033	0.676	1.310	2.149	1.369	-0.012	0.008	22	11.547	0.525	0.933	0.917
1 DEU	55.862	18.797 ***	-0.322	0.301	-5.592	1.074 ***	0.401	0.714	-1.705	0.492 ***	0.011	0.003 ***	22	3.373	0.153	0.971	0.964
1 ESP	-3.107	17.710	0.864	0.392 **	-4.511	0.760 ***	-0.186	0.627	-0.174	0.458	0.001	0.003	22	2.028	0.092	0.979	0.974
1 FRA	40.089	17.541 **	-0.276	0.203	-4.696	0.925 ***	0.629	0.636	-1.264	0.449 **	0.009	0.003 ***	22	2.735	0.124	0.975	0.969
1 GBR	10.630	15.997	-0.282	0.183	-4.164	0.869 ***	0.235	0.599	-0.530	0.418	0.004	0.002	22	2.236	0.102	0.976	0.971
1 ITA	74.686	20.487 ***	-0.539	0.378	-6.504	1.042 ***	-0.601	0.778	-2.199	0.532 ***	0.014	0.003 ***	22	3.883	0.177	0.966	0.959
1 JPN	103.783	32.609 ***	0.514	0.546	-8.472	2.807 ***	-0.084	0.890	-3.018	0.887 ***	0.018	0.005 ***	20	4.417	0.221	0.962	0.953
1 LUX	19.007	24.646	0.538	0.314	-3.609	2.523	-0.097	0.604	-0.820	0.699	0.005	0.004	19	1.345	0.071	0.970	0.963
1 NOR	33.781	15.943 **	-0.127	0.240	-4.718	0.870 ***	0.182	0.570	-1.121	0.415 **	0.007	0.002 ***	22	2.024	0.092	0.977	0.972
1 SWE	38.606	16.419 **	-0.164	0.184	-4.712	0.894 ***	0.314	0.574	-1.250	0.427 ***	0.008	0.002 ***	22	2.218	0.101	0.977	0.971
1 USA	-118.862	21.919 ***	0.031	0.268	-0.051	1.178	-1.234	0.845	2.898	0.573 ***	-0.016	0.003 ***	22	4.529	0.206	0.981	0.976
2 AUS	-40.804	30.938	0.313	0.275	-0.291	2.516	1.539	0.755 *	0.993	0.831	-0.005	0.005	20	2.890	0.145	0.941	0.927
2 BRA	2.467	20.131	0.387	0.433	-3.849	0.941 ***	1.586	0.670 **	-0.248	0.526	0.002	0.003	22	3.034	0.138	0.966	0.959
2 IDN	-53.630	26.047 *	-0.272	0.184	-0.628	2.093	1.883	0.699 **	1.177	0.690	-0.006	0.004	20	2.604	0.130	0.950	0.938
2 IND	-138.618	47.471 ***	-0.194	0.315	13.747	5.429 **	1.135	0.893	3.799	1.363 **	-0.020	0.008 **	18	4.219	0.234	0.926	0.905
2 KOR	-100.284	38.152 **	-0.138	0.419	2.743	2.918	2.018	0.842 **	2.456	1.048 **	-0.014	0.006 **	20	4.231	0.212	0.896	0.869
2 MEX	61.354	40.259	0.043	0.100	-3.924	2.074 *	1.864	1.526	-1.841	1.037 *	0.012	0.006 **	21	13.803	0.657	0.901	0.878
2 MYS	-100.785	31.799 ***	0.402	0.246	5.095	3.243	1.400	0.840	2.687	0.907 ***	-0.015	0.005 ***	20	3.837	0.192	0.898	0.873
2 SAU	15.595	22.031	0.110	0.073	-3.301	1.042 ***	1.901	0.743 **	-0.561	0.554	0.004	0.003	22	3.582	0.163	0.958	0.949
2 THA	-97.305	44.485 **	0.079	0.061	6.895	5.331	0.013	0.846	2.616	1.273 *	-0.014	0.007 *	18	3.712	0.206	0.877	0.843
2 TUR	65.235	24.794 **	0.395	0.226 *	-9.038	2.179 ***	0.337	0.635	-1.961	0.664 ***	0.011	0.004 ***	20	2.031	0.102	0.960	0.950
3 BFA	-123.840	79.049	0.278	0.157	26.480	27.190	-0.204	0.547	4.127	3.092	-0.022	0.016	11	0.457	0.042	0.943	0.917
3 CAF	-98.690	40.389 **	-0.055	1.076	17.317	8.556 *	-0.234	0.606	3.110	1.341 **	-0.016	0.007 **	15	0.882	0.059	0.930	0.906
3 CIV	13.947	19.368	-0.231	0.164	-5.240	1.781 ***	-0.033	0.422	-0.614	0.532	0.004	0.003	19	0.828	0.044	0.968	0.959
3 COG	-191.155	78.865 **	0.149	0.192	51.548	25.892 *	-0.085	0.684	6.867	3.033 **	-0.036	0.016 **	11	0.593	0.054	0.926	0.892
3 DZA	-11.655	16.001	0.453	0.165 **	-2.062	1.094 *	0.927	0.596	0.203	0.427	-0.001	0.003	22	2.350	0.107	0.974	0.968
3 ETH	-2.324	18.075	0.082	0.102	-4.085	0.916 ***	0.635	0.657	-0.113	0.463	0.001	0.003	22	2.916	0.133	0.961	0.952
3 GAB	-25.449	26.915	0.111	0.178	2.865	3.918	0.278	0.472	0.697	0.801	-0.003	0.004	17	0.948	0.056	0.942	0.926
3 GHA	-29.012	23.152	0.229	0.124 *	1.852	3.573	0.424	0.432	0.757	0.697	-0.004	0.004	17	0.807	0.047	0.951	0.936
3 GIN	60.760	110.912	-0.199	0.176	-65.510	47.601	-0.670	0.466	-4.615	4.757	0.023	0.024	8	0.202	0.025	0.957	0.930
3 KEN	31.563	16.748 *	0.077	0.090	-8.730	1.786 ***	0.298	0.509	-1.137	0.458 **	0.006	0.003 **	21	1.638	0.078	0.971	0.964

Table L.2: Continued.

Country	α	S. Err	β	S. Err	γ	S. Err	ε	S. Err	φ	S. Err	ψ	S. Err	DFE	SSE	MSE	R^2	AdjR^2
3 LBR	530.762	892.447	-0.667	0.971	-255.490	992.584	-1.816	1.853	-24.830	68.010	0.128	0.328	3	0.270	0.090	0.966	0.910
3 MAR	8.914	16.218	0.169	0.129	-3.709	0.897 ***	0.720	0.598	-0.433	0.414	0.003	0.002	22	2.328	0.106	0.973	0.967
3 MDG	-72.394	36.061 *	-1.491	1.496	11.320	5.407 *	0.289	0.656	2.170	1.083 *	-0.011	0.006 *	17	1.962	0.115	0.888	0.855
3 MRT	-9.779	23.854	0.332	0.152 **	-0.247	3.611	0.297	0.429	0.245	0.717	-0.001	0.004	17	0.860	0.051	0.960	0.948
3 NER	71.325	95.163	-0.053	0.087	-95.496	44.118 *	-0.448	0.424	-6.177	4.255	0.030	0.022	8	0.193	0.024	0.961	0.936
3 NGA	-13.320	17.890	0.331	0.207	-4.132	0.847 ***	0.714	0.608	0.124	0.464	-0.001	0.003	22	2.492	0.113	0.969	0.962
3 SEN	10.788	23.171	-0.362	0.219	-4.415	2.468 *	-0.277	0.378	-0.522	0.648	0.004	0.004	18	0.613	0.034	0.968	0.959
3 TCD	-239.870	67.218 ***	-1.158	0.390 **	82.610	24.678 ***	-0.409	0.499	9.294	2.665 ***	-0.046	0.014 ***	11	0.395	0.036	0.950	0.927
3 TUN	-9.053	15.983	0.799	0.317 **	-3.446	0.864 ***	0.631	0.631	0.005	0.419	0.000	0.002	22	2.420	0.110	0.973	0.967
3 TZA	26.679	16.117	1.492	1.398	-7.703	1.092 ***	0.289	0.503	-1.062	0.430 **	0.006	0.002 **	21	1.608	0.077	0.971	0.964
3 ZAF	-25.231	20.493	0.453	0.306	-3.940	0.881 ***	0.572	0.622	0.440	0.525	-0.003	0.003	22	2.607	0.119	0.965	0.957
3 ZMB	-17.418	25.387	0.057	0.236	-0.400	3.327	0.139	0.483	0.403	0.752	-0.002	0.004	18	1.239	0.069	0.925	0.904
4 ARE	-252.806	110.338 **	1.081	0.552 *	48.763	31.175	-0.133	0.863	8.075	4.007 *	-0.043	0.021 *	12	1.204	0.100	0.955	0.937
4 EGY	-43.977	21.139 **	0.837	0.357 **	-2.487	1.006 **	0.785	0.606	0.954	0.560	-0.006	0.003	22	2.365	0.108	0.972	0.966
4 IRN	1.789	48.135	-0.657	0.426	-3.521	4.011	0.798	0.737	-0.231	1.313	0.002	0.008	20	3.174	0.159	0.931	0.913
4 ISR	-15.593	17.951	-0.218	0.271	-3.806	1.056 ***	0.620	0.654	0.102	0.466	0.000	0.003	22	2.789	0.127	0.963	0.954
4 JOR	-10.196	15.925	0.276	0.127 **	-3.203	0.880 ***	1.104	0.600 *	0.043	0.413	0.000	0.002	22	2.435	0.111	0.971	0.965
4 KWT	-57.956	26.699 **	0.447	0.295	-1.218	1.074	1.452	0.757 *	1.166	0.679	-0.006	0.004	22	3.817	0.174	0.958	0.948
4 LBN	-5.076	23.999	0.007	0.011	-4.104	0.978 ***	1.041	0.661	-0.219	0.633	0.002	0.004	22	2.906	0.132	0.966	0.958
4 OMN	-246.051	90.555 **	0.515	0.211 **	42.773	23.652 *	0.250	0.790	7.732	3.189 **	-0.041	0.017 **	13	1.321	0.102	0.958	0.941
4 QAT	-325.263	74.777 ***	0.551	0.379	77.363	21.472 ***	0.045	0.704	11.079	2.728 ***	-0.058	0.014 ***	12	0.872	0.073	0.956	0.938
4 SYR	-3.488	18.838	0.252	0.269	-4.307	1.026 ***	1.106	0.693	-0.167	0.488	0.001	0.003	22	3.237	0.147	0.960	0.951
4 YEM	-42.256	33.347	0.314	0.237	-3.218	1.038 ***	1.654	0.760 **	0.790	0.836	-0.004	0.005	22	3.845	0.175	0.955	0.945
5 BGD	-205.455	186.402	-0.136	0.354	32.083	56.403	-0.499	1.463	6.232	6.907	-0.033	0.036	12	3.308	0.276	0.718	0.600
5 CYP	-113.536	50.902 **	-0.020	0.199	27.318	12.268 **	-0.621	0.567	3.883	1.757 **	-0.020	0.009 *	14	0.770	0.055	0.957	0.942
5 LKA	-160.876	47.777 ***	-0.194	0.120	14.168	5.944 **	-0.044	0.826	4.328	1.377 ***	-0.023	0.008 ***	18	3.535	0.196	0.883	0.851
5 PAK	-43.355	25.106 *	-0.373	0.094 ***	-2.508	2.204	-1.127	0.802	0.906	0.686	-0.005	0.004	20	2.509	0.125	0.952	0.940
5 PHL	-104.151	30.644 ***	0.391	0.350	2.656	2.591	2.140	0.818 **	2.614	0.835 ***	-0.015	0.005 ***	20	4.000	0.200	0.901	0.877
5 SGP	-120.559	44.371 **	-0.196	0.789	8.830	5.338	0.213	0.894	3.048	1.280 **	-0.016	0.007 **	18	4.069	0.226	0.866	0.829
5 VNM	-60.794	34.132 *	0.002	0.004	-0.157	3.240	1.355	0.734 *	1.391	0.936	-0.007	0.005	19	3.077	0.162	0.899	0.873
6 FJI	-528.307	140.020 ***	0.246	0.218	164.578	44.524 ***	-0.486	0.755	20.062	5.282 ***	-0.104	0.027 ***	9	0.520	0.058	0.933	0.895
6 NZL	-246.820	69.578 ***	0.738	0.547	8.761	5.622	3.681	1.770 *	6.361	1.877 ***	-0.037	0.011 ***	20	18.788	0.939	0.654	0.567

Table L.2: Continued.

Country	α	S. Err	β	S. Err	γ	S. Err	ε	S. Err	φ	S. Err	ψ	S. Err	DFE	SSE	MSE	R^2	AdjR^2
6 PNG	-2394.66	657.989 **	0.060	0.486	1294.77	470.179 **	-2.517	1.522	117.43	37.508 **	-0.591	0.185 **	5	0.998	0.200	0.888	0.777
7 AUT	16.428	17.107	0.318	0.440	-4.986	0.905 ***	0.584	0.647	-0.732	0.446	0.005	0.003 *	22	2.830	0.129	0.969	0.962
7 BEL	14.473	14.640	0.599	0.218 **	-4.533	0.762 ***	0.391	0.562	-0.688	0.381 *	0.004	0.002 *	22	2.072	0.094	0.978	0.974
7 CHE	9.642	17.495	0.704	0.543	-4.684	0.911 ***	0.477	0.710	-0.603	0.455	0.004	0.003	22	2.953	0.134	0.970	0.963
7 DNK	16.088	17.144	-0.069	0.210	-4.813	0.944 ***	0.460	0.688	-0.725	0.447	0.005	0.003 *	22	2.782	0.126	0.969	0.963
7 FIN	-120.963	50.485 **	-0.878	0.602	32.697	10.905 ***	-0.616	0.631	4.220	1.678 **	-0.020	0.009 **	15	1.177	0.078	0.963	0.951
7 GRC	-13.882	18.281	-0.533	0.240 **	-3.716	0.888 ***	0.217	0.636	0.064	0.472	0.001	0.003	22	2.393	0.109	0.974	0.969
7 IRL	16.937	24.175	-0.017	0.341	-4.737	0.921 ***	0.500	0.614	-0.762	0.636	0.005	0.004	22	2.474	0.112	0.974	0.968
7 ISL	-65.112	37.958	0.443	0.192 **	14.426	8.509	-0.303	0.522	2.096	1.267	-0.010	0.007	15	0.824	0.055	0.967	0.956
7 MLT	-323.561	446.325	-0.298	0.414	297.279	479.695	-0.083	1.054	21.485	32.983	-0.103	0.159	3	0.115	0.038	0.953	0.873
7 NLD	-9.232	19.726	-0.217	0.114 *	-3.813	0.928 ***	0.158	0.650	-0.090	0.508	0.001	0.003	22	2.386	0.108	0.975	0.970
7 PRT	3.217	22.717	0.265	0.309	-4.361	0.918 ***	0.490	0.595	-0.368	0.595	0.003	0.004	22	2.395	0.109	0.975	0.969
8 YUG	35.248	23.233	0.478	0.205 **	-5.201	2.926 *	0.041	0.413	-1.134	0.674	0.007	0.004 *	18	0.866	0.048	0.969	0.961
9 ARG	1.568	18.758	0.146	0.384	-4.334	1.032 ***	0.793	0.718	-0.227	0.488	0.002	0.003	22	3.336	0.152	0.955	0.945
9 BOL	-109.367	52.104 *	-0.023	0.382	26.975	14.441 *	-0.432	0.679	3.797	1.791 *	-0.019	0.009 *	14	0.876	0.063	0.926	0.899
9 CHL	5.678	34.770	-0.400	0.305	-5.545	2.078 **	1.396	1.151	-0.446	0.930	0.003	0.006	22	8.488	0.386	0.904	0.882
9 COL	-22.644	24.305	-0.452	0.298	-3.161	1.219 **	0.885	0.753	0.329	0.615	-0.001	0.003	22	3.828	0.174	0.950	0.939
9 ECU	31.812	27.857	0.026	0.146	-5.718	3.348	0.220	0.584	-1.057	0.797	0.006	0.004	18	1.502	0.083	0.918	0.895
9 PER	27.406	30.553	0.598	0.354	-7.684	2.139 ***	0.344	0.924	-0.959	0.828	0.005	0.005	21	5.271	0.251	0.927	0.910
9 PRY	-222.263	99.258 **	-0.023	0.263	65.187	31.142 *	-0.387	0.686	8.196	3.742 *	-0.042	0.019 *	11	0.620	0.056	0.929	0.897
9 URY	120.578	253.422	-0.038	0.742	-114.637	155.719	-0.137	0.566	-8.331	13.237	0.041	0.066	6	0.189	0.031	0.922	0.856
9 VEN	1.255	21.591	-0.144	0.264	-4.238	0.901 ***	0.823	0.625	-0.257	0.548	0.002	0.003	22	2.642	0.120	0.963	0.955
10 BHS	-187.600	806.764	0.474	0.972	332.113	786.548	0.225	1.476	20.300	56.021	-0.095	0.272	3	0.212	0.071	0.781	0.415
10 BRB	-28.256	28.330	-0.317	0.115 **	4.883	5.070	0.022	0.427	0.683	0.891	-0.003	0.005	16	0.697	0.044	0.951	0.936
10 CRI	-9.505	28.410	-0.003	0.223	1.345	4.236	0.062	0.521	0.202	0.853	0.000	0.005	17	1.212	0.071	0.910	0.884
10 GTM	106.849	26.361 ***	-0.137	0.217	-10.844	2.793 ***	-0.788	0.561	-3.126	0.750 ***	0.018	0.004 ***	19	1.748	0.092	0.926	0.906
10 HND	212.063	151.259	-0.004	0.213	-139.471	78.775	-0.305	0.614	-11.609	7.195	0.058	0.036	8	0.412	0.052	0.907	0.849
10 JAM	36.678	22.940	-0.337	0.373	-8.162	2.434 ***	0.543	0.545	-1.350	0.644 **	0.008	0.004 **	19	1.569	0.083	0.936	0.919
10 NIC	37.478	24.057	0.005	0.040	-7.468	2.362 ***	0.387	0.556	-1.285	0.665 *	0.008	0.004 *	19	1.635	0.086	0.933	0.916
10 PAN	46.085	17.811 **	0.303	0.242	-8.018	1.173 ***	0.529	0.511	-1.522	0.469 ***	0.009	0.003 ***	20	1.514	0.076	0.965	0.956
10 SLV	-107.175	83.108	0.113	0.186	37.607	27.537	-0.505	0.655	4.158	3.206	-0.021	0.017	11	0.656	0.060	0.909	0.868
10 TTO	-2.819	25.319	0.005	0.211	-1.856	3.107	0.560	0.678	-0.170	0.731	0.002	0.004	18	1.376	0.076	0.930	0.910

Table L.3: Stock demand regression results (equation 5.11); second traffic demand predicted results (equation 5.7); All countries manufacturing price index, model 3 (table 3.3).

Country	α	S. Err	β	S. Err	γ	S. Err	ε	S. Err	φ	S. Err	ψ	S. Err	DFE	SSE	MSE	R^2	AdjR^2
1 CAN	-27.798	36.437	0.726	0.193 ***	-1.827	1.482	0.440	0.954	0.711	0.902	-0.005	0.005	22	6.789	0.309	0.960	0.951
1 DEU	62.835	23.679 **	0.015	0.052	-6.088	1.065 ***	0.070	0.738	-1.898	0.592 ***	0.012	0.003 ***	22	3.551	0.161	0.969	0.962
1 ESP	16.670	21.978	-0.185	0.356	-4.884	0.896 ***	0.151	0.576	-0.695	0.541	0.005	0.003	22	2.515	0.114	0.973	0.967
1 FRA	-17.572	24.673	-0.636	0.207 ***	-4.221	0.915 ***	-0.192	0.528	0.123	0.618	0.001	0.003	22	2.161	0.098	0.980	0.976
1 GBR	-16.516	28.798	-0.083	0.050	-4.210	0.944 ***	0.145	0.537	0.100	0.710	0.000	0.004	22	2.267	0.103	0.976	0.971
1 ITA	59.015	22.330 **	0.149	0.741	-6.028	1.174 ***	0.414	0.756	-1.823	0.576 ***	0.012	0.003 ***	22	4.222	0.192	0.963	0.955
1 JPN	113.876	34.936 ***	-0.504	0.434	-9.603	3.222 ***	-0.443	0.875	-3.380	0.950 ***	0.022	0.005 ***	20	4.325	0.216	0.963	0.954
1 LUX	80.112	23.716 ***	-1.512	0.615 **	-10.970	2.710 ***	-0.477	0.444	-2.594	0.672 ***	0.016	0.004 ***	19	1.204	0.063	0.974	0.967
1 NOR	40.176	16.522 **	0.120	0.392	-5.029	0.823 ***	-0.003	0.515	-1.284	0.424 ***	0.008	0.002 ***	22	2.044	0.093	0.977	0.972
1 SWE	57.398	26.364 **	0.064	0.166	-5.177	0.912 ***	-0.115	0.542	-1.701	0.629 **	0.011	0.004 ***	22	2.303	0.105	0.976	0.970
1 USA	-97.487	31.116 ***	0.477	0.561	-0.153	1.206	-1.307	0.788	2.424	0.747 ***	-0.014	0.004 ***	22	4.406	0.200	0.981	0.977
2 AUS	-47.727	29.711	0.470	0.196 **	0.526	2.444	0.333	0.701	1.220	0.803	-0.007	0.005	20	3.126	0.156	0.936	0.921
2 BRA	23.491	19.908	0.415	0.298	-3.641	1.172 ***	0.557	0.664	-0.734	0.512	0.005	0.003	22	3.481	0.158	0.961	0.952
2 IDN	-37.729	31.805	-0.197	0.162	-1.501	2.603	0.570	0.726	0.779	0.839	-0.003	0.005	20	3.300	0.165	0.937	0.921
2 IND	-148.150	54.291 **	-0.050	0.513	14.377	6.367 **	0.519	0.903	4.080	1.595 **	-0.022	0.009 **	18	4.576	0.254	0.919	0.897
2 KOR	-74.527	42.944 *	-0.436	0.520	1.736	3.294	0.737	0.900	1.781	1.173	-0.009	0.007	20	5.202	0.260	0.872	0.839
2 MEX	91.229	43.121 **	0.091	0.104	-4.867	2.232 **	-0.289	1.416	-2.531	1.105 **	0.016	0.006 **	21	14.645	0.697	0.895	0.870
2 MYS	-121.620	37.203 ***	0.717	0.236 ***	10.987	4.253 **	0.422	0.747	3.518	1.078 ***	-0.020	0.006 ***	20	3.639	0.182	0.904	0.880
2 SAU	33.164	28.624	0.121	0.093	-3.878	1.182 ***	0.582	0.744	-0.990	0.704	0.006	0.004	22	4.328	0.197	0.950	0.938
2 THA	-135.571	47.187 **	0.044	0.104	10.078	5.437 *	0.738	0.864	3.618	1.341 **	-0.020	0.007 **	18	3.900	0.217	0.871	0.835
2 TUR	73.312	26.100 **	0.503	0.266 *	-9.527	2.275 ***	0.041	0.573	-2.155	0.698 ***	0.012	0.004 ***	20	2.144	0.107	0.958	0.948
3 BFA	-139.510	72.957 *	0.212	0.187	46.147	23.029 *	-0.509	0.513	5.429	2.715 *	-0.028	0.014 *	11	0.531	0.048	0.934	0.904
3 CAF	-98.913	38.361 **	0.453	0.984	18.067	7.954 **	-0.208	0.463	3.168	1.262 **	-0.017	0.007 **	15	0.859	0.057	0.932	0.909
3 CIV	6.923	26.316	-0.409	0.250	-4.966	2.067 **	-0.455	0.377	-0.430	0.703	0.003	0.004	19	0.794	0.042	0.969	0.961
3 COG	-207.744	91.700 **	0.251	0.326	60.047	32.978 *	-0.086	0.536	7.672	3.687 *	-0.040	0.019 *	11	0.599	0.054	0.925	0.891
3 DZA	4.256	19.797	0.036	0.035	-3.402	1.424 **	0.404	0.658	-0.260	0.520	0.002	0.003	22	3.370	0.153	0.962	0.954
3 ETH	-11.822	27.215	-0.068	0.301	-4.147	1.003 ***	0.493	0.668	0.079	0.625	0.000	0.003	22	3.011	0.137	0.959	0.950
3 GAB	-80.290	32.205 **	-0.466	0.191 **	7.689	3.630 **	-0.379	0.366	2.180	0.904 **	-0.011	0.005 **	17	0.711	0.042	0.957	0.944
3 GHA	85.880	30.841 **	0.638	0.142 ***	-0.488	2.689	-0.651	0.299 **	-1.909	0.798 **	0.011	0.004 **	17	0.440	0.026	0.973	0.965
3 GIN	82.271	138.171	-0.311	0.356	-76.579	50.498	-0.628	0.395	-5.661	5.443	0.029	0.028	8	0.200	0.025	0.957	0.931
3 KEN	35.265	19.201 *	0.054	0.087	-8.308	1.622 ***	0.066	0.489	-1.203	0.512 **	0.007	0.003 **	21	1.687	0.080	0.970	0.962

Table L.3: Continued.

Country	α	S. Err	β	S. Err	γ	S. Err	ε	S. Err	φ	S. Err	ψ	S. Err	DFE	SSE	MSE	R^2	AdjR^2
3 LBR	330.209	941.490	-0.392	0.758	244.371	1001.64	0.529	1.718	4.103	69.658	-0.008	0.337	3	0.413	0.138	0.948	0.862
3 MAR	-50.689	22.470 **	-1.280	0.375 ***	-6.351	0.940 ***	-0.012	0.483	0.859	0.533	-0.004	0.003	22	1.773	0.081	0.980	0.975
3 MDG	-92.238	38.722 **	-3.006	2.536	13.565	5.504 **	0.255	0.609	2.725	1.142 **	-0.013	0.006 **	17	1.909	0.112	0.891	0.859
3 MRT	12.720	25.657	0.520	0.200 **	-3.112	3.859	-0.133	0.387	-0.365	0.757	0.002	0.004	17	0.810	0.048	0.962	0.951
3 NER	170.342	100.753	-0.019	0.021	-127.743	47.062 **	-0.384	0.332	-10.016	4.539 *	0.050	0.023 *	8	0.183	0.023	0.963	0.939
3 NGA	13.512	19.151	0.063	0.054	-4.485	0.941 ***	-0.044	0.640	-0.527	0.485	0.003	0.003	22	2.769	0.126	0.965	0.957
3 SEN	43.988	25.757	-0.037	0.243	-7.207	2.361 ***	-0.378	0.343	-1.409	0.696 *	0.008	0.004 **	18	0.662	0.037	0.966	0.956
3 TCD	-185.918	58.562 ***	-1.079	0.328 ***	61.418	20.096 **	-0.215	0.397	7.056	2.263 ***	-0.035	0.012 **	11	0.362	0.033	0.954	0.933
3 TUN	-2.085	20.449	0.153	0.134	-2.782	1.759	0.380	0.647	-0.150	0.548	0.001	0.003	22	3.284	0.149	0.964	0.955
3 TZA	4.884	22.560	8.324	4.798 *	-7.282	1.145 ***	0.169	0.465	-0.943	0.447 **	0.007	0.003 **	21	1.502	0.072	0.973	0.967
3 ZAF	-30.245	32.094	-0.148	0.184	-3.616	1.138 ***	0.348	0.626	0.539	0.785	-0.003	0.004	22	2.778	0.126	0.963	0.954
3 ZMB	-19.583	26.046	0.163	0.250	1.366	4.168	0.238	0.473	0.542	0.770	-0.003	0.004	18	1.212	0.067	0.926	0.906
4 ARE	-418.939	96.336 ***	0.057	0.446	93.356	27.656 ***	0.575	0.806	14.001	3.509 ***	-0.073	0.018 ***	12	1.550	0.129	0.942	0.918
4 EGY	-5.239	20.219	0.002	0.024	-3.979	1.021 ***	0.543	0.639	-0.079	0.511	0.001	0.003	22	3.216	0.146	0.962	0.954
4 IRN	-62.930	32.574 *	0.015	0.016	0.642	2.812	0.611	0.748	1.477	0.868	-0.008	0.005	20	3.599	0.180	0.921	0.902
4 ISR	-6.586	15.944	0.181	0.070 **	-3.007	0.944 ***	0.309	0.533	-0.056	0.408	0.001	0.002	22	2.196	0.100	0.971	0.964
4 JOR	13.270	19.376	0.408	0.173 **	-4.450	0.927 ***	0.700	0.575	-0.517	0.480	0.003	0.003	22	2.572	0.117	0.970	0.963
4 KWT	-63.969	30.615 **	1.013	0.493 *	-1.842	1.149	1.116	0.779	1.291	0.764	-0.007	0.005	22	4.111	0.187	0.955	0.944
4 OMN	-299.895	73.149 ***	0.874	0.376 **	54.301	18.933 **	-0.073	0.614	9.559	2.554 ***	-0.052	0.013 ***	13	1.362	0.105	0.956	0.939
4 QAT	-362.017	88.914 ***	0.007	0.398	84.767	27.207 ***	0.424	0.679	12.247	3.328 ***	-0.064	0.017 ***	12	0.997	0.083	0.950	0.929
4 SYR	4.351	18.992	0.801	0.393 *	-4.273	0.993 ***	0.861	0.632	-0.324	0.485	0.002	0.003	22	3.048	0.139	0.963	0.954
4 YEM	4.431	21.557	0.626	0.291 **	-4.279	1.200 ***	0.847	0.726	-0.279	0.557	0.002	0.003	22	4.102	0.186	0.952	0.941
5 BGD	-196.274	142.080	-0.496	0.746	19.333	39.392	0.183	1.344	5.316	5.039	-0.028	0.026	12	3.148	0.262	0.731	0.620
5 CYP	-103.945	49.043 *	0.157	0.309	27.448	14.292 *	-0.464	0.449	3.684	1.798 *	-0.019	0.010 *	14	0.772	0.055	0.957	0.942
5 LKA	-128.964	60.935 **	0.010	0.089	9.608	6.417	0.594	0.849	3.395	1.689 *	-0.018	0.009 *	18	3.934	0.219	0.870	0.834
5 PAK	-76.895	41.935 *	-0.023	0.072	1.282	2.958	0.352	0.972	1.825	1.097	-0.010	0.006	20	4.528	0.226	0.913	0.892
5 PHL	-97.806	37.302 **	0.595	0.396	1.469	3.123	0.699	0.861	2.438	1.006 **	-0.014	0.006 **	20	4.836	0.242	0.881	0.851
5 SGP	-128.217	46.913 **	-1.255	1.400	6.980	6.273	0.666	0.809	3.072	1.386 **	-0.016	0.008 *	18	3.798	0.211	0.875	0.840
5 VNM	-41.773	37.758	0.001	0.001	-1.598	3.944	0.267	0.758	0.894	1.048	-0.005	0.006	19	3.535	0.186	0.884	0.854
6 FJI	-517.108	176.248 **	0.109	0.165	144.645	63.628 **	0.112	0.558	18.816	7.055 **	-0.098	0.036 **	9	0.558	0.062	0.928	0.888
6 NZL	-212.621	75.014 **	1.515	0.678 **	4.709	6.294	0.709	1.716	5.502	2.019 **	-0.034	0.012 ***	20	19.235	0.962	0.646	0.557
6 PNG	-1835.88	692.939 **	-0.303	0.717	895.449	503.746	-0.310	1.280	85.322	39.834 *	-0.432	0.196 *	5	1.525	0.305	0.829	0.659

Table L.3: Continued.

Country	α	S. Err	β	S. Err	γ	S. Err	ε	S. Err	φ	S. Err	ψ	S. Err	DFE	SSE	MSE	R^2	AdjR^2
7 AUT	18.131	18.377	-0.402	0.626	-4.725	1.036 ***	0.229	0.611	-0.741	0.478	0.005	0.003 *	22	2.932	0.133	0.968	0.961
7 BEL	24.786	19.344	0.078	0.103	-5.024	0.973 ***	0.136	0.599	-0.950	0.496 *	0.006	0.003 **	22	2.833	0.129	0.971	0.964
7 CHE	17.189	18.918	-1.131	0.922	-5.583	1.168 ***	0.296	0.639	-0.729	0.489	0.006	0.003 *	22	3.154	0.143	0.968	0.960
7 DNK	2.204	19.738	-0.265	0.155	-4.139	1.027 ***	-0.070	0.597	-0.363	0.510	0.003	0.003	22	2.527	0.115	0.972	0.966
7 FIN	-57.787	42.805	-0.339	0.381	21.506	8.421 **	-1.066	0.565 *	2.238	1.372	-0.010	0.007	15	1.181	0.079	0.963	0.951
7 GRC	-26.323	23.676	-0.395	0.182 **	-3.551	1.004 ***	0.319	0.564	0.366	0.600	-0.001	0.003	22	2.504	0.114	0.973	0.967
7 IRL	41.851	18.947 **	0.297	0.150 *	-6.078	1.025 ***	-0.138	0.536	-1.362	0.479 ***	0.008	0.003 ***	22	2.162	0.098	0.977	0.972
7 ISL	-20.269	37.720	0.624	0.280 **	9.764	7.979	-0.791	0.401 *	0.882	1.226	-0.004	0.006	15	0.684	0.046	0.973	0.964
7 MLT	-20.272	340.121	0.695	0.321	84.232	356.872	-0.077	0.474	4.376	24.964	-0.020	0.121	3	0.052	0.017	0.979	0.943
7 NLD	-1.618	29.201	-0.198	0.217	-4.162	1.219 ***	0.395	0.659	-0.289	0.735	0.003	0.004	22	2.801	0.127	0.971	0.964
7 PRT	20.263	18.333	-0.067	0.270	-4.962	0.949 ***	0.106	0.570	-0.823	0.455 *	0.006	0.003 **	22	2.541	0.115	0.973	0.967
8 YUG	38.550	24.451	0.449	0.189 **	-4.012	2.744	-0.155	0.387	-1.155	0.692	0.007	0.004 *	18	0.869	0.048	0.969	0.961
9 ARG	8.610	20.819	0.025	0.712	-4.373	1.105 ***	0.293	0.673	-0.399	0.522	0.003	0.003	22	3.548	0.161	0.952	0.941
9 BOL	-116.159	41.709 **	-0.170	0.122	25.571	9.115 **	-0.598	0.423	3.866	1.362 **	-0.020	0.007 **	14	0.671	0.048	0.943	0.923
9 CHL	69.074	36.999 *	-0.554	0.167 ***	-9.770	2.312 ***	-0.354	0.943	-2.135	0.980 **	0.013	0.006 **	22	6.214	0.282	0.930	0.914
9 COL	-14.437	26.097	-0.389	0.329	-3.626	1.263 ***	0.481	0.728	0.117	0.651	0.000	0.004	22	4.133	0.188	0.946	0.934
9 ECU	57.907	34.227	0.152	0.187	-7.910	3.884 *	-0.527	0.545	-1.742	0.961 *	0.010	0.005 *	18	1.434	0.080	0.921	0.899
9 PER	50.553	38.501	0.097	0.653	-9.351	3.019 ***	-0.002	0.987	-1.618	1.062	0.009	0.006	21	6.091	0.290	0.916	0.896
9 PRY	-186.153	71.654 **	0.286	0.265	57.624	23.482 **	-0.071	0.576	7.030	2.744 **	-0.036	0.014 **	11	0.548	0.050	0.937	0.909
9 URY	137.967	149.302	-0.041	0.225	-116.010	95.501	-0.451	0.383	-8.787	7.963	0.044	0.040	6	0.154	0.026	0.936	0.883
9 VEN	4.622	27.778	-0.179	0.329	-4.371	1.077 ***	0.127	0.606	-0.331	0.704	0.002	0.004	22	2.834	0.129	0.961	0.952
10 BHS	-118.055	529.920	0.396	0.782	163.613	576.650	-0.918	0.799	10.542	39.897	-0.050	0.193	3	0.123	0.041	0.873	0.661
10 BRB	-69.467	26.785 **	-0.391	0.141 **	9.077	4.326 *	-0.292	0.371	1.808	0.805 **	-0.009	0.004 *	16	0.646	0.040	0.955	0.940
10 CRI	-0.163	29.033	-0.043	0.070	0.025	4.282	-0.463	0.454	-0.071	0.856	0.001	0.005	17	1.122	0.066	0.917	0.892
10 GTM	125.691	23.101 ***	0.055	0.148	-11.415	2.968 ***	-1.421	0.466 ***	-3.557	0.643 ***	0.021	0.004 ***	19	1.319	0.069	0.944	0.929
10 HND	225.875	148.224	0.087	0.241	-132.700	81.653	-0.667	0.445	-11.583	7.278	0.058	0.037	8	0.329	0.041	0.926	0.879
10 JAM	46.341	27.073	-0.118	0.411	-8.254	2.574 ***	-0.314	0.520	-1.573	0.752 *	0.009	0.004 **	19	1.644	0.087	0.933	0.915
10 NIC	51.441	26.028 *	0.001	0.031	-8.363	2.600 ***	-0.331	0.521	-1.642	0.717 **	0.010	0.004 **	19	1.651	0.087	0.933	0.915
10 PAN	42.374	17.009 **	-0.518	0.290 *	-13.356	3.154 ***	-0.345	0.461	-1.682	0.443 ***	0.010	0.002 ***	20	1.422	0.071	0.967	0.959
10 SLV	-44.791	53.039	0.587	0.173 ***	28.562	17.284	-0.690	0.359 *	2.309	2.020	-0.011	0.010	11	0.298	0.027	0.959	0.940
10 TTO	-0.069	30.505	-0.275	0.392	-2.697	3.323	-0.583	0.736	-0.252	0.843	0.002	0.005	18	1.413	0.079	0.928	0.908

Table L.4: Stock demand regression results (equation 5.11); second traffic demand predicted results (equation 5.7); US manufacturing price index, model 3 (table 3.12).

Country	α	S. Err	β	S. Err	γ	S. Err	ε	S. Err	φ	S. Err	ψ	S. Err	DFE	SSE	MSE	R^2	AdjR^2
1 CAN	-21.139	34.059	0.743	0.190 ***	-2.080	1.385	0.173	1.013	0.554	0.851	-0.004	0.005	22	6.846	0.311	0.960	0.951
1 DEU	60.793	21.589 **	0.013	0.049	-6.043	1.006 ***	0.227	0.756	-1.849	0.548 ***	0.012	0.003 ***	22	3.538	0.161	0.969	0.962
1 ESP	10.135	20.957	-0.237	0.351	-4.729	0.824 ***	0.575	0.613	-0.539	0.517	0.004	0.003	22	2.426	0.110	0.974	0.969
1 FRA	-19.899	24.000	-0.614	0.217 ***	-4.067	0.861 ***	0.110	0.597	0.178	0.603	0.000	0.003	22	2.171	0.099	0.980	0.976
1 GBR	-14.681	26.946	-0.076	0.052	-4.232	0.858 ***	0.287	0.593	0.056	0.667	0.000	0.004	22	2.251	0.102	0.976	0.971
1 ITA	68.090	21.192 ***	-0.115	0.801	-6.554	1.112 ***	-0.406	0.882	-2.038	0.552 ***	0.013	0.003 ***	22	4.239	0.193	0.963	0.955
1 JPN	104.482	32.301 ***	-0.424	0.412	-8.717	2.851 ***	0.003	0.864	-3.123	0.873 ***	0.020	0.005 ***	20	4.381	0.219	0.962	0.953
1 LUX	60.472	22.061 **	-1.384	0.627 **	-9.484	2.618 ***	0.374	0.469	-2.081	0.632 ***	0.013	0.004 ***	19	1.236	0.065	0.973	0.966
1 NOR	38.996	15.611 **	0.114	0.389	-4.984	0.765 ***	0.085	0.552	-1.256	0.404 ***	0.008	0.002 ***	22	2.042	0.093	0.977	0.972
1 SWE	50.718	26.307 *	0.050	0.167	-4.997	0.856 ***	0.251	0.589	-1.542	0.628 **	0.010	0.004 **	22	2.289	0.104	0.976	0.970
1 USA	-99.384	30.055 ***	0.505	0.563	0.155	1.139	-1.464	0.853	2.466	0.724 ***	-0.014	0.004 ***	22	4.371	0.199	0.981	0.977
2 AUS	-59.577	24.773 **	0.350	0.189 *	1.051	2.067	1.423	0.705 *	1.505	0.676 **	-0.008	0.004 **	20	2.626	0.131	0.947	0.933
2 BRA	12.403	16.999	0.448	0.267	-3.224	1.004 ***	1.618	0.643 **	-0.459	0.442	0.003	0.003	22	2.789	0.127	0.969	0.962
2 IDN	-49.594	25.376 *	-0.204	0.142	-1.152	2.196	1.623	0.661 **	1.067	0.679	-0.005	0.004	20	2.614	0.131	0.950	0.937
2 IND	-130.778	48.683 **	-0.509	0.588	11.128	6.195 *	1.639	1.084	3.427	1.479 **	-0.017	0.009 *	18	4.135	0.230	0.927	0.907
2 KOR	-90.111	36.402 **	-0.411	0.457	2.275	2.761	2.067	0.824 **	2.167	1.002 **	-0.012	0.006 *	20	4.089	0.204	0.899	0.874
2 MEX	62.052	40.787	0.043	0.108	-3.797	2.031 *	1.805	1.585	-1.850	1.044 *	0.013	0.006 **	21	13.821	0.658	0.901	0.878
2 MYS	-130.535	30.712 ***	0.653	0.216 ***	10.658	3.693 ***	1.547	0.710 **	3.692	0.904 ***	-0.021	0.005 ***	20	2.988	0.149	0.921	0.901
2 SAU	23.973	24.213	0.138	0.084	-3.443	1.008 ***	1.742	0.722 **	-0.759	0.600	0.005	0.003	22	3.519	0.160	0.959	0.950
2 THA	-119.214	43.428 **	0.026	0.107	8.817	5.330	0.262	0.923	3.190	1.253 **	-0.017	0.007 **	18	4.040	0.224	0.866	0.829
2 TUR	62.053	23.164 **	0.501	0.254 *	-8.958	2.058 ***	0.782	0.570	-1.874	0.623 ***	0.011	0.003 ***	20	1.960	0.098	0.962	0.952
3 BFA	-183.157	76.410 **	0.158	0.178	56.604	25.116 **	-0.458	0.588	6.920	2.913 **	-0.035	0.015 **	11	0.548	0.050	0.932	0.900
3 CAF	-103.675	39.548 **	0.500	0.999	18.668	8.653 **	-0.134	0.561	3.305	1.324 **	-0.017	0.007 **	15	0.867	0.058	0.931	0.908
3 CIV	2.864	27.662	-0.324	0.282	-4.557	2.155 **	-0.020	0.440	-0.325	0.740	0.002	0.004	19	0.855	0.045	0.967	0.958
3 COG	-224.141	88.858 **	0.251	0.310	65.001	31.784 *	-0.268	0.612	8.287	3.562 **	-0.043	0.019 **	11	0.590	0.054	0.926	0.893
3 DZA	-3.867	17.734	0.035	0.033	-3.166	1.263 **	1.177	0.666 *	-0.063	0.469	0.001	0.003	22	3.002	0.136	0.967	0.959
3 ETH	-7.540	27.412	-0.018	0.326	-4.223	0.943 ***	0.613	0.783	-0.009	0.623	0.000	0.003	22	3.002	0.136	0.960	0.950
3 GAB	-87.889	33.638 **	-0.463	0.208 **	8.317	3.929 **	-0.156	0.427	2.380	0.952 **	-0.012	0.005 **	17	0.750	0.044	0.955	0.941
3 GHA	57.294	31.920 *	0.549	0.156 ***	0.847	2.979	-0.056	0.352	-1.214	0.831	0.007	0.005	17	0.562	0.033	0.966	0.956
3 GIN	57.375	157.770	-0.202	0.359	-66.400	55.942	-0.571	0.492	-4.586	6.147	0.023	0.031	8	0.225	0.028	0.952	0.922
3 KEN	32.584	18.046 *	0.053	0.087	-8.192	1.558 ***	0.273	0.512	-1.136	0.485 **	0.007	0.003 **	21	1.666	0.079	0.970	0.963

Table L.4: Continued.

Country	α	S. Err	β	S. Err	γ	S. Err	ε	S. Err	φ	S. Err	ψ	S. Err	DFE	SSE	MSE	R^2	AdjR^2
3 LBR	628.251	619.722	-0.520	0.406	-437.668	664.291	-2.458	1.347	-35.903	45.812	0.180	0.221	3	0.202	0.067	0.975	0.932
3 MAR	-50.647	22.235 **	-1.268	0.419 ***	-6.310	0.986 ***	0.032	0.583	0.859	0.524	-0.004	0.003	22	1.772	0.081	0.980	0.975
3 MDG	-88.050	37.119 **	-3.092	2.487	12.929	5.595 **	0.302	0.641	2.600	1.111 **	-0.013	0.006 **	17	1.904	0.112	0.891	0.859
3 MRT	8.525	24.461	0.507	0.202 **	-3.110	3.839	0.203	0.420	-0.274	0.730	0.002	0.004	17	0.804	0.047	0.962	0.951
3 NER	122.528	105.181	-0.016	0.021	-112.265	48.322 **	-0.434	0.420	-8.180	4.699	0.040	0.024	8	0.189	0.024	0.962	0.938
3 NGA	4.894	17.892	0.046	0.053	-4.263	0.875 ***	0.546	0.679	-0.323	0.457	0.002	0.003	22	2.690	0.122	0.966	0.959
3 SEN	38.192	26.136	0.015	0.260	-6.690	2.404 **	0.005	0.385	-1.257	0.707 *	0.008	0.004 *	18	0.707	0.039	0.963	0.953
3 TCD	-212.680	61.305 ***	-1.085	0.322 ***	69.418	21.186 ***	-0.386	0.470	8.053	2.384 ***	-0.040	0.012 ***	11	0.350	0.032	0.956	0.935
3 TUN	-9.910	18.344	0.147	0.126	-2.579	1.600	1.138	0.659 *	0.038	0.496	0.000	0.003	22	2.937	0.134	0.967	0.960
3 TZA	-8.038	22.613	10.567	4.933 **	-6.955	1.036 ***	0.679	0.505	-0.763	0.413 *	0.006	0.002 **	21	1.392	0.066	0.975	0.969
3 ZAF	-27.625	32.801	-0.146	0.198	-3.760	1.121 ***	0.273	0.730	0.477	0.802	-0.002	0.004	22	2.799	0.127	0.962	0.954
3 ZMB	-16.344	23.703	0.178	0.259	1.110	3.995	0.264	0.511	0.459	0.709	-0.002	0.004	18	1.212	0.067	0.926	0.906
4 ARE	-383.990	101.321 ***	0.035	0.453	84.294	29.349 **	0.450	0.963	12.770	3.712 ***	-0.067	0.019 ***	12	1.587	0.132	0.941	0.916
4 EGY	-9.929	18.515	0.003	0.023	-3.859	0.919 ***	1.093	0.661	0.038	0.471	0.000	0.003	22	2.955	0.134	0.965	0.958
4 IRN	-64.096	28.611 **	0.014	0.015	0.542	2.594	1.029	0.752	1.503	0.771 *	-0.008	0.004 *	20	3.400	0.170	0.926	0.907
4 ISR	-5.310	15.243	0.181	0.070 **	-3.095	0.907 ***	0.297	0.577	-0.086	0.393	0.001	0.002	22	2.203	0.100	0.970	0.964
4 JOR	9.418	18.828	0.370	0.167 **	-4.428	0.860 ***	1.033	0.599 *	-0.427	0.466	0.002	0.003	22	2.419	0.110	0.972	0.965
4 KWT	-60.274	24.776 **	0.817	0.430 *	-1.825	1.010 *	1.689	0.734 **	1.208	0.627 *	-0.007	0.004 *	22	3.623	0.165	0.960	0.951
4 OMN	-299.709	84.159 ***	0.873	0.377 **	53.948	22.584 **	-0.002	0.799	9.536	2.993 ***	-0.051	0.016 ***	13	1.364	0.105	0.956	0.939
4 QAT	-331.741	86.683 ***	-0.083	0.373	75.956	26.460 **	0.227	0.750	11.131	3.245 ***	-0.058	0.017 ***	12	1.022	0.085	0.949	0.928
4 SYR	2.026	17.700	0.773	0.373 *	-4.301	0.904 ***	1.265	0.648 *	-0.265	0.454	0.001	0.003	22	2.817	0.128	0.965	0.958
4 YEM	-2.359	19.395	0.509	0.273 *	-3.980	1.096 ***	1.598	0.735 **	-0.125	0.501	0.001	0.003	22	3.585	0.163	0.958	0.948
5 BGD	-275.767	164.438	-0.919	0.728	35.073	41.875	-1.380	1.544	7.814	5.640	-0.041	0.029	12	2.956	0.246	0.748	0.643
5 CYP	-146.459	58.949 **	0.285	0.322	39.496	17.716 **	-0.826	0.595	5.247	2.203 **	-0.027	0.012 **	14	0.730	0.052	0.959	0.945
5 LKA	-109.895	54.785 *	0.025	0.088	8.036	6.063	0.162	0.872	2.893	1.537 *	-0.016	0.008 *	18	4.034	0.224	0.867	0.830
5 PAK	-70.338	41.793	-0.003	0.080	0.993	2.774	0.730	1.125	1.664	1.087	-0.009	0.006	20	4.463	0.223	0.915	0.893
5 PHL	-111.346	29.996 ***	0.536	0.351	2.066	2.590	1.988	0.795 **	2.771	0.817 ***	-0.016	0.005 ***	20	3.806	0.190	0.906	0.883
5 SGP	-114.065	43.774 **	-1.236	1.431	5.817	6.248	0.265	0.865	2.701	1.319 *	-0.014	0.008	18	3.920	0.218	0.871	0.835
5 VNM	-54.121	31.699	0.001	0.001	-1.096	3.447	1.309	0.730 *	1.198	0.890	-0.006	0.005	19	3.043	0.160	0.901	0.874
6 FJI	-512.197	175.912 **	0.117	0.161	143.099	63.641 *	-0.066	0.668	18.633	7.055 **	-0.097	0.036 **	9	0.560	0.062	0.928	0.887
6 NZL	-237.047	63.536 ***	1.329	0.645 *	6.379	5.554	2.912	1.699	6.113	1.728 ***	-0.037	0.010 ***	20	16.913	0.846	0.688	0.610
6 PNG	-2398.29	658.466 **	-0.017	0.603	1287.78	470.917 **	-2.546	1.548	117.17	37.586 **	-0.590	0.186 **	5	1.001	0.200	0.888	0.776

Table L.4: Continued.

Country	α	S. Err	β	S. Err	γ	S. Err	ε	S. Err	φ	S. Err	ψ	S. Err	DFE	SSE	MSE	R^2	AdjR^2
7 AUT	14.266	17.361	-0.411	0.615	-4.602	0.973 ***	0.601	0.648	-0.646	0.457	0.005	0.003 *	22	2.840	0.129	0.969	0.962
7 BEL	18.848	17.832	0.089	0.100	-4.804	0.883 ***	0.711	0.633	-0.806	0.461 *	0.005	0.003 *	22	2.685	0.122	0.972	0.966
7 CHE	8.675	17.207	-1.434	0.896	-5.503	1.058 ***	1.084	0.670	-0.514	0.450	0.004	0.003 *	22	2.847	0.129	0.971	0.964
7 DNK	0.670	19.242	-0.244	0.157	-4.088	0.998 ***	0.175	0.655	-0.328	0.500	0.003	0.003	22	2.520	0.115	0.972	0.966
7 FIN	-85.867	48.226 *	-0.093	0.376	25.098	10.311 **	-0.782	0.665	3.044	1.595 *	-0.014	0.009	15	1.338	0.089	0.958	0.944
7 GRC	-22.353	22.297	-0.370	0.195 *	-3.723	0.930 ***	0.282	0.652	0.270	0.569	-0.001	0.003	22	2.519	0.115	0.973	0.967
7 IRL	32.173	16.204 *	0.318	0.144 **	-5.707	0.875 ***	0.694	0.554	-1.128	0.416 **	0.007	0.002 ***	22	2.024	0.092	0.979	0.974
7 ISL	-28.795	42.746	0.716	0.304 **	9.638	9.288	-0.482	0.519	1.072	1.408	-0.005	0.007	15	0.814	0.054	0.967	0.957
7 MLT	-27.574	196.064	1.050	0.269 **	270.064	208.100	1.172	0.581	13.646	14.234	-0.062	0.069	3	0.022	0.007	0.991	0.976
7 NLD	-4.919	24.857	-0.195	0.196	-4.086	1.033 ***	0.797	0.642	-0.207	0.632	0.002	0.004	22	2.660	0.121	0.972	0.966
7 PRT	16.107	16.963	-0.055	0.265	-4.790	0.901 ***	0.490	0.605	-0.720	0.427	0.005	0.002 *	22	2.471	0.112	0.974	0.968
8 YUG	31.409	22.231	0.447	0.187 **	-3.681	2.610	0.266	0.401	-0.979	0.636	0.006	0.003 *	18	0.856	0.048	0.970	0.961
9 ARG	2.692	19.264	0.017	0.690	-4.189	1.021 ***	0.848	0.705	-0.255	0.488	0.002	0.003	22	3.358	0.153	0.955	0.945
9 BOL	-145.201	50.176 **	-0.230	0.125 *	30.060	11.537 **	-0.602	0.551	4.733	1.684 **	-0.024	0.009 **	14	0.706	0.050	0.940	0.919
9 CHL	53.054	33.486	-0.519	0.160 ***	-8.932	2.076 ***	0.474	0.973	-1.732	0.895 *	0.011	0.005 *	22	6.187	0.281	0.930	0.914
9 COL	-20.023	24.698	-0.417	0.321	-3.479	1.164 ***	0.976	0.768	0.253	0.619	-0.001	0.003	22	3.927	0.179	0.949	0.937
9 ECU	34.692	30.818	0.053	0.188	-6.034	3.639	0.203	0.572	-1.136	0.875	0.007	0.005	18	1.498	0.083	0.918	0.895
9 PER	41.401	32.995	0.110	0.609	-8.898	2.566 ***	0.607	0.971	-1.389	0.913	0.008	0.005	21	5.979	0.285	0.918	0.898
9 PRY	-190.274	79.095 **	0.297	0.247	58.883	25.145 **	-0.043	0.643	7.185	2.994 **	-0.037	0.016 **	11	0.549	0.050	0.937	0.909
9 URY	131.268	195.581	0.040	0.237	-120.391	121.953	-0.124	0.567	-8.848	10.306	0.044	0.051	6	0.188	0.031	0.922	0.857
9 VEN	2.714	26.361	-0.097	0.325	-4.238	0.995 ***	0.771	0.647	-0.289	0.670	0.002	0.004	22	2.667	0.121	0.963	0.955
10 BHS	-434.132	523.502	0.871	0.867	513.157	577.930	-0.409	1.296	34.715	39.474	-0.167	0.190	3	0.171	0.057	0.823	0.528
10 BRB	-72.371	26.371 **	-0.426	0.141 ***	7.667	4.699	0.275	0.418	1.796	0.817 **	-0.009	0.004 *	16	0.653	0.041	0.954	0.940
10 CRI	-10.628	28.093	-0.041	0.072	0.518	4.417	0.057	0.502	0.185	0.843	0.000	0.005	17	1.189	0.070	0.912	0.886
10 GTM	101.193	24.245 ***	0.085	0.170	-8.928	3.241 **	-0.821	0.558	-2.892	0.678 ***	0.017	0.004 ***	19	1.762	0.093	0.925	0.905
10 HND	181.420	167.761	0.079	0.269	-119.371	91.480	-0.313	0.611	-9.934	8.191	0.050	0.041	8	0.408	0.051	0.908	0.850
10 JAM	30.854	24.380	-0.173	0.408	-7.315	2.381 ***	0.427	0.535	-1.177	0.684	0.007	0.004 *	19	1.621	0.085	0.934	0.916
10 NIC	36.449	23.390	-0.003	0.031	-7.539	2.441 ***	0.410	0.537	-1.267	0.652 *	0.008	0.004 *	19	1.636	0.086	0.933	0.916
10 PAN	31.797	15.781 *	-0.483	0.296	-12.432	3.213 ***	0.273	0.496	-1.404	0.422 ***	0.008	0.002 ***	20	1.440	0.072	0.967	0.959
10 SLV	-98.277	60.026	0.612	0.187 ***	44.208	19.839 **	-0.619	0.467	4.281	2.307 *	-0.021	0.012	11	0.343	0.031	0.953	0.931
10 TTO	30.826	32.679	0.696	0.463	-2.514	2.954	1.711	0.909 *	-1.001	0.883	0.006	0.005	18	1.222	0.068	0.938	0.920

Appendix M : Stock adjustment analysis

Table M.1: Stock adjustment pooled results, fixed λ (equation 5.14); first traffic demand predicted results (equation 5.6); All manufacturers price indices, model 3 (table 3.3).

SSE	279.4161		MSE	0.1291		R^2	0.2475		Adj R^2	0.2080	
Variable	Estimate	Std Err	Variable	Estimate	Std Err	Variable	Estimate	Std Err	Variable	Estimate	Std Err
a_0	16.9807	2.5471 ***	3 DBEN	-0.3235	0.1888 *	3 DZWE	-0.0355	0.2134	7 DGRC	-0.1341	0.1360
a_1	0.0022	0.0015	3 DBFA	-0.0300	0.1460	4 DARE	-0.5011	0.1515 ***	7 DIRL	-0.6063	0.1445 ***
a_2	-2.0012	0.2226 ***	3 DCAF	0.2062	0.1391	4 DBHR	-1.9672	0.2221 ***	7 DISL	-0.2907	0.1437 **
a_3	-0.3635	0.0655 ***	3 DCIV	0.0215	0.1362	4 DDJI	-1.1957	0.1920 ***	7 DMLT	-2.0195	0.2219 ***
a_4	-0.4898	0.0686 ***	3 DCOG	0.0433	0.1454	4 DEGY	0.4061	0.1330 ***	7 DNLD	-0.4771	0.1417 ***
a_5	0.0028	0.0004 ***	3 DDZA	0.6710	0.1344 ***	4 DIRN	0.2343	0.1344 *	7 DPRT	-0.2564	0.1378 *
a_6	-0.2882	0.0168 ***	3 DETH	0.4201	0.1331 ***	4 DISR	-0.7544	0.1471 ***	8 DPOL	0.2629	0.2791
1 DCAN	1.1529	0.1406 ***	3 DGAB	-0.0355	0.1382	4 DJOR	-0.2888	0.1378 **	8 DROM	0.1480	0.2369
1 DDEU	0.2132	0.1335	3 DGHA	-0.0666	0.1385	4 DKWT	-0.6512	0.1444 ***	8 DYUG	0.0300	0.1371
1 DESP	0.2333	0.1332 *	3 DGIN	-0.0574	0.1529	4 DLBN	-0.9620	0.1563 ***	9 DARG	0.5868	0.1338 ***
1 DFRA	0.3104	0.1332 **	3 DKEN	0.2283	0.1338 *	4 DOMN	-0.2449	0.1457 *	9 DBOL	0.2727	0.1401 *
1 DGBR	0.0209	0.1345	3 DLBR	-1.9614	0.2241 ***	4 DQAT	-1.0306	0.1636 ***	9 DCHL	0.1812	0.1332
1 DITA	0.1671	0.1337	3 DLBY	0.5831	0.1338 ***	4 DSYR	-0.1065	0.1354	9 DCOL	0.3252	0.1329 **
1 DJPN	0.5135	0.1345 ***	3 DMAR	0.1910	0.1332	4 DYEM	0.0830	0.1337	9 DECU	-0.0958	0.1380
1 DLUX	-1.2356	0.1640 ***	3 DMDG	0.1248	0.1372	5 DBGD	-0.5470	0.1517 ***	9 DPER	0.3528	0.1336 ***
1 DNOR	0.0260	0.1344	3 DMRT	0.3882	0.1370 ***	5 DCYP	0.3151	0.1401 **	9 DPRY	-0.0152	0.1457
1 DSWE	0.1404	0.1336	3 DMUS	0.2495	0.1767	5 DLKA	-0.8017	0.1504 ***	9 DURY	-0.1770	0.1597
1 DUSA	1.4231	0.1456 ***	3 DNER	0.4701	0.1509 ***	5 DNPL	-0.7102	0.2211 ***	9 DVEN	0.2821	0.1330 **
2 DAUS	1.1258	0.1431 ***	3 DNGA	0.3623	0.1330 ***	5 DPAK	-0.0465	0.1360	10 DBHS	-1.0339	0.1874 ***
2 DBRA	0.9895	0.1382 ***	3 DRWA	-0.8076	0.1881 ***	5 DPHL	0.1234	0.1345	10 DBRB	-1.9912	0.1911 ***
2 DHKG	-2.2754	0.3144 ***	3 DSEN	-0.1386	0.1384	5 DSGP	-2.1718	0.1980 ***	10 DCRI	-0.6248	0.1467 ***
2 DIDN	0.7650	0.1370 ***	3 DSWZ	-0.9368	0.2099 ***	5 DVNM	-0.1027	0.1459	10 DGTM	-0.5481	0.1440 ***
2 DIND	0.4834	0.1362 ***	3 DTCD	0.4331	0.1447 ***	6 DFJI	-0.6832	0.1569 ***	10 DHND	-0.3525	0.1567 **
2 DKOR	-0.1990	0.1366	3 DTGO	-0.5232	0.1914 ***	6 DNZL	-0.1104	0.1348	10 DJAM	-1.0346	0.1563 ***
2 DMEX	0.4662	0.1339 ***	3 DTUN	-0.0977	0.1354	7 DAUT	-0.2775	0.1381 **	10 DNIC	-0.2765	0.1395 **
2 DMYS	0.1383	0.1344	3 DTZA	0.3682	0.1336 ***	7 DBEL	-0.5628	0.1435 ***	10 DPAN	-0.5021	0.1421 ***
2 DSAU	0.5708	0.1337 ***	3 DUGA	-0.0462	0.1361	7 DCHE	-0.4653	0.1415 ***	10 DSLV	-0.9319	0.1617 ***
2 DTHA	-0.2098	0.1392	3 DZAF	0.4189	0.1331 ***	7 DDNK	-0.4727	0.1415 ***	10 DTTO	-1.2488	0.1630 ***
2 DTUR	0.3552	0.1343 ***	3 DZMB	0.2504	0.1360 *	7 DFIN	-0.0532	0.1410			

Table M.2: Stock adjustment pooled results, fixed λ (equation 5.14); first traffic demand predicted results (equation 5.6); North American manufacturers price indices, model 3 (table 3.12);

SSE	283.2638		MSE	0.1308		R^2	0.2369		Adj R^2	0.1969	
Variable	Estimate	Std Err	Variable	Estimate	Std Err	Variable	Estimate	Std Err	Variable	Estimate	Std Err
a_0	9.6730	2.3331 ***	3 DBEN	-0.3506	0.1904 *	3 DZWE	-0.0453	0.2149	7 DGRC	-0.1527	0.1371
a_1	0.0022	0.0015	3 DBFA	-0.0435	0.1470	4 DARE	-0.5300	0.1528 ***	7 DIRL	-0.6416	0.1459 ***
a_2	-1.6288	0.2139 ***	3 DCAF	0.2013	0.1400	4 DBHR	-2.0613	0.2259 ***	7 DISL	-0.3146	0.1449 **
a_3	-0.0099	0.0703	3 DCIV	0.0095	0.1371	4 DDJI	-1.2543	0.1942 ***	7 DMLT	-2.1084	0.2259 ***
a_4	-0.3110	0.0635 ***	3 DCOG	0.0324	0.1464	4 DEGY	0.4074	0.1340 ***	7 DNLD	-0.5078	0.1430 ***
a_5	0.0019	0.0004 ***	3 DDZA	0.6813	0.1354 ***	4 DIRN	0.2312	0.1353 *	7 DPRT	-0.2794	0.1389 **
a_6	-0.2983	0.0174 ***	3 DETH	0.4219	0.1340 ***	4 DISR	-0.7935	0.1487 ***	8 DPOL	0.2444	0.2810
1 DCAN	1.1788	0.1421 ***	3 DGAB	-0.0504	0.1392	4 DJOR	-0.3119	0.1389 **	8 DROM	0.1332	0.2386
1 DDEU	0.2055	0.1345	3 DGHA	-0.0827	0.1395	4 DKWT	-0.6864	0.1459 ***	8 DYUG	0.0168	0.1381
1 DESP	0.2275	0.1342 *	3 DGIN	-0.0771	0.1540	4 DLBN	-1.0075	0.1581 ***	9 DARG	0.5947	0.1349 ***
1 DFRA	0.3067	0.1341 **	3 DKEN	0.2235	0.1347 *	4 DOMN	-0.2615	0.1468 *	9 DBOL	0.2725	0.1411 *
1 DGBR	0.0077	0.1355	3 DLBR	-2.0524	0.2282 ***	4 DQAT	-1.0773	0.1656 ***	9 DCHL	0.1748	0.1341
1 DITA	0.1576	0.1347	3 DLBY	0.5904	0.1348 ***	4 DSYR	-0.1232	0.1364	9 DCOL	0.3238	0.1339 **
1 DJPN	0.5158	0.1355 ***	3 DMAR	0.1846	0.1342	4 DYEM	0.0732	0.1346	9 DECU	-0.1130	0.1391
1 DLUX	-1.2932	0.1664 ***	3 DMDG	0.1158	0.1381	5 DBGD	-0.5765	0.1531 ***	9 DPER	0.3523	0.1346 ***
1 DNOR	0.0129	0.1354	3 DMRT	0.3877	0.1380 ***	5 DCYP	0.3150	0.1411 **	9 DPRY	-0.0278	0.1468
1 DSWE	0.1312	0.1346	3 DMUS	0.2343	0.1779	5 DLKA	-0.8431	0.1520 ***	9 DURY	-0.1994	0.1610
1 DUSA	1.4571	0.1473 ***	3 DNER	0.4690	0.1519 ***	5 DNPL	-0.7438	0.2229 ***	9 DVEN	0.2792	0.1339 **
2 DAUS	1.1544	0.1446 ***	3 DNGA	0.3620	0.1339 ***	5 DPAK	-0.0600	0.1370	10 DBHS	-1.0845	0.1896 ***
2 DBRA	1.0108	0.1396 ***	3 DRWA	-0.8599	0.1901 ***	5 DPHL	0.1188	0.1354	10 DBRB	-2.0738	0.1946 ***
2 DHKG	-2.3668	0.3175 ***	3 DSEN	-0.1572	0.1395	5 DSGP	-2.2610	0.2019 ***	10 DCRI	-0.6601	0.1481 ***
2 DIDN	0.7803	0.1382 ***	3 DSWZ	-0.9727	0.2121 ***	5 DVNM	-0.1166	0.1470	10 DGTM	-0.5798	0.1454 ***
2 DIND	0.4854	0.1372 ***	3 DTCD	0.4358	0.1458 ***	6 DFJI	-0.7197	0.1584 ***	10 DHND	-0.3826	0.1580 **
2 DKOR	-0.2148	0.1377	3 DTGO	-0.5573	0.1931 ***	6 DNZL	-0.1177	0.1357	10 DJAM	-1.0835	0.1583 ***
2 DMEX	0.4687	0.1348 ***	3 DTUN	-0.1143	0.1364	7 DAUT	-0.3011	0.1392 **	10 DNIC	-0.2991	0.1407 **
2 DMYS	0.1342	0.1354	3 DTZA	0.3683	0.1346 ***	7 DBEL	-0.5964	0.1449 ***	10 DPAN	-0.5312	0.1434 ***
2 DSAU	0.5778	0.1347 ***	3 DUGA	-0.0602	0.1371	7 DCHE	-0.4955	0.1428 ***	10 DSLV	-0.9766	0.1635 ***
2 DTHA	-0.2305	0.1402	3 DZAF	0.4209	0.1341 ***	7 DDNK	-0.5032	0.1429 ***	10 DTTO	-1.3057	0.1653 ***
2 DTUR	0.3540	0.1353 ***	3 DZMB	0.2462	0.1369 *	7 DFIN	-0.0693	0.1420			

Table M.3: Stock adjustment pooled results, fixed λ (equation 5.14); second traffic demand predicted results (equation 5.7); All manufacturers price indices, model 3 (table 3.3).

SSE	281.2415		MSE	0.1284		R^2	0.2449		Adj R^2	0.2052	
Variable	Estimate	Std Err	Variable	Estimate	Std Err	Variable	Estimate	Std Err	Variable	Estimate	Std Err
a_0	16.7744	2.5720 ***	3 DBEN	-0.3216	0.1894 *	3 DZWE	-0.0322	0.2140	7 DIRL	-0.5981	0.1449 ***
a_1	0.0009	0.0008	3 DBFA	-0.0304	0.1464	4 DARE	-0.4930	0.1519 ***	7 DISL	-0.2867	0.1441 **
a_2	-1.9772	0.2250 ***	3 DCAF	0.2042	0.1394	4 DBHR	-1.9511	0.2229 ***	7 DMLT	-2.0044	0.2227 ***
a_3	-0.3605	0.0660 ***	3 DCIV	0.0232	0.1365	4 DDJI	-1.1895	0.1926 ***	7 DNLD	-0.4692	0.1421 ***
a_4	-0.4839	0.0692 ***	3 DCOG	0.0428	0.1458	4 DEGY	0.4137	0.1335 ***	7 DPRT	-0.2501	0.1381 *
a_5	0.0028	0.0004 ***	3 DDZA	0.6731	0.1348 ***	4 DIRN	0.2327	0.1348 *	8 DPOL	0.2692	0.2798
a_6	-0.2865	0.0169 ***	3 DETH	0.4177	0.1334 ***	4 DISR	-0.7454	0.1475 ***	8 DROM	0.1515	0.2376
1 DCAN	1.1527	0.1410 ***	3 DGAB	-0.0340	0.1386	4 DJOR	-0.2847	0.1382 **	8 DYUG	0.0340	0.1374
1 DDEU	0.2216	0.1337 *	3 DGHA	-0.0656	0.1388	4 DKWT	-0.6427	0.1448 ***	9 DARG	0.5870	0.1342 ***
1 DESP	0.2383	0.1335 *	3 DGIN	-0.0564	0.1533	4 DOMN	-0.2417	0.1461 *	9 DBOL	0.2724	0.1405 *
1 DFRA	0.3174	0.1334 **	3 DKEN	0.2297	0.1342 *	4 DQAT	-1.0212	0.1642 ***	9 DCHL	0.1827	0.1336
1 DGBR	0.0314	0.1347	3 DLBR	-1.9475	0.2250 ***	4 DSYR	-0.1039	0.1358	9 DCOL	0.3258	0.1333 **
1 DITA	0.1728	0.1340	3 DLBY	0.5832	0.1341 ***	4 DYEM	0.0862	0.1341	9 DECU	-0.0934	0.1384
1 DJPN	0.5170	0.1348 ***	3 DMAR	0.1930	0.1336	5 DBGD	-0.5436	0.1522 ***	9 DPER	0.3528	0.1340 ***
1 DLUX	-1.2233	0.1646 ***	3 DMDG	0.1243	0.1375	5 DCYP	0.3161	0.1405 **	9 DPRY	-0.0141	0.1461
1 DNOR	0.0309	0.1347	3 DMRT	0.3849	0.1373 ***	5 DLKA	-0.7956	0.1508 ***	9 DURY	-0.1733	0.1602
1 DSWE	0.1462	0.1340	3 DMUS	0.2492	0.1771	5 DNPL	-0.7040	0.2218 ***	9 DVEN	0.2840	0.1333 **
1 DUSA	1.4230	0.1460 ***	3 DNER	0.4714	0.1513 ***	5 DPAK	-0.0392	0.1364	10 DBHS	-1.0245	0.1879 ***
2 DAUS	1.1233	0.1435 ***	3 DNGA	0.3640	0.1333 ***	5 DPHL	0.1251	0.1349	10 DBRB	-1.9758	0.1918 ***
2 DBRA	0.9878	0.1387 ***	3 DRWA	-0.8034	0.1887 ***	5 DSGP	-2.1538	0.1987 ***	10 DCRI	-0.6185	0.1472 ***
2 DHKG	-2.2541	0.3153 ***	3 DSEN	-0.1363	0.1388	5 DVNM	-0.0527	0.1386	10 DGTM	-0.5419	0.1444 ***
2 DIDN	0.7626	0.1374 ***	3 DSWZ	-0.9292	0.2106 ***	6 DFJI	-0.6791	0.1574 ***	10 DHND	-0.3477	0.1571 **
2 DIND	0.4836	0.1366 ***	3 DTCD	0.4287	0.1451 ***	6 DNZL	-0.1074	0.1351	10 DJAM	-1.0243	0.1568 ***
2 DKOR	-0.1943	0.1370	3 DTGO	-0.5190	0.1920 ***	7 DAUT	-0.2697	0.1384 *	10 DNIC	-0.2752	0.1399 **
2 DMEX	0.4648	0.1342 ***	3 DTUN	-0.0933	0.1357	7 DBEL	-0.5528	0.1439 ***	10 DPAN	-0.4963	0.1425 ***
2 DMYS	0.1390	0.1348	3 DTZA	0.3677	0.1340 ***	7 DCHE	-0.4551	0.1418 ***	10 DSLV	-0.9237	0.1622 ***
2 DSAU	0.5697	0.1341 ***	3 DUGA	-0.0441	0.1365	7 DDNK	-0.4644	0.1419 ***	10 DTTO	-1.2386	0.1636 ***
2 DTHA	-0.2102	0.1396	3 DZAF	0.4229	0.1334 ***	7 DFIN	-0.0480	0.1413			
2 DTUR	0.3564	0.1347 ***	3 DZMB	0.2497	0.1363 *	7 DGRC	-0.1284	0.1364			

Table M.4: Stock adjustment pooled results, fixed λ (equation 5.14); second traffic demand predicted results (equation 5.7); North American manufacturers price indices, model 3 (table 3.12).

SSE	285.1951		MSE	0.1302		R^2	0.2345		Adj R^2	0.1942	
Variable	Estimate	Std Err	Variable	Estimate	Std Err	Variable	Estimate	Std Err	Variable	Estimate	Std Err
a_0	9.5013	2.3549 ***	3 DBEN	-0.3482	0.1909 *	3 DZWE	-0.0418	0.2154	7 DIRL	-0.6326	0.1463 ***
a_1	0.0010	0.0008	3 DBFA	-0.0436	0.1474	4 DARE	-0.5213	0.1532 ***	7 DISL	-0.3101	0.1453 **
a_2	-1.6056	0.2160 ***	3 DCAF	0.1994	0.1404	4 DBHR	-2.0434	0.2266 ***	7 DMLT	-2.0915	0.2267 ***
a_3	-0.0085	0.0709	3 DCIV	0.0114	0.1375	4 DDJI	-1.2470	0.1948 ***	7 DNLD	-0.4992	0.1434 ***
a_4	-0.3058	0.0641 ***	3 DCOG	0.0322	0.1468	4 DEGY	0.4152	0.1344 ***	7 DPRT	-0.2726	0.1393 *
a_5	0.0019	0.0004 ***	3 DDZA	0.6832	0.1358 ***	4 DIRN	0.2296	0.1358 *	8 DPOL	0.2512	0.2817
a_6	-0.2963	0.0174 ***	3 DETH	0.4195	0.1344 ***	4 DISR	-0.7836	0.1491 ***	8 DROM	0.1371	0.2392
1 DCAN	1.1781	0.1425 ***	3 DGAB	-0.0487	0.1395	4 DJOR	-0.3072	0.1393 **	8 DYUG	0.0210	0.1384
1 DDEU	0.2142	0.1347	3 DGHA	-0.0813	0.1398	4 DKWT	-0.6772	0.1463 ***	9 DARG	0.5947	0.1352 ***
1 DESP	0.2325	0.1344 *	3 DGIN	-0.0757	0.1544	4 DOMN	-0.2579	0.1472 *	9 DBOL	0.2722	0.1415 *
1 DFRA	0.3138	0.1343 **	3 DKEN	0.2251	0.1351 *	4 DQAT	-1.0669	0.1661 ***	9 DCHL	0.1765	0.1345
1 DGBR	0.0186	0.1357	3 DLBR	-2.0365	0.2291 ***	4 DSYR	-0.1202	0.1368	9 DCOL	0.3244	0.1342 **
1 DITA	0.1635	0.1350	3 DLBY	0.5904	0.1351 ***	4 DYEM	0.0767	0.1350	9 DECU	-0.1102	0.1394
1 DJPN	0.5192	0.1358 ***	3 DMAR	0.1867	0.1345	5 DBGD	-0.5723	0.1535 ***	9 DPER	0.3524	0.1349 ***
1 DLUX	-1.2797	0.1669 ***	3 DMDG	0.1154	0.1385	5 DCYP	0.3161	0.1415 **	9 DPRY	-0.0265	0.1472
1 DNOR	0.0182	0.1357	3 DMRT	0.3843	0.1383 ***	5 DLKA	-0.8361	0.1525 ***	9 DURY	-0.1953	0.1614
1 DSWE	0.1372	0.1349	3 DMUS	0.2341	0.1783	5 DNPL	-0.7367	0.2236 ***	9 DVEN	0.2812	0.1343 **
1 DUSA	1.4562	0.1477 ***	3 DNER	0.4703	0.1523 ***	5 DPAK	-0.0523	0.1373	10 DBHS	-1.0741	0.1901 ***
2 DAUS	1.1514	0.1450 ***	3 DNGA	0.3637	0.1342 ***	5 DPHL	0.1206	0.1358	10 DBRB	-2.0566	0.1953 ***
2 DBRA	1.0086	0.1400 ***	3 DRWA	-0.8547	0.1907 ***	5 DSGP	-2.2410	0.2026 ***	10 DCRI	-0.6530	0.1486 ***
2 DHKG	-2.3434	0.3184 ***	3 DSEN	-0.1545	0.1399	5 DVNM	-0.0660	0.1396	10 DGTM	-0.5729	0.1458 ***
2 DIDN	0.7776	0.1385 ***	3 DSWZ	-0.9641	0.2127 ***	6 DFJI	-0.7148	0.1588 ***	10 DHND	-0.3772	0.1585 **
2 DIND	0.4856	0.1375 ***	3 DTCD	0.4314	0.1461 ***	6 DNZL	-0.1146	0.1361	10 DJAM	-1.0722	0.1587 ***
2 DKOR	-0.2097	0.1380	3 DTGO	-0.5525	0.1937 ***	7 DAUT	-0.2928	0.1395 **	10 DNIC	-0.2973	0.1410 **
2 DMEX	0.4672	0.1352 ***	3 DTUN	-0.1096	0.1368	7 DBEL	-0.5857	0.1453 ***	10 DPAN	-0.5248	0.1438 ***
2 DMYS	0.1350	0.1357	3 DTZA	0.3678	0.1349 ***	7 DCHE	-0.4847	0.1431 ***	10 DSLV	-0.9674	0.1640 ***
2 DSAU	0.5765	0.1350 ***	3 DUGA	-0.0578	0.1375	7 DDNK	-0.4942	0.1432 ***	10 DTTO	-1.2942	0.1659 ***
2 DTHA	-0.2305	0.1406	3 DZAF	0.4249	0.1344 ***	7 DFIN	-0.0637	0.1423			
2 DTUR	0.3553	0.1356 ***	3 DZMB	0.2455	0.1373 *	7 DGRC	-0.1466	0.1374			

Table M.5: Stock adjustment results, fixed λ (equation 5.14); first traffic demand predicted results (equation 5.6); All manufacturers price index, model 3 (table 3.3).

	Country	a_0	Std Err	a_1	Std Err	a_2	Std Err	a_3	Std Err	a_4	Std Err	a_5	Std Err	a_6	Std Err	SSE	MSE	R^2	Adj R^2
1	CAN	8.785	54.238	-0.290	0.552	-6.910	2.666	0.270	0.985	-0.467	1.390	0.0028	0.0083	-0.665	0.168	6.2974	0.3149	0.5508	0.4160
1	DEU	90.872	16.966	0.306	0.199	-8.042	1.542	-0.640	0.393	-2.594	0.476	0.0151	0.0028	-0.610	0.141	1.0139	0.0507	0.7201	0.6361
1	ESP	35.590	16.086	0.577	0.245	-5.594	1.315	-0.725	0.339	-1.107	0.441	0.0061	0.0027	-0.658	0.126	0.6951	0.0348	0.7643	0.6936
1	FRA	64.550	16.880	0.274	0.168	-6.927	1.515	-0.634	0.392	-1.888	0.468	0.0109	0.0028	-0.561	0.160	1.0255	0.0513	0.6909	0.5982
1	GBR	55.333	14.283	-0.112	0.126	-6.651	1.363	-0.522	0.362	-1.664	0.393	0.0100	0.0022	-0.756	0.144	0.8593	0.0430	0.7086	0.6212
1	ITA	96.907	22.445	-0.100	0.281	-8.720	2.015	-0.304	0.533	-2.797	0.625	0.0169	0.0036	-0.786	0.157	1.8620	0.0931	0.6392	0.5310
1	JPN	93.593	58.476	0.659	0.590	-8.750	5.081	0.019	0.862	-2.750	1.641	0.0164	0.0099	-0.858	0.254	4.2376	0.2354	0.5116	0.3488
1	LUX	-2.717	25.671	0.069	0.281	2.040	3.255	-0.341	0.410	0.063	0.763	0.0003	0.0043	-0.480	0.215	0.8666	0.0510	0.5110	0.3384
1	NOR	78.743	12.213	0.244	0.131	-7.606	1.165	-0.571	0.280	-2.274	0.341	0.0133	0.0020	-0.750	0.122	0.5196	0.0260	0.7906	0.7278
1	SWE	80.611	14.930	0.138	0.121	-7.093	1.365	-0.653	0.329	-2.288	0.417	0.0135	0.0024	-0.682	0.140	0.7254	0.0363	0.7208	0.6371
1	USA	-33.558	37.895	-0.363	0.260	-4.193	1.892	-1.046	0.752	0.681	0.971	-0.0036	0.0056	-0.689	0.207	3.2554	0.1628	0.5974	0.4767
2	AUS	-32.281	36.171	0.420	0.318	1.893	3.486	0.059	0.735	0.914	0.992	-0.0052	0.0055	-0.615	0.263	2.8169	0.1565	0.3693	0.1591
2	BRA	28.714	22.719	0.398	0.367	-3.639	1.787	-0.195	0.567	-0.823	0.612	0.0047	0.0037	-0.479	0.173	1.8566	0.0928	0.4793	0.3231
2	IDN	-37.367	32.152	-0.217	0.201	0.937	3.472	0.383	0.656	0.903	0.894	-0.0046	0.0050	-0.396	0.218	2.4259	0.1348	0.3395	0.1193
2	IND	-31.947	59.117	-0.558	0.278	6.316	7.235	0.235	0.697	0.927	1.707	-0.0037	0.0095	-0.310	0.199	2.4646	0.1540	0.4076	0.1854
2	KOR	-74.796	50.145	-0.029	0.437	5.104	4.466	0.112	0.865	2.032	1.379	-0.0115	0.0079	-0.338	0.285	3.9761	0.2209	0.3742	0.1656
2	MEX	37.487	44.128	0.118	0.077	-2.945	3.003	-1.400	1.128	-0.953	1.182	0.0051	0.0069	-0.198	0.180	7.5801	0.3990	0.2677	0.0364
2	MYS	-98.955	43.331	0.451	0.250	9.478	4.618	-0.118	0.776	2.895	1.234	-0.0169	0.0070	-0.417	0.287	3.2258	0.1792	0.4555	0.2740
2	SAU	22.185	21.669	-0.089	0.074	-3.539	1.891	-0.701	0.659	-0.672	0.577	0.0039	0.0033	-0.297	0.181	2.2240	0.1112	0.4345	0.2649
2	THA	-13.782	71.137	0.099	0.072	-3.156	9.318	0.216	0.769	0.206	2.063	-0.0014	0.0112	-0.553	0.219	2.8575	0.1786	0.3621	0.1229
2	TUR	-5.140	24.823	0.150	0.157	2.190	2.866	-0.224	0.383	0.234	0.698	-0.0011	0.0038	-0.282	0.132	0.7065	0.0393	0.6929	0.5905
3	BFA	-75.381	99.447	0.297	0.172	12.847	35.803	-0.319	0.474	2.375	3.965	-0.0125	0.0203	-0.818	0.284	0.4127	0.0459	0.5712	0.2853
3	CAF	-37.574	59.211	-0.692	1.092	6.460	13.068	-0.383	0.454	1.170	1.999	-0.0060	0.0107	-0.468	0.251	0.6228	0.0479	0.3341	0.0268
3	CIV	-0.561	21.371	-0.218	0.142	-1.010	2.830	-0.477	0.345	-0.050	0.622	0.0007	0.0035	-0.643	0.204	0.6023	0.0354	0.6006	0.4596
3	COG	-75.929	126.055	0.051	0.203	11.588	44.678	-0.134	0.527	2.307	5.014	-0.0122	0.0258	-0.646	0.352	0.5184	0.0576	0.3918	-0.0137
3	DZA	34.955	21.188	0.060	0.208	-4.298	1.796	-0.438	0.564	-1.003	0.573	0.0058	0.0033	-0.546	0.220	1.6821	0.0841	0.5348	0.3953
3	ETH	33.922	15.232	-0.143	0.079	-5.236	1.390	-0.324	0.439	-1.040	0.403	0.0060	0.0023	-0.481	0.153	1.1874	0.0594	0.6566	0.5536
3	GAB	-37.731	28.845	0.025	0.163	7.239	4.775	-0.336	0.413	1.210	0.882	-0.0061	0.0048	-0.624	0.220	0.6915	0.0461	0.3982	0.1574
3	GHA	-39.347	28.174	0.010	0.175	7.338	4.853	-0.341	0.474	1.250	0.862	-0.0064	0.0047	-0.633	0.285	0.6930	0.0462	0.3980	0.1572
3	GIN	160.960	144.686	-0.263	0.197	-111.523	83.120	-0.771	0.395	-9.143	7.255	0.0464	0.0364	-1.286	0.343	0.1376	0.0229	0.8085	0.6170
3	KEN	14.916	20.061	0.080	0.085	-2.125	2.999	-0.286	0.389	-0.427	0.587	0.0024	0.0032	-0.325	0.167	0.8901	0.0469	0.7381	0.6554

Table M.5: Continued.

	Country	a_0	Std Err	a_1	Std Err	a_2	Std Err	a_3	Std Err	a_4	Std Err	a_5	Std Err	a_6	Std Err	SSE	MSE	R^2	Adj R^2
3	MAR	44.298	15.938	-0.086	0.120	-6.125	1.594	-0.454	0.456	-1.342	0.435	0.0079	0.0025	-0.633	0.190	1.2483	0.0624	0.6384	0.5299
3	MDG	-69.829	41.001	-0.649	1.314	12.213	7.002	-0.029	0.530	2.184	1.263	-0.0113	0.0068	-0.513	0.212	1.2405	0.0827	0.3146	0.0404
3	MRT	-31.224	29.307	0.189	0.191	6.144	5.213	-0.380	0.453	1.045	0.909	-0.0053	0.0050	-0.689	0.305	0.7475	0.0498	0.4667	0.2534
3	NER	186.247	137.842	-0.049	0.104	-174.749	87.907	-0.387	0.411	-12.623	7.249	0.0619	0.0361	-1.377	0.375	0.1703	0.0284	0.7705	0.5411
3	NGA	32.343	19.348	0.173	0.200	-5.895	1.535	-0.185	0.511	-1.026	0.494	0.0059	0.0029	-0.717	0.184	1.2432	0.0622	0.6453	0.5389
3	SEN	3.531	23.154	-0.369	0.200	-1.735	3.288	-0.629	0.310	-0.213	0.683	0.0019	0.0038	-0.946	0.218	0.4440	0.0278	0.6745	0.5524
3	TCD	-190.728	117.502	-1.187	0.539	74.468	48.959	-0.214	0.424	7.767	4.942	-0.0382	0.0247	-0.722	0.256	0.3271	0.0363	0.5856	0.3093
3	TUN	32.198	15.545	0.673	0.245	-5.085	1.430	-0.489	0.435	-1.004	0.420	0.0055	0.0024	-0.690	0.157	1.1897	0.0595	0.6662	0.5660
3	TZA	3.845	16.836	1.516	1.175	-0.357	2.141	-0.381	0.391	-0.178	0.478	0.0013	0.0027	-0.337	0.164	0.8559	0.0451	0.7482	0.6686
3	ZAF	22.414	18.998	0.239	0.230	-5.076	1.403	-0.170	0.453	-0.739	0.486	0.0041	0.0029	-0.631	0.160	1.2121	0.0606	0.6486	0.5432
3	ZMB	-19.460	25.541	-0.160	0.228	3.185	3.425	-0.281	0.425	0.602	0.750	-0.0029	0.0042	-0.443	0.198	0.7332	0.0458	0.3892	0.1602
4	ARE	-118.793	209.059	1.126	0.659	12.426	61.572	-0.236	0.832	3.297	7.694	-0.0185	0.0396	-0.732	0.266	1.0940	0.1094	0.6157	0.3850
4	EGY	33.496	32.227	-0.037	0.454	-4.380	1.691	-0.422	0.582	-0.981	0.822	0.0057	0.0049	-0.507	0.240	1.6515	0.0826	0.5485	0.4131
4	IRN	-11.228	64.153	-0.336	0.516	-0.491	6.295	0.263	0.689	0.234	1.791	-0.0008	0.0102	-0.561	0.217	2.6685	0.1483	0.3208	0.0944
4	ISR	40.193	16.263	0.289	0.203	-6.010	1.515	-0.217	0.434	-1.249	0.429	0.0069	0.0024	-0.575	0.151	1.1604	0.0580	0.6637	0.5628
4	JOR	33.235	18.878	-0.080	0.149	-4.488	1.641	-0.532	0.582	-1.008	0.500	0.0058	0.0029	-0.457	0.214	1.6310	0.0816	0.5543	0.4206
4	KWT	-23.423	39.376	0.299	0.331	-1.132	1.972	0.064	0.804	0.442	0.986	-0.0024	0.0057	-0.535	0.219	3.3936	0.1697	0.3327	0.1325
4	LBN	52.192	26.744	0.011	0.010	-5.251	1.766	-0.716	0.584	-1.547	0.712	0.0091	0.0042	-0.538	0.175	1.5514	0.0776	0.5760	0.4488
4	OMN	-97.903	142.984	0.591	0.236	9.700	37.518	0.352	0.636	2.798	5.025	-0.0158	0.0260	-0.555	0.217	0.9183	0.0835	0.6872	0.5167
4	QAT	-293.742	131.064	0.613	0.376	74.665	39.372	0.197	0.595	10.266	4.836	-0.0539	0.0250	-0.749	0.267	0.7034	0.0703	0.6137	0.3819
4	SYR	38.667	18.178	0.359	0.211	-5.044	1.671	-0.197	0.527	-1.143	0.487	0.0064	0.0027	-0.530	0.165	1.5996	0.0800	0.5676	0.4378
4	YEM	-32.320	29.603	0.514	0.212	-3.694	1.719	0.086	0.600	0.619	0.732	-0.0040	0.0043	-0.472	0.166	1.9870	0.0994	0.4849	0.3304
5	BGD	32.027	191.577	-0.035	0.411	-25.819	64.067	0.940	1.346	-1.993	7.349	0.0100	0.0377	-0.359	0.280	2.0730	0.2073	0.3357	-0.0629
5	CYP	-50.851	53.144	-0.231	0.227	14.580	14.171	-0.354	0.413	1.833	1.875	-0.0089	0.0098	-0.493	0.242	0.5437	0.0453	0.3537	0.0306
5	LKA	-117.199	71.024	-0.146	0.119	10.235	8.823	0.437	0.760	3.147	2.034	-0.0170	0.0111	-0.633	0.230	2.9198	0.1825	0.3486	0.1043
5	PAK	-38.902	37.060	-0.308	0.109	-2.778	3.827	-0.511	0.747	0.789	1.019	-0.0043	0.0056	-0.925	0.208	2.6595	0.1478	0.5582	0.4109
5	PHL	-68.518	42.760	0.467	0.426	3.651	4.181	0.436	0.885	1.862	1.165	-0.0111	0.0064	-0.311	0.275	3.7299	0.2072	0.4134	0.2179
5	SGP	-70.297	63.292	0.088	0.778	4.134	8.218	0.421	0.807	1.743	1.806	-0.0096	0.0098	-0.549	0.240	3.2136	0.2009	0.2866	0.0191
5	VNM	-83.000	32.666	-0.002	0.003	10.488	3.750	-0.131	0.566	2.464	0.910	-0.0136	0.0050	-0.385	0.211	1.6485	0.0970	0.6170	0.4818
6	FJI	-431.088	316.547	0.242	0.230	136.866	111.933	0.014	0.788	16.476	12.520	-0.0855	0.0642	-1.012	0.449	0.6273	0.0784	0.6476	0.3833
6	NZL	-167.406	105.727	0.201	0.669	13.587	8.358	-0.284	2.116	4.763	2.786	-0.0283	0.0158	0.390	0.653	16.9073	0.9393	0.4469	0.2625
6	PNG	-1999.5	1331.34	0.304	0.843	1153.24	1076.29	-0.378	3.177	101.590	78.185	-0.5093	0.3826	-0.929	2.617	1.4929	0.4976	0.7991	0.3973

Table M.5: Continued.

	Country	a_0	Std Err	a_1	Std Err	a_2	Std Err	a_3	Std Err	a_4	Std Err	a_5	Std Err	a_6	Std Err	SSE	MSE	R^2	Adj R^2
7	AUT	54.067	15.336	-0.035	0.302	-5.991	1.512	-0.421	0.412	-1.604	0.424	0.0095	0.0024	-0.613	0.149	1.1156	0.0558	0.6475	0.5417
7	BEL	51.981	14.594	0.355	0.218	-6.919	1.536	-0.273	0.400	-1.650	0.408	0.0097	0.0023	-0.831	0.186	0.9954	0.0498	0.6753	0.5778
7	CHE	50.011	15.946	0.689	0.382	-5.913	1.520	-0.757	0.461	-1.539	0.442	0.0086	0.0025	-0.615	0.142	1.2010	0.0601	0.6331	0.5230
7	DNK	57.525	14.838	0.091	0.132	-6.416	1.438	-0.363	0.398	-1.715	0.409	0.0100	0.0023	-0.627	0.141	1.0022	0.0501	0.6782	0.5817
7	FIN	-91.080	66.029	-0.696	0.627	25.028	17.340	-0.583	0.529	3.224	2.317	-0.0157	0.0118	-0.623	0.255	0.8256	0.0635	0.4134	0.1427
7	GRC	28.167	16.931	-0.316	0.174	-5.138	1.354	-0.259	0.404	-0.957	0.439	0.0060	0.0024	-0.668	0.152	1.0506	0.0525	0.6569	0.5540
7	IRL	56.272	17.661	0.016	0.217	-6.684	1.399	-0.482	0.374	-1.721	0.484	0.0102	0.0030	-0.716	0.140	0.8938	0.0447	0.6970	0.6061
7	ISL	-91.325	38.655	-0.104	0.305	27.352	9.992	-0.979	0.421	3.354	1.342	-0.0169	0.0070	-0.559	0.312	0.5292	0.0407	0.5604	0.3576
7	NLD	37.358	17.060	-0.129	0.077	-5.665	1.409	-0.591	0.394	-1.218	0.456	0.0074	0.0026	-0.690	0.142	0.9904	0.0495	0.6769	0.5800
7	PRT	60.210	19.980	-0.042	0.266	-6.659	1.408	-0.508	0.417	-1.795	0.511	0.0107	0.0031	-0.699	0.175	0.8928	0.0446	0.6973	0.6064
8	YUG	24.099	19.639	0.508	0.141	-1.773	2.769	-0.432	0.262	-0.656	0.581	0.0037	0.0031	-0.400	0.136	0.3348	0.0209	0.6650	0.5394
9	ARG	48.077	15.122	0.623	0.240	-6.964	1.386	-0.480	0.422	-1.402	0.405	0.0075	0.0023	-0.621	0.135	1.1476	0.0574	0.7065	0.6185
9	BOL	-103.222	67.223	-0.114	0.449	30.889	14.305	-0.767	0.567	3.846	2.150	-0.0195	0.0117	-0.799	0.249	0.6507	0.0542	0.5329	0.2993
9	CHL	61.485	35.285	-0.181	0.272	-8.722	2.510	-0.162	0.939	-1.872	0.934	0.0109	0.0054	-0.766	0.183	5.6184	0.2809	0.5567	0.4237
9	COL	45.601	23.184	-0.136	0.232	-6.306	1.739	-0.437	0.547	-1.374	0.600	0.0081	0.0033	-0.669	0.158	1.9347	0.0967	0.5976	0.4768
9	ECU	8.019	30.232	0.092	0.123	1.482	4.227	-0.641	0.470	-0.126	0.890	0.0011	0.0049	-0.658	0.196	0.9359	0.0585	0.5744	0.4148
9	PER	98.862	30.358	0.866	0.320	-18.714	2.969	0.061	0.664	-3.130	0.835	0.0171	0.0048	-1.435	0.183	2.4622	0.1296	0.8046	0.7429
9	PRY	-125.040	119.603	-0.052	0.268	29.156	42.962	-0.449	0.577	4.248	4.760	-0.0219	0.0243	-0.856	0.316	0.5629	0.0626	0.5662	0.2771
9	URY	129.728	325.856	0.102	0.796	-107.009	240.092	-0.460	0.428	-8.163	18.937	0.0406	0.0931	-1.225	0.449	0.1331	0.0333	0.7552	0.3881
9	VEN	46.441	20.374	-0.060	0.200	-5.847	1.599	-0.465	0.462	-1.367	0.535	0.0080	0.0030	-0.666	0.164	1.3522	0.0676	0.6206	0.5068
10	BRB	-28.308	32.515	-0.297	0.115	7.574	6.453	-0.652	0.366	0.860	1.043	-0.0038	0.0056	-0.836	0.206	0.5354	0.0382	0.6185	0.4551
10	CRI	-13.428	31.151	-0.264	0.226	5.920	5.186	-0.777	0.476	0.529	0.953	-0.0021	0.0052	-0.632	0.233	0.8649	0.0577	0.4842	0.2779
10	GTM	140.414	42.394	-0.132	0.223	-13.684	4.957	-1.527	0.576	-4.027	1.231	0.0233	0.0069	-1.104	0.239	1.2747	0.0750	0.6321	0.5022
10	HND	177.156	159.700	-0.662	0.350	-107.327	96.017	-0.810	0.381	-9.304	8.237	0.0475	0.0411	-1.216	0.282	0.1736	0.0289	0.8549	0.7099
10	JAM	11.311	27.949	-0.275	0.353	-1.194	3.786	-0.307	0.478	-0.362	0.828	0.0024	0.0046	-0.521	0.209	1.1604	0.0683	0.5301	0.3643
10	NIC	-4.949	33.735	-0.042	0.048	0.955	4.252	-0.370	0.460	0.132	0.977	-0.0003	0.0054	-0.544	0.203	1.1500	0.0676	0.5344	0.3700
10	PAN	70.042	28.429	0.265	0.260	-8.500	3.308	-0.503	0.529	-2.055	0.808	0.0115	0.0045	-0.538	0.234	1.6252	0.0903	0.3477	0.1302
10	SLV	-11.237	96.523	0.172	0.221	4.226	36.444	-0.619	0.537	0.399	3.915	-0.0017	0.0201	-0.709	0.341	0.5283	0.0587	0.5485	0.2474
10	TTO	-17.504	26.278	-0.277	0.204	3.360	3.885	-1.060	0.613	0.514	0.788	-0.0024	0.0044	-0.568	0.192	0.7748	0.0484	0.5497	0.3808

Table M.6: Stock adjustment results, fixed λ (equation 5.14); first traffic demand predicted results (equation 5.6); US manufacturers price index, model 3 (table 3.12).

	Country	a_0	Std Err	a_1	Std Err	a_2	Std Err	a_3	Std Err	a_4	Std Err	a_5	Std Err	a_6	Std Err	SSE	MSE	R^2	Adj R^2
1	CAN	11.708	48.278	-0.329	0.543	-6.996	2.427	0.394	1.024	-0.540	1.245	0.0032	0.0076	-0.657	0.168	6.2745	0.3137	0.5524	0.4181
1	DEU	82.789	17.672	0.293	0.215	-7.684	1.630	-0.188	0.445	-2.406	0.500	0.0142	0.0030	-0.641	0.148	1.1380	0.0569	0.6858	0.5916
1	ESP	27.012	17.489	0.559	0.301	-4.958	1.468	-0.403	0.450	-0.891	0.486	0.0050	0.0031	-0.647	0.145	0.8209	0.0410	0.7216	0.6381
1	FRA	52.467	16.660	0.254	0.181	-6.324	1.561	0.068	0.456	-1.597	0.468	0.0094	0.0028	-0.592	0.176	1.1584	0.0579	0.6509	0.5462
1	GBR	46.172	13.948	-0.087	0.133	-6.173	1.389	0.000	0.416	-1.442	0.388	0.0088	0.0022	-0.762	0.154	0.9488	0.0474	0.6783	0.5818
1	ITA	102.244	20.667	-0.201	0.271	-8.813	1.883	-0.813	0.542	-2.926	0.581	0.0177	0.0034	-0.788	0.149	1.7006	0.0850	0.6705	0.5716
1	JPN	93.278	57.123	0.653	0.594	-8.719	5.092	0.038	0.944	-2.741	1.615	0.0164	0.0097	-0.856	0.260	4.2373	0.2354	0.5116	0.3489
1	LUX	-11.463	23.856	-0.008	0.332	2.860	3.160	0.056	0.528	0.303	0.719	-0.0010	0.0041	-0.446	0.216	0.9012	0.0530	0.4915	0.3120
1	NOR	75.048	12.387	0.298	0.146	-7.261	1.187	-0.505	0.333	-2.179	0.347	0.0128	0.0020	-0.730	0.130	0.5628	0.0281	0.7732	0.7052
1	SWE	69.250	15.687	0.132	0.134	-6.487	1.459	-0.091	0.384	-2.012	0.441	0.0121	0.0026	-0.697	0.154	0.8657	0.0433	0.6669	0.5669
1	USA	-43.636	40.100	-0.329	0.295	-3.274	1.817	-0.600	0.920	0.939	1.027	-0.0049	0.0060	-0.661	0.234	3.4957	0.1748	0.5677	0.4380
2	AUS	-48.047	32.687	0.340	0.314	2.174	3.164	1.034	0.867	1.283	0.895	-0.0071	0.0049	-0.759	0.274	2.6115	0.1451	0.4153	0.2204
2	BRA	21.738	19.895	0.425	0.350	-3.943	1.784	0.614	0.659	-0.688	0.547	0.0040	0.0033	-0.600	0.197	1.7899	0.0895	0.4980	0.3474
2	IDN	-45.684	26.835	-0.327	0.194	-0.212	3.081	1.383	0.710	1.021	0.749	-0.0051	0.0042	-0.531	0.212	2.0416	0.1134	0.4441	0.2588
2	IND	-30.864	57.299	-0.559	0.277	5.974	7.150	0.330	0.769	0.887	1.661	-0.0035	0.0093	-0.329	0.205	2.4539	0.1534	0.4101	0.1889
2	KOR	-96.365	45.312	-0.017	0.418	5.450	4.018	1.239	0.968	2.533	1.244	-0.0143	0.0072	-0.534	0.308	3.6476	0.2026	0.4259	0.2346
2	MEX	21.697	42.022	0.137	0.086	-1.895	2.903	-1.124	1.462	-0.540	1.135	0.0028	0.0067	-0.162	0.212	7.9474	0.4183	0.2322	-0.0103
2	MYS	-108.850	38.555	0.417	0.252	9.316	4.416	0.622	0.908	3.099	1.113	-0.0179	0.0064	-0.524	0.305	3.1479	0.1749	0.4686	0.2915
2	SAU	14.046	21.037	-0.052	0.080	-2.990	1.868	0.117	0.853	-0.478	0.564	0.0030	0.0033	-0.393	0.223	2.3475	0.1174	0.4031	0.2241
2	THA	-1.773	66.219	0.103	0.070	-3.731	9.003	-0.300	0.823	-0.091	1.936	0.0002	0.0105	-0.527	0.224	2.8480	0.1780	0.3642	0.1258
2	TUR	-9.160	21.102	0.149	0.151	2.813	2.557	-0.308	0.417	0.357	0.601	-0.0018	0.0033	-0.244	0.138	0.6989	0.0388	0.6962	0.5950
3	BFA	-93.878	113.888	0.279	0.177	18.209	40.693	-0.150	0.600	3.050	4.535	-0.0160	0.0233	-0.801	0.291	0.4305	0.0478	0.5527	0.2545
3	CAF	-55.454	57.998	-0.776	1.077	10.729	13.366	-0.595	0.568	1.782	1.983	-0.0092	0.0106	-0.440	0.250	0.6056	0.0466	0.3524	0.0535
3	CIV	-9.869	21.539	-0.202	0.155	-0.035	2.982	-0.245	0.410	0.206	0.635	-0.0007	0.0036	-0.625	0.219	0.6564	0.0386	0.5647	0.4110
3	COG	-82.667	129.637	0.039	0.225	13.398	45.814	-0.095	0.720	2.545	5.152	-0.0134	0.0265	-0.634	0.353	0.5211	0.0579	0.3886	-0.0190
3	DZA	20.270	18.582	0.155	0.196	-4.024	1.739	0.420	0.615	-0.657	0.509	0.0040	0.0030	-0.699	0.230	1.6931	0.0847	0.5318	0.3913
3	ETH	31.501	14.213	-0.147	0.081	-5.029	1.375	-0.296	0.490	-0.979	0.380	0.0057	0.0022	-0.473	0.162	1.1979	0.0599	0.6536	0.5497
3	GAB	-41.563	30.061	0.054	0.167	7.330	5.284	-0.125	0.482	1.300	0.936	-0.0066	0.0050	-0.607	0.229	0.7189	0.0479	0.3743	0.1241
3	GHA	-43.744	28.508	0.073	0.179	6.888	5.557	-0.044	0.552	1.331	0.905	-0.0068	0.0049	-0.688	0.315	0.7165	0.0478	0.3776	0.1286
3	GIN	128.010	158.499	-0.164	0.191	-104.650	89.446	-0.763	0.483	-8.055	7.853	0.0406	0.0395	-1.419	0.372	0.1588	0.0265	0.7790	0.5579
3	KEN	11.761	18.279	0.072	0.084	-1.310	3.000	-0.430	0.428	-0.319	0.547	0.0018	0.0030	-0.278	0.176	0.8694	0.0458	0.7442	0.6634

Table M.6: Continued.

	Country	a_0	Std Err	a_1	Std Err	a_2	Std Err	a_3	Std Err	a_4	Std Err	a_5	Std Err	a_6	Std Err	SSE	MSE	R^2	Adj R^2
3	MAR	33.698	15.032	-0.079	0.121	-6.231	1.633	0.374	0.513	-1.121	0.417	0.0068	0.0024	-0.754	0.202	1.2763	0.0638	0.6303	0.5194
3	MDG	-71.415	38.784	-0.774	1.287	13.793	7.044	-0.544	0.607	2.300	1.217	-0.0119	0.0065	-0.464	0.212	1.1777	0.0785	0.3493	0.0890
3	MRT	-34.353	31.465	0.245	0.186	5.586	6.014	-0.072	0.549	1.090	1.003	-0.0055	0.0055	-0.771	0.334	0.7818	0.0521	0.4423	0.2192
3	NER	134.926	128.072	-0.077	0.091	-167.931	82.066	-0.621	0.461	-11.108	6.734	0.0537	0.0335	-1.475	0.365	0.1501	0.0250	0.7977	0.5954
3	NGA	24.165	15.634	0.221	0.171	-5.905	1.526	0.265	0.479	-0.842	0.414	0.0049	0.0024	-0.777	0.178	1.2324	0.0616	0.6484	0.5429
3	SEN	-8.254	25.513	-0.349	0.224	-0.377	3.698	-0.428	0.378	0.117	0.757	0.0001	0.0042	-0.930	0.236	0.5166	0.0323	0.6213	0.4792
3	TCD	-249.050	131.959	-1.303	0.545	96.001	54.156	-0.477	0.526	10.119	5.529	-0.0501	0.0277	-0.762	0.254	0.3082	0.0342	0.6096	0.3493
3	TUN	22.583	14.712	0.668	0.255	-4.862	1.469	0.094	0.523	-0.787	0.402	0.0044	0.0023	-0.744	0.171	1.2629	0.0631	0.6456	0.5393
3	TZA	0.448	15.743	1.135	1.152	0.312	2.184	-0.402	0.427	-0.050	0.446	0.0006	0.0025	-0.298	0.177	0.8586	0.0452	0.7474	0.6676
3	ZAF	19.792	17.489	0.252	0.228	-4.980	1.392	-0.090	0.487	-0.675	0.450	0.0037	0.0027	-0.639	0.165	1.2185	0.0609	0.6468	0.5408
3	ZMB	-23.596	22.498	-0.132	0.204	4.261	3.324	-0.492	0.423	0.750	0.674	-0.0038	0.0037	-0.399	0.198	0.6944	0.0434	0.4215	0.2046
4	ARE	-148.753	181.196	1.084	0.607	21.074	54.311	-0.245	0.913	4.396	6.714	-0.0241	0.0346	-0.737	0.263	1.0948	0.1095	0.6153	0.3846
4	EGY	15.399	28.237	0.125	0.428	-4.261	1.703	0.238	0.639	-0.557	0.726	0.0033	0.0044	-0.648	0.247	1.6831	0.0842	0.5399	0.4018
4	IRN	-9.894	63.289	-0.330	0.517	-0.716	6.197	0.284	0.767	0.195	1.768	-0.0006	0.0101	-0.577	0.229	2.6697	0.1483	0.3205	0.0940
4	ISR	44.462	16.645	0.361	0.211	-6.069	1.494	-0.447	0.489	-1.346	0.436	0.0074	0.0024	-0.540	0.156	1.1280	0.0564	0.6731	0.5750
4	JOR	20.644	17.603	-0.007	0.151	-4.345	1.680	0.191	0.687	-0.725	0.468	0.0044	0.0027	-0.599	0.243	1.6925	0.0846	0.5375	0.3987
4	KWT	-31.046	32.278	0.296	0.300	-1.130	1.767	0.681	0.860	0.601	0.817	-0.0032	0.0048	-0.621	0.231	3.2914	0.1646	0.3528	0.1586
4	LBN	28.052	21.865	0.006	0.009	-4.764	1.790	0.204	0.622	-0.972	0.599	0.0059	0.0036	-0.634	0.204	1.6593	0.0830	0.5466	0.4105
4	OMN	-77.894	140.605	0.597	0.240	4.780	37.121	0.059	0.765	2.111	4.954	-0.0123	0.0257	-0.543	0.221	0.9434	0.0858	0.6787	0.5035
4	QAT	-288.714	127.393	0.656	0.384	74.193	39.078	-0.233	0.719	10.140	4.747	-0.0533	0.0245	-0.721	0.263	0.7037	0.0704	0.6135	0.3816
4	SYR	35.005	17.472	0.373	0.208	-5.033	1.696	0.049	0.607	-1.064	0.469	0.0060	0.0027	-0.560	0.180	1.6102	0.0805	0.5647	0.4341
4	YEM	-31.972	25.164	0.498	0.201	-3.774	1.714	0.276	0.682	0.601	0.634	-0.0038	0.0038	-0.501	0.180	1.9728	0.0986	0.4886	0.3352
5	BGD	-38.942	227.919	-0.272	0.355	1.805	74.437	-0.384	1.388	0.924	8.698	-0.0047	0.0448	-0.350	0.285	2.1575	0.2158	0.3086	-0.1062
5	CYP	-83.948	57.994	-0.225	0.216	23.256	15.745	-0.688	0.506	3.011	2.069	-0.0151	0.0108	-0.479	0.230	0.4998	0.0417	0.4059	0.1088
5	LKA	-102.620	68.333	-0.155	0.120	10.064	8.811	-0.444	0.843	2.814	1.972	-0.0152	0.0107	-0.597	0.233	2.9295	0.1831	0.3464	0.1013
5	PAK	-29.800	33.561	-0.364	0.113	-3.403	3.435	-1.224	0.850	0.551	0.923	-0.0029	0.0052	-0.895	0.200	2.4464	0.1359	0.5936	0.4581
5	PHL	-82.532	40.058	0.418	0.386	3.629	3.925	1.284	0.938	2.177	1.086	-0.0128	0.0059	-0.490	0.299	3.4239	0.1902	0.4616	0.2821
5	SGP	-53.627	60.793	0.225	0.793	3.219	8.082	-0.357	0.901	1.340	1.743	-0.0076	0.0095	-0.503	0.249	3.2364	0.2023	0.2815	0.0121
5	VNM	-91.167	29.743	-0.001	0.003	10.346	3.692	0.360	0.655	2.637	0.835	-0.0145	0.0047	-0.460	0.233	1.6247	0.0956	0.6225	0.4893
6	FJI	-394.591	246.289	0.361	0.263	132.412	90.888	-0.721	0.952	15.464	9.897	-0.0802	0.0507	-0.903	0.378	0.5854	0.0732	0.6712	0.4245
6	NZL	-214.956	88.298	0.384	0.584	14.245	7.833	1.750	2.172	5.888	2.351	-0.0346	0.0134	0.010	0.699	16.3351	0.9075	0.4656	0.2875
6	PNG	-2499.1	700.764	-0.413	0.517	1787.82	613.871	-5.589	2.055	143.664	44.870	-0.7114	0.2191	1.229	1.149	0.4329	0.1443	0.9417	0.8252

Table M.6: Continued.

	Country	a_0	Std Err	a_1	Std Err	a_2	Std Err	a_3	Std Err	a_4	Std Err	a_5	Std Err	a_6	Std Err	SSE	MSE	R^2	Adj R^2
7	AUT	46.492	14.504	-0.017	0.309	-5.681	1.523	-0.021	0.466	-1.425	0.406	0.0085	0.0024	-0.634	0.159	1.1738	0.0587	0.6291	0.5178
7	BEL	45.586	13.633	0.397	0.212	-6.806	1.540	0.134	0.427	-1.510	0.390	0.0089	0.0023	-0.875	0.187	1.0136	0.0507	0.6693	0.5701
7	CHE	37.355	15.517	0.453	0.392	-5.073	1.524	-0.053	0.525	-1.211	0.431	0.0070	0.0025	-0.608	0.157	1.3621	0.0681	0.5839	0.4590
7	DNK	51.083	14.055	0.122	0.139	-6.223	1.455	0.074	0.459	-1.567	0.393	0.0092	0.0023	-0.649	0.148	1.0425	0.0521	0.6653	0.5649
7	FIN	-103.124	73.806	-0.613	0.628	26.463	19.255	-0.573	0.648	3.573	2.594	-0.0177	0.0133	-0.568	0.245	0.8515	0.0655	0.3950	0.1158
7	GRC	24.489	15.104	-0.349	0.178	-4.917	1.332	-0.237	0.462	-0.864	0.400	0.0056	0.0023	-0.668	0.155	1.0582	0.0529	0.6544	0.5508
7	IRL	49.850	17.939	-0.051	0.224	-6.297	1.421	0.072	0.416	-1.576	0.493	0.0096	0.0030	-0.734	0.149	0.9665	0.0483	0.6723	0.5740
7	ISL	-121.914	48.044	-0.126	0.342	32.472	12.716	-1.048	0.589	4.315	1.703	-0.0222	0.0090	-0.409	0.363	0.6028	0.0464	0.4994	0.2683
7	NLD	29.588	17.113	-0.110	0.084	-5.151	1.448	-0.102	0.471	-1.026	0.460	0.0064	0.0026	-0.688	0.152	1.0993	0.0550	0.6414	0.5338
7	PRT	43.042	16.722	0.121	0.243	-6.434	1.445	0.083	0.412	-1.391	0.441	0.0083	0.0027	-0.782	0.176	0.9571	0.0479	0.6755	0.5781
8	YUG	15.701	17.787	0.510	0.137	-0.416	2.649	-0.546	0.289	-0.394	0.534	0.0022	0.0029	-0.324	0.141	0.3202	0.0200	0.6796	0.5594
9	ARG	39.975	14.446	0.632	0.257	-6.640	1.399	-0.075	0.490	-1.208	0.391	0.0065	0.0023	-0.645	0.144	1.2204	0.0610	0.6879	0.5943
9	BOL	-146.902	69.130	0.136	0.406	35.290	17.711	-0.497	0.665	5.086	2.375	-0.0265	0.0126	-0.783	0.262	0.7165	0.0597	0.4856	0.2284
9	CHL	51.595	32.570	-0.229	0.274	-8.399	2.378	0.640	1.001	-1.641	0.871	0.0097	0.0051	-0.786	0.181	5.5141	0.2757	0.5649	0.4344
9	COL	32.886	22.763	-0.148	0.235	-5.893	1.712	0.279	0.596	-1.074	0.589	0.0065	0.0033	-0.715	0.163	1.9747	0.0987	0.5892	0.4660
9	ECU	-8.276	28.869	0.046	0.129	2.961	4.387	-0.233	0.542	0.307	0.870	-0.0011	0.0048	-0.654	0.211	1.0328	0.0646	0.5303	0.3542
9	PER	94.248	26.101	0.843	0.301	-18.688	2.824	0.514	0.660	-3.027	0.733	0.0166	0.0042	-1.450	0.176	2.3872	0.1256	0.8105	0.7507
9	PRY	-163.239	136.966	-0.038	0.285	40.960	48.193	-0.331	0.747	5.685	5.411	-0.0293	0.0277	-0.879	0.321	0.5881	0.0653	0.5469	0.2448
9	URY	91.496	406.255	-0.034	0.887	-102.036	289.818	-0.278	0.685	-7.070	23.174	0.0349	0.1142	-1.301	0.499	0.1647	0.0412	0.6971	0.2427
9	VEN	33.245	19.075	-0.092	0.202	-5.597	1.597	0.301	0.515	-1.064	0.506	0.0064	0.0029	-0.737	0.174	1.3968	0.0698	0.6081	0.4905
10	BRB	-34.529	37.901	-0.276	0.127	6.543	8.012	-0.114	0.485	0.951	1.247	-0.0043	0.0067	-0.801	0.229	0.6539	0.0467	0.5341	0.3344
10	CRI	-27.676	32.949	-0.152	0.233	6.399	6.058	-0.279	0.553	0.880	1.039	-0.0041	0.0056	-0.644	0.253	1.0018	0.0668	0.4026	0.1636
10	GTM	90.792	43.938	-0.218	0.257	-8.475	5.211	-0.696	0.702	-2.636	1.287	0.0157	0.0073	-0.916	0.279	1.7040	0.1002	0.5082	0.3346
10	HND	94.162	182.838	-0.786	0.416	-83.139	109.138	-0.849	0.586	-6.257	9.379	0.0318	0.0468	-1.273	0.334	0.2255	0.0376	0.8116	0.6232
10	JAM	4.035	26.204	-0.376	0.355	-1.162	3.848	0.215	0.520	-0.199	0.792	0.0016	0.0045	-0.541	0.214	1.1767	0.0692	0.5235	0.3554
10	NIC	-18.007	32.491	-0.050	0.050	1.636	4.222	0.197	0.518	0.454	0.946	-0.0021	0.0053	-0.575	0.212	1.1836	0.0696	0.5207	0.3516
10	PAN	56.663	26.234	0.289	0.269	-8.149	3.319	0.359	0.588	-1.746	0.762	0.0098	0.0043	-0.594	0.246	1.6724	0.0929	0.3287	0.1050
10	SLV	-48.720	116.053	0.179	0.237	15.014	43.784	-0.301	0.727	1.771	4.721	-0.0088	0.0242	-0.686	0.366	0.5949	0.0661	0.4916	0.1527
10	TTO	-37.408	25.781	-0.014	0.185	5.904	3.976	-0.043	0.635	1.074	0.787	-0.0054	0.0044	-0.570	0.224	0.9197	0.0575	0.4655	0.2650

Table M.7: Stock adjustment results, fixed λ (equation 5.14); second traffic demand predicted results (equation 5.7); All manufacturers price index, model 3 (table 3.3).

	Country	a_0	Std Err	a_1	Std Err	a_2	Std Err	a_3	Std Err	a_4	Std Err	a_5	Std Err	a_6	Std Err	SSE	MSE	R^2	Adj R^2
1	CAN	20.174	35.142	0.549	0.194	-6.354	2.053	-0.045	0.836	-0.640	0.892	0.0031	0.0050	-0.885	0.163	4.5525	0.2276	0.6752	0.5778
1	DEU	84.842	19.046	-0.030	0.031	-8.026	1.594	-0.426	0.433	-2.455	0.522	0.0147	0.0030	-0.679	0.134	1.0828	0.0541	0.7011	0.6114
1	ESP	44.222	14.461	-0.443	0.203	-6.797	1.244	-0.371	0.331	-1.409	0.384	0.0088	0.0022	-0.700	0.126	0.7168	0.0358	0.7569	0.6840
1	FRA	46.205	22.437	-0.303	0.180	-7.095	1.508	-0.605	0.390	-1.486	0.575	0.0094	0.0032	-0.823	0.157	1.0187	0.0509	0.6930	0.6009
1	GBR	22.924	17.709	-0.078	0.028	-6.332	1.191	-0.421	0.312	-0.895	0.454	0.0056	0.0026	-0.750	0.120	0.6495	0.0325	0.7798	0.7137
1	ITA	95.490	21.508	-0.699	0.521	-9.108	1.906	-0.565	0.538	-2.755	0.599	0.0170	0.0035	-0.755	0.153	1.7191	0.0860	0.6669	0.5669
1	JPN	143.851	55.509	-0.665	0.487	-13.746	6.042	-0.631	0.920	-4.298	1.612	0.0270	0.0095	-1.058	0.244	4.1064	0.2281	0.5267	0.3690
1	LUX	29.443	25.636	-1.387	0.564	-3.497	3.579	-0.395	0.343	-0.932	0.772	0.0065	0.0045	-0.417	0.157	0.6413	0.0377	0.6381	0.5104
1	NOR	78.499	12.705	0.328	0.215	-7.435	1.182	-0.595	0.290	-2.267	0.354	0.0133	0.0020	-0.788	0.123	0.5458	0.0273	0.7801	0.7141
1	SWE	64.114	18.790	-0.109	0.102	-7.210	1.384	-0.629	0.330	-1.915	0.490	0.0116	0.0028	-0.715	0.135	0.7304	0.0365	0.7189	0.6346
1	USA	-62.002	34.465	-0.448	0.683	-3.670	2.001	-0.933	0.859	1.369	0.870	-0.0074	0.0050	-0.709	0.236	3.4974	0.1749	0.5675	0.4377
2	AUS	-28.219	33.334	0.458	0.205	0.136	3.387	-0.178	0.692	0.749	0.920	-0.0046	0.0051	-0.511	0.218	2.4215	0.1345	0.4578	0.2771
2	BRA	35.905	20.060	0.311	0.240	-2.814	1.961	-0.323	0.543	-0.959	0.552	0.0056	0.0032	-0.448	0.173	1.8138	0.0907	0.4913	0.3387
2	IDN	-36.146	31.529	-0.229	0.166	-0.343	3.705	0.431	0.646	0.810	0.883	-0.0041	0.0049	-0.430	0.209	2.3348	0.1297	0.3643	0.1524
2	IND	-62.295	57.655	-0.785	0.522	7.422	7.537	0.525	0.736	1.637	1.697	-0.0073	0.0095	-0.386	0.199	2.7027	0.1689	0.3503	0.1067
2	KOR	-62.858	48.114	-0.308	0.483	4.322	4.250	0.184	0.861	1.686	1.323	-0.0093	0.0077	-0.344	0.281	3.8891	0.2161	0.3879	0.1839
2	MEX	37.893	43.918	0.128	0.080	-2.471	2.950	-1.583	1.135	-0.926	1.175	0.0049	0.0068	-0.180	0.181	7.5054	0.3950	0.2749	0.0459
2	MYS	-125.739	38.406	0.672	0.208	14.834	4.534	-0.007	0.673	3.815	1.114	-0.0222	0.0063	-0.372	0.237	2.4160	0.1342	0.5922	0.4562
2	SAU	24.449	24.471	-0.023	0.083	-2.906	1.885	-0.400	0.627	-0.702	0.636	0.0041	0.0037	-0.357	0.182	2.3758	0.1188	0.3959	0.2147
2	THA	-65.369	60.253	0.103	0.101	3.361	7.698	0.691	0.810	1.682	1.744	-0.0093	0.0095	-0.492	0.233	2.9998	0.1875	0.3303	0.0792
2	TUR	-25.308	24.123	-0.072	0.193	4.684	2.897	-0.080	0.357	0.790	0.684	-0.0039	0.0037	-0.222	0.142	0.7365	0.0409	0.6798	0.5731
3	BFA	-128.179	112.346	0.278	0.274	49.117	47.675	-0.532	0.592	5.329	4.783	-0.0272	0.0244	-0.805	0.313	0.4925	0.0547	0.4882	0.1470
3	CAF	-54.484	58.050	-0.204	1.066	9.856	13.494	-0.286	0.432	1.737	1.989	-0.0091	0.0106	-0.503	0.266	0.6402	0.0493	0.3154	-0.0005
3	CIV	-8.512	26.841	-0.273	0.259	-0.605	2.948	-0.445	0.359	0.151	0.741	-0.0004	0.0041	-0.688	0.226	0.6442	0.0379	0.5728	0.4220
3	COG	-90.974	161.618	0.104	0.408	18.624	62.364	-0.089	0.559	2.997	6.710	-0.0157	0.0346	-0.624	0.319	0.5184	0.0576	0.3918	-0.0136
3	DZA	16.789	15.304	0.092	0.025	0.914	1.952	-0.485	0.399	-0.305	0.437	0.0017	0.0025	-0.175	0.159	1.0017	0.0501	0.7230	0.6399
3	ETH	33.141	21.423	-0.010	0.226	-4.828	1.591	-0.270	0.500	-0.989	0.503	0.0057	0.0028	-0.556	0.167	1.3799	0.0690	0.6010	0.4813
3	GAB	-80.463	32.093	-0.373	0.182	10.016	4.355	-0.445	0.348	2.314	0.926	-0.0121	0.0050	-0.693	0.197	0.5414	0.0361	0.5288	0.3404
3	GHA	59.333	32.787	0.575	0.151	3.793	3.492	-0.718	0.295	-1.097	0.872	0.0064	0.0047	-0.909	0.174	0.3534	0.0236	0.6930	0.5702
3	GIN	147.294	183.399	-0.212	0.408	-104.659	93.154	-0.593	0.423	-8.500	8.448	0.0431	0.0426	-1.316	0.381	0.1709	0.0285	0.7622	0.5243
3	KEN	26.997	22.131	0.132	0.088	-2.717	2.703	-0.355	0.381	-0.723	0.621	0.0039	0.0034	-0.278	0.164	0.8337	0.0439	0.7547	0.6773

Table M.7: Continued.

	Country	a_0	Std Err	a_1	Std Err	a_2	Std Err	a_3	Std Err	a_4	Std Err	a_5	Std Err	a_6	Std Err	SSE	MSE	R^2	Adj R^2
3	MAR	-2.887	18.180	-1.021	0.281	-8.459	1.417	-0.478	0.359	-0.349	0.439	0.0026	0.0025	-0.881	0.147	0.7704	0.0385	0.7768	0.7099
3	MDG	-83.797	38.050	-3.722	1.996	14.710	6.456	-0.254	0.498	2.601	1.170	-0.0130	0.0062	-0.474	0.183	1.0235	0.0682	0.4345	0.2083
3	MRT	-14.882	34.938	0.310	0.290	3.224	6.607	-0.371	0.449	0.551	1.088	-0.0028	0.0058	-0.751	0.332	0.7396	0.0493	0.4724	0.2613
3	NER	236.768	144.732	-0.017	0.024	-186.079	88.073	-0.437	0.375	-14.345	7.440	0.0710	0.0372	-1.288	0.372	0.1628	0.0271	0.7807	0.5613
3	NGA	37.892	15.973	-0.051	0.045	-5.410	1.506	-0.277	0.447	-1.138	0.430	0.0066	0.0024	-0.536	0.173	1.2119	0.0606	0.6543	0.5506
3	SEN	23.389	27.211	0.040	0.236	-2.186	3.615	-0.448	0.330	-0.678	0.784	0.0043	0.0044	-0.804	0.228	0.5377	0.0336	0.6058	0.4580
3	TCD	-241.265	110.664	-1.422	0.496	94.936	45.714	-0.252	0.381	9.872	4.641	-0.0486	0.0232	-0.870	0.248	0.2633	0.0293	0.6663	0.4439
3	TUN	1.792	18.055	0.355	0.106	2.687	2.544	-0.512	0.408	0.108	0.537	-0.0007	0.0031	-0.165	0.169	1.0506	0.0525	0.7052	0.6168
3	TZA	-7.498	18.734	5.986	4.067	-0.904	2.165	-0.197	0.379	-0.213	0.475	0.0021	0.0028	-0.364	0.164	0.8356	0.0440	0.7541	0.6765
3	ZAF	79.937	29.123	0.259	0.142	-6.043	1.431	-0.162	0.424	-2.110	0.713	0.0118	0.0039	-0.484	0.157	1.0947	0.0547	0.6827	0.5874
3	ZMB	-21.951	24.658	0.182	0.223	5.063	3.779	-0.071	0.401	0.777	0.718	-0.0041	0.0039	-0.426	0.200	0.7255	0.0454	0.3956	0.1689
4	ARE	-329.206	200.973	0.155	0.557	73.380	60.454	0.478	0.845	11.026	7.436	-0.0580	0.0382	-0.720	0.335	1.4025	0.1403	0.5072	0.2116
4	EGY	39.876	19.212	0.019	0.018	-4.528	1.591	-0.446	0.521	-1.123	0.499	0.0064	0.0028	-0.523	0.175	1.5627	0.0781	0.5728	0.4446
4	IRN	-45.848	35.991	0.003	0.017	2.622	4.163	0.279	0.703	1.192	0.994	-0.0064	0.0055	-0.515	0.208	2.7280	0.1516	0.3056	0.0742
4	ISR	36.616	16.944	-0.064	0.084	-5.485	1.509	-0.345	0.457	-1.146	0.445	0.0066	0.0025	-0.496	0.196	1.2419	0.0621	0.6401	0.5321
4	JOR	44.111	17.906	0.286	0.144	-5.410	1.582	-0.138	0.506	-1.266	0.469	0.0070	0.0026	-0.654	0.178	1.3817	0.0691	0.6224	0.5092
4	KWT	-24.921	35.599	0.579	0.506	-1.783	1.840	0.243	0.836	0.451	0.883	-0.0027	0.0052	-0.561	0.219	3.3156	0.1658	0.3480	0.1524
4	OMN	-351.000	123.779	0.725	0.440	73.538	32.107	0.395	0.714	11.633	4.342	-0.0620	0.0227	-0.916	0.272	1.1579	0.1053	0.6057	0.3906
4	QAT	-304.359	147.835	-0.002	0.480	72.939	44.349	0.304	0.713	10.399	5.453	-0.0543	0.0281	-0.748	0.320	0.8903	0.0890	0.5110	0.2175
4	SYR	44.535	16.490	0.812	0.280	-5.219	1.450	-0.071	0.476	-1.265	0.438	0.0068	0.0025	-0.567	0.148	1.2883	0.0644	0.6517	0.5472
4	YEM	28.075	20.539	0.512	0.232	-3.908	1.811	-0.169	0.587	-0.767	0.550	0.0039	0.0031	-0.444	0.167	2.0637	0.1032	0.4650	0.3045
5	BGD	2.003	181.112	-0.349	0.748	-21.335	51.770	0.665	1.246	-1.158	6.496	0.0060	0.0335	-0.369	0.270	2.0304	0.2030	0.3494	-0.0410
5	CYP	-50.993	54.723	0.248	0.453	14.191	14.957	-0.343	0.429	1.860	1.945	-0.0096	0.0102	-0.495	0.251	0.5762	0.0480	0.3150	-0.0274
5	LKA	-71.554	73.030	-0.004	0.086	4.711	8.632	0.445	0.817	1.853	2.067	-0.0101	0.0113	-0.556	0.232	3.1933	0.1996	0.2876	0.0204
5	PAK	-40.714	52.516	0.045	0.078	2.450	3.975	0.597	0.949	1.063	1.365	-0.0057	0.0076	-0.577	0.242	3.7778	0.2099	0.3724	0.1632
5	PHL	-71.695	42.734	0.421	0.435	2.848	4.660	0.153	0.843	1.902	1.171	-0.0114	0.0064	-0.376	0.279	3.7829	0.2102	0.4051	0.2068
5	SGP	-70.794	62.788	-0.399	1.462	3.600	8.378	0.462	0.802	1.697	1.808	-0.0089	0.0102	-0.578	0.245	3.2013	0.2001	0.2893	0.0228
5	VNM	-90.936	31.195	-0.001	0.001	11.708	4.207	-0.105	0.558	2.701	0.901	-0.0148	0.0050	-0.380	0.207	1.6285	0.0958	0.6216	0.4881
6	FJI	-424.505	310.120	0.291	0.244	124.043	111.571	0.035	0.763	15.716	12.386	-0.0820	0.0634	-1.064	0.438	0.6058	0.0757	0.6597	0.4044
6	NZL	-185.022	89.419	0.943	0.706	11.151	8.207	-0.290	1.739	5.149	2.407	-0.0315	0.0136	0.140	0.609	15.4629	0.8591	0.4941	0.3255
6	PNG	-1757.6	1239.03	-0.312	1.120	895.341	1132.50	-0.582	3.112	83.533	78.009	-0.4216	0.3789	-0.743	2.531	1.5182	0.5061	0.7957	0.3871

Table M.7: Continued.

	Country	a_0	Std Err	a_1	Std Err	a_2	Std Err	a_3	Std Err	a_4	Std Err	a_5	Std Err	a_6	Std Err	SSE	MSE	R^2	Adj R^2
7	AUT	52.040	15.124	-0.391	0.397	-5.700	1.483	-0.441	0.402	-1.532	0.420	0.0093	0.0024	-0.609	0.140	1.0647	0.0532	0.6636	0.5626
7	BEL	51.389	15.390	-0.049	0.074	-6.110	1.511	-0.474	0.408	-1.568	0.426	0.0093	0.0025	-0.636	0.145	1.1035	0.0552	0.6400	0.5320
7	CHE	47.445	15.771	-1.133	0.592	-6.066	1.523	-0.315	0.424	-1.396	0.434	0.0089	0.0025	-0.560	0.137	1.1802	0.0590	0.6394	0.5313
7	DNK	51.597	17.190	-0.048	0.111	-6.131	1.472	-0.457	0.404	-1.567	0.463	0.0093	0.0026	-0.656	0.144	1.0165	0.0508	0.6736	0.5757
7	FIN	-46.466	42.859	-0.819	0.354	16.458	11.184	-0.948	0.501	1.823	1.490	-0.0085	0.0078	-0.394	0.205	0.6401	0.0492	0.5452	0.3353
7	GRC	22.851	18.934	-0.232	0.133	-4.969	1.361	-0.311	0.404	-0.815	0.487	0.0051	0.0027	-0.635	0.146	1.0610	0.0531	0.6535	0.5496
7	IRL	54.647	11.474	-0.434	0.139	-7.625	1.177	-0.438	0.300	-1.791	0.320	0.0111	0.0019	-0.754	0.115	0.6013	0.0301	0.7961	0.7350
7	ISL	-69.371	46.010	0.244	0.318	21.588	11.196	-0.885	0.388	2.582	1.565	-0.0129	0.0081	-0.715	0.213	0.5109	0.0393	0.5757	0.3799
7	NLD	35.738	20.446	-0.169	0.143	-5.605	1.468	-0.228	0.438	-1.180	0.531	0.0073	0.0030	-0.659	0.144	1.0541	0.0527	0.6561	0.5530
7	PRT	52.319	14.223	-0.207	0.165	-6.754	1.338	-0.448	0.352	-1.628	0.387	0.0099	0.0022	-0.685	0.137	0.8287	0.0414	0.7190	0.6347
8	YUG	13.506	19.916	0.415	0.136	0.750	2.659	-0.270	0.275	-0.301	0.583	0.0019	0.0032	-0.428	0.145	0.3851	0.0241	0.6147	0.4702
9	ARG	60.181	17.229	0.822	0.481	-5.760	1.472	-0.614	0.463	-1.614	0.446	0.0086	0.0025	-0.585	0.149	1.3392	0.0670	0.6575	0.5548
9	BOL	-124.600	59.380	-0.093	0.213	31.057	14.229	-0.632	0.452	4.339	1.975	-0.0222	0.0103	-0.921	0.363	0.6440	0.0537	0.5376	0.3065
9	CHL	60.078	38.728	-0.154	0.457	-8.623	2.587	-0.345	0.975	-1.830	1.028	0.0107	0.0061	-0.801	0.183	5.7106	0.2855	0.5494	0.4142
9	COL	42.041	22.788	-0.212	0.236	-6.192	1.701	-0.369	0.546	-1.294	0.587	0.0077	0.0032	-0.661	0.154	1.8918	0.0946	0.6065	0.4885
9	ECU	16.623	33.045	0.157	0.165	0.534	4.458	-0.681	0.466	-0.362	0.961	0.0024	0.0052	-0.626	0.198	0.9169	0.0573	0.5830	0.4266
9	PER	119.735	34.462	0.475	0.584	-18.478	3.460	-0.204	0.808	-3.632	0.963	0.0202	0.0056	-1.227	0.198	3.2972	0.1735	0.7383	0.6557
9	PRY	-157.498	126.630	0.237	0.346	44.671	48.173	-0.127	0.680	5.750	5.185	-0.0296	0.0265	-0.978	0.348	0.5374	0.0597	0.5860	0.3099
9	URY	144.938	233.721	-0.290	0.321	-135.552	187.315	-0.590	0.417	-9.930	14.325	0.0495	0.0705	-1.540	0.541	0.1110	0.0278	0.7959	0.4897
9	VEN	51.002	23.522	0.015	0.242	-5.937	1.626	-0.481	0.460	-1.478	0.613	0.0086	0.0034	-0.661	0.165	1.3580	0.0679	0.6190	0.5047
10	BRB	-86.951	34.049	-0.372	0.161	14.139	6.436	-0.408	0.383	2.468	1.052	-0.0123	0.0056	-0.947	0.233	0.5733	0.0410	0.5915	0.4164
10	CRI	-18.348	32.441	-0.007	0.073	5.156	6.127	-0.553	0.457	0.623	1.019	-0.0028	0.0055	-0.726	0.229	0.9432	0.0629	0.4375	0.2125
10	GTM	153.110	46.467	0.100	0.186	-14.100	4.917	-1.616	0.559	-4.336	1.308	0.0250	0.0074	-1.174	0.242	1.2791	0.0752	0.6308	0.5005
10	HND	260.439	163.309	-1.019	0.647	-156.704	98.197	-0.885	0.411	-13.609	8.426	0.0693	0.0421	-1.191	0.301	0.1958	0.0326	0.8364	0.6727
10	JAM	6.609	28.984	-0.210	0.405	-0.629	3.810	-0.386	0.467	-0.225	0.859	0.0016	0.0048	-0.525	0.214	1.1831	0.0696	0.5209	0.3518
10	NIC	-12.198	34.265	-0.060	0.051	0.746	3.916	-0.294	0.462	0.274	0.961	-0.0010	0.0053	-0.651	0.215	1.1131	0.0655	0.5493	0.3902
10	PAN	45.027	22.842	-0.891	0.327	-16.359	4.221	-0.568	0.459	-1.863	0.649	0.0104	0.0037	-0.707	0.212	1.2182	0.0677	0.5110	0.3481
10	SLV	9.075	53.260	0.732	0.153	8.215	19.922	-0.541	0.296	0.155	2.148	-0.0004	0.0110	-0.526	0.175	0.1599	0.0178	0.8634	0.7723
10	TTO	-31.325	27.484	-0.119	0.329	5.173	3.851	-0.581	0.610	0.914	0.799	-0.0046	0.0044	-0.552	0.202	0.8577	0.0536	0.5015	0.3146

Table M.8: Stock adjustment results, fixed λ (equation 5.14); second traffic demand predicted results (equation 5.7); US manufacturers price index, model 3 (table 3.12).

	Country	a_0	Std Err	a_1	Std Err	a_2	Std Err	a_3	Std Err	a_4	Std Err	a_5	Std Err	a_6	Std Err	SSE	MSE	R^2	Adj R^2
1	CAN	19.303	32.040	0.548	0.193	-6.311	1.931	-0.011	0.880	-0.619	0.820	0.0029	0.0047	-0.885	0.165	4.5532	0.2277	0.6752	0.5777
1	DEU	73.693	18.805	-0.043	0.030	-7.649	1.624	0.124	0.450	-2.189	0.523	0.0133	0.0031	-0.685	0.137	1.1307	0.0565	0.6878	0.5942
1	ESP	33.064	13.831	-0.497	0.209	-6.457	1.234	0.206	0.368	-1.147	0.368	0.0074	0.0021	-0.726	0.131	0.7501	0.0375	0.7456	0.6693
1	FRA	34.959	22.506	-0.296	0.195	-6.508	1.546	0.030	0.456	-1.213	0.580	0.0079	0.0032	-0.838	0.166	1.1411	0.0571	0.6561	0.5529
1	GBR	14.161	16.999	-0.084	0.030	-5.913	1.197	-0.166	0.359	-0.679	0.440	0.0044	0.0025	-0.751	0.127	0.7012	0.0351	0.7622	0.6909
1	ITA	99.724	18.878	-1.107	0.511	-9.421	1.710	-1.314	0.553	-2.858	0.531	0.0179	0.0031	-0.747	0.137	1.4147	0.0707	0.7259	0.6436
1	JPN	127.701	56.564	-0.537	0.467	-12.013	5.924	-0.064	0.960	-3.842	1.642	0.0244	0.0098	-1.049	0.265	4.2127	0.2340	0.5145	0.3526
1	LUX	17.553	24.347	-1.335	0.586	-2.401	3.586	-0.051	0.389	-0.609	0.746	0.0047	0.0044	-0.401	0.170	0.6905	0.0406	0.6104	0.4729
1	NOR	69.698	12.728	0.268	0.229	-6.915	1.241	-0.289	0.330	-2.048	0.360	0.0122	0.0021	-0.790	0.134	0.6359	0.0318	0.7438	0.6669
1	SWE	51.612	20.210	-0.113	0.111	-6.597	1.470	0.012	0.382	-1.612	0.527	0.0100	0.0031	-0.730	0.147	0.8632	0.0432	0.6678	0.5682
1	USA	-68.751	34.445	-0.504	0.760	-3.134	2.016	-0.643	1.033	1.532	0.875	-0.0082	0.0051	-0.680	0.263	3.6334	0.1817	0.5507	0.4159
2	AUS	-44.655	30.426	0.389	0.211	0.905	3.121	0.710	0.851	1.154	0.842	-0.0067	0.0046	-0.641	0.246	2.3400	0.1300	0.4761	0.3015
2	BRA	27.433	18.277	0.316	0.237	-3.071	1.965	0.627	0.654	-0.792	0.512	0.0048	0.0030	-0.583	0.197	1.7647	0.0882	0.5051	0.3566
2	IDN	-39.981	27.172	-0.238	0.155	-0.965	3.431	1.094	0.680	0.865	0.773	-0.0044	0.0044	-0.552	0.214	2.0919	0.1162	0.4304	0.2406
2	IND	-56.771	52.674	-1.206	0.573	6.227	7.075	1.419	0.896	1.364	1.567	-0.0051	0.0088	-0.432	0.190	2.4109	0.1507	0.4205	0.2032
2	KOR	-81.481	44.550	-0.326	0.459	4.449	3.882	1.274	0.955	2.107	1.223	-0.0115	0.0071	-0.540	0.302	3.5485	0.1971	0.4415	0.2554
2	MEX	21.343	41.721	0.158	0.094	-1.186	2.838	-1.554	1.563	-0.471	1.124	0.0022	0.0066	-0.116	0.220	7.8639	0.4139	0.2402	0.0003
2	MYS	-136.153	34.011	0.658	0.203	14.661	4.248	0.750	0.761	4.035	0.997	-0.0234	0.0057	-0.501	0.257	2.2923	0.1274	0.6130	0.4841
2	SAU	17.465	22.932	-0.005	0.087	-2.789	1.874	0.377	0.788	-0.551	0.603	0.0034	0.0035	-0.455	0.215	2.3967	0.1198	0.3906	0.2078
2	THA	-48.671	59.231	0.073	0.103	2.750	7.870	-0.090	0.905	1.277	1.728	-0.0071	0.0095	-0.486	0.241	3.1342	0.1959	0.3003	0.0380
2	TUR	-27.782	22.674	-0.092	0.197	5.194	2.945	-0.213	0.412	0.871	0.654	-0.0044	0.0036	-0.187	0.157	0.7278	0.0404	0.6836	0.5782
3	BFA	-163.521	132.028	0.204	0.254	55.127	53.957	-0.442	0.676	6.413	5.567	-0.0329	0.0284	-0.792	0.320	0.5124	0.0569	0.4676	0.1127
3	CAF	-68.653	59.030	-0.274	1.062	13.247	14.118	-0.466	0.546	2.222	2.042	-0.0116	0.0109	-0.479	0.266	0.6266	0.0482	0.3300	0.0207
3	CIV	-15.125	28.598	-0.230	0.284	0.166	3.150	-0.180	0.428	0.335	0.793	-0.0014	0.0044	-0.667	0.237	0.6951	0.0409	0.5390	0.3763
3	COG	-111.054	162.972	0.126	0.383	25.662	62.357	-0.151	0.646	3.798	6.738	-0.0199	0.0347	-0.635	0.323	0.5167	0.0574	0.3938	-0.0103
3	DZA	9.605	14.252	0.097	0.027	1.558	2.121	-0.252	0.500	-0.114	0.417	0.0007	0.0024	-0.162	0.191	1.0622	0.0531	0.7063	0.6181
3	ETH	30.846	21.185	0.007	0.241	-4.629	1.549	-0.127	0.584	-0.928	0.493	0.0054	0.0027	-0.561	0.171	1.3967	0.0698	0.5961	0.4749
3	GAB	-93.366	34.025	-0.405	0.193	11.606	4.851	-0.441	0.419	2.684	0.996	-0.0141	0.0054	-0.651	0.201	0.5591	0.0373	0.5134	0.3187
3	GHA	30.214	35.518	0.467	0.167	5.009	4.271	-0.269	0.371	-0.394	0.969	0.0026	0.0052	-0.815	0.200	0.4767	0.0318	0.5859	0.4202
3	GIN	127.390	190.080	-0.124	0.390	-101.131	94.637	-0.673	0.508	-7.867	8.649	0.0398	0.0436	-1.423	0.391	0.1754	0.0292	0.7558	0.5116
3	KEN	24.264	20.147	0.132	0.086	-1.959	2.625	-0.526	0.414	-0.626	0.572	0.0034	0.0031	-0.222	0.172	0.8035	0.0423	0.7636	0.6889

Table M.8: Continued.

	Country	a_0	Std Err	a_1	Std Err	a_2	Std Err	a_3	Std Err	a_4	Std Err	a_5	Std Err	a_6	Std Err	SSE	MSE	R^2	Adj R^2
3	MAR	-10.553	18.102	-1.048	0.312	-8.348	1.472	-0.142	0.444	-0.177	0.442	0.0017	0.0025	-0.924	0.154	0.8346	0.0417	0.7582	0.6857
3	MDG	-90.455	35.911	-3.901	1.876	16.812	6.409	-0.709	0.547	2.857	1.121	-0.0143	0.0059	-0.415	0.182	0.9363	0.0624	0.4826	0.2757
3	MRT	-12.521	38.480	0.399	0.287	1.621	7.504	-0.019	0.554	0.425	1.218	-0.0021	0.0066	-0.860	0.366	0.7731	0.0515	0.4484	0.2278
3	NER	172.188	149.161	-0.011	0.025	-168.526	87.568	-0.582	0.503	-12.025	7.474	0.0589	0.0374	-1.361	0.393	0.1631	0.0272	0.7802	0.5604
3	NGA	27.737	14.546	-0.067	0.045	-5.207	1.454	0.368	0.484	-0.903	0.395	0.0053	0.0023	-0.561	0.175	1.2003	0.0600	0.6576	0.5548
3	SEN	15.973	28.818	0.063	0.255	-1.565	3.927	-0.165	0.387	-0.485	0.837	0.0033	0.0046	-0.810	0.241	0.5927	0.0370	0.5655	0.4026
3	TCD	-329.595	121.188	-1.628	0.489	128.200	49.346	-0.652	0.460	13.460	5.063	-0.0668	0.0254	-0.951	0.239	0.2257	0.0251	0.7140	0.5234
3	TUN	-6.721	17.055	0.381	0.117	3.637	2.836	-0.329	0.522	0.346	0.529	-0.0019	0.0031	-0.134	0.207	1.1112	0.0556	0.6882	0.5947
3	TZA	-9.016	18.713	5.441	4.662	-0.547	2.317	-0.168	0.484	-0.131	0.447	0.0016	0.0027	-0.351	0.187	0.8422	0.0443	0.7522	0.6740
3	ZAF	79.832	29.090	0.289	0.152	-6.108	1.457	0.186	0.494	-2.113	0.715	0.0118	0.0039	-0.509	0.157	1.0949	0.0547	0.6826	0.5874
3	ZMB	-23.069	22.875	0.119	0.232	5.196	3.616	-0.356	0.462	0.805	0.670	-0.0042	0.0037	-0.394	0.200	0.7010	0.0438	0.4160	0.1970
4	ARE	-289.857	213.271	0.153	0.585	62.504	65.065	0.312	1.058	9.610	7.947	-0.0507	0.0408	-0.701	0.338	1.4349	0.1435	0.4959	0.1934
4	EGY	29.372	18.041	0.018	0.018	-4.516	1.646	0.201	0.613	-0.893	0.473	0.0053	0.0027	-0.613	0.196	1.6114	0.0806	0.5595	0.4273
4	IRN	-44.122	33.584	0.003	0.017	2.293	4.039	0.324	0.784	1.139	0.931	-0.0061	0.0052	-0.536	0.224	2.7262	0.1515	0.3061	0.0748
4	ISR	32.485	15.721	-0.057	0.084	-5.241	1.488	-0.225	0.496	-1.045	0.416	0.0060	0.0024	-0.512	0.201	1.2642	0.0632	0.6336	0.5237
4	JOR	38.908	17.226	0.310	0.139	-5.695	1.619	0.390	0.568	-1.168	0.452	0.0065	0.0025	-0.747	0.191	1.3550	0.0678	0.6297	0.5186
4	KWT	-33.734	29.108	0.616	0.444	-1.934	1.723	0.927	0.863	0.630	0.728	-0.0036	0.0043	-0.671	0.232	3.1479	0.1574	0.3810	0.1953
4	OMN	-326.896	121.928	0.736	0.444	67.297	31.973	0.272	0.850	10.786	4.299	-0.0576	0.0225	-0.915	0.276	1.1791	0.1072	0.5984	0.3794
4	QAT	-287.153	147.698	-0.074	0.454	68.189	44.694	0.038	0.797	9.780	5.471	-0.0511	0.0282	-0.741	0.323	0.9063	0.0906	0.5022	0.2035
4	SYR	40.257	15.425	0.856	0.275	-5.430	1.470	0.367	0.547	-1.183	0.412	0.0064	0.0023	-0.635	0.163	1.2613	0.0631	0.6590	0.5567
4	YEM	22.110	19.260	0.520	0.228	-3.940	1.797	0.360	0.693	-0.642	0.518	0.0032	0.0030	-0.510	0.184	2.0446	0.1022	0.4700	0.3110
5	BGD	-171.973	246.271	-1.129	0.836	22.672	67.904	-1.493	1.663	4.787	8.729	-0.0242	0.0448	-0.408	0.262	1.9325	0.1933	0.3807	0.0092
5	CYP	-91.470	59.418	0.402	0.443	26.444	17.010	-0.817	0.541	3.391	2.165	-0.0177	0.0114	-0.468	0.234	0.5099	0.0425	0.3939	0.0909
5	LKA	-51.578	68.206	0.007	0.084	3.684	8.433	-0.288	0.876	1.358	1.949	-0.0074	0.0106	-0.527	0.239	3.2307	0.2019	0.2792	0.0089
5	PAK	-35.190	52.574	0.044	0.083	1.732	3.785	0.564	1.100	0.907	1.362	-0.0049	0.0076	-0.602	0.243	3.8053	0.2114	0.3678	0.1571
5	PHL	-91.932	38.125	0.442	0.415	2.971	4.255	1.289	0.939	2.368	1.043	-0.0139	0.0057	-0.580	0.300	3.4306	0.1906	0.4605	0.2807
5	SGP	-55.391	60.574	-0.174	1.517	3.454	8.487	-0.269	0.911	1.364	1.757	-0.0073	0.0099	-0.535	0.257	3.2500	0.2031	0.2785	0.0080
5	VNM	-96.972	28.288	-0.001	0.001	11.437	4.172	0.365	0.639	2.820	0.831	-0.0154	0.0046	-0.450	0.227	1.6012	0.0942	0.6280	0.4967
6	FJI	-413.522	248.442	0.298	0.238	120.430	92.809	-0.081	0.787	15.295	10.088	-0.0798	0.0516	-1.040	0.381	0.6052	0.0757	0.6600	0.4051
6	NZL	-223.379	81.178	0.995	0.690	12.138	7.667	1.533	1.997	6.064	2.184	-0.0365	0.0124	-0.169	0.666	14.9962	0.8331	0.5094	0.3459
6	PNG	-3180.3	481.495	1.242	0.481	2774.85	521.083	-7.095	1.412	207.168	35.567	-1.0154	0.1720	1.914	0.751	0.1632	0.0544	0.9780	0.9341

Table M.8: Continued.

	Country	a_0	Std Err	a_1	Std Err	a_2	Std Err	a_3	Std Err	a_4	Std Err	a_5	Std Err	a_6	Std Err	SSE	MSE	R^2	Adj R^2
7	AUT	44.287	14.430	-0.367	0.408	-5.375	1.499	-0.028	0.456	-1.349	0.406	0.0084	0.0023	-0.629	0.151	1.1284	0.0564	0.6434	0.5365
7	BEL	41.550	14.583	-0.040	0.077	-5.625	1.501	0.073	0.463	-1.330	0.408	0.0081	0.0024	-0.655	0.155	1.1766	0.0588	0.6161	0.5010
7	CHE	37.081	14.376	-1.330	0.605	-5.955	1.487	0.409	0.480	-1.156	0.400	0.0077	0.0023	-0.609	0.144	1.1702	0.0585	0.6425	0.5352
7	DNK	46.200	17.038	-0.025	0.116	-5.864	1.516	-0.079	0.464	-1.440	0.463	0.0087	0.0026	-0.664	0.153	1.0801	0.0540	0.6532	0.5492
7	FIN	-63.575	54.501	-0.604	0.353	17.262	14.273	-0.677	0.611	2.251	1.915	-0.0110	0.0100	-0.347	0.219	0.7457	0.0574	0.4702	0.2257
7	GRC	17.827	17.393	-0.255	0.138	-4.686	1.345	-0.253	0.469	-0.688	0.453	0.0044	0.0026	-0.633	0.151	1.0768	0.0538	0.6484	0.5429
7	IRL	51.594	10.668	-0.540	0.156	-7.460	1.162	-0.508	0.364	-1.728	0.307	0.0109	0.0018	-0.734	0.118	0.6066	0.0303	0.7944	0.7327
7	ISL	-92.892	54.242	0.265	0.340	25.049	13.288	-0.892	0.516	3.299	1.861	-0.0169	0.0097	-0.605	0.227	0.5818	0.0448	0.5168	0.2937
7	NLD	24.154	17.473	-0.223	0.133	-5.374	1.392	0.294	0.448	-0.912	0.460	0.0059	0.0026	-0.702	0.149	1.0458	0.0523	0.6588	0.5565
7	PRT	43.198	13.470	-0.220	0.172	-6.332	1.348	0.009	0.397	-1.409	0.372	0.0087	0.0021	-0.696	0.147	0.8956	0.0448	0.6963	0.6052
8	YUG	7.130	18.950	0.401	0.137	1.604	2.714	-0.275	0.313	-0.112	0.565	0.0009	0.0031	-0.392	0.154	0.3895	0.0243	0.6102	0.4640
9	ARG	45.552	16.489	0.686	0.496	-5.403	1.504	0.166	0.518	-1.280	0.433	0.0070	0.0025	-0.647	0.159	1.4495	0.0725	0.6293	0.5181
9	BOL	-166.715	70.178	-0.194	0.215	37.975	17.243	-0.667	0.592	5.613	2.385	-0.0288	0.0124	-1.016	0.372	0.6775	0.0565	0.5136	0.2705
9	CHL	44.905	34.654	-0.083	0.443	-8.032	2.412	0.417	0.999	-1.455	0.930	0.0086	0.0056	-0.822	0.184	5.6967	0.2848	0.5505	0.4156
9	COL	28.653	21.528	-0.254	0.237	-5.774	1.645	0.333	0.589	-0.979	0.557	0.0061	0.0031	-0.706	0.158	1.9044	0.0952	0.6039	0.4850
9	ECU	-3.429	31.271	0.090	0.172	2.443	4.549	-0.262	0.534	0.176	0.927	-0.0005	0.0051	-0.633	0.217	1.0236	0.0640	0.5345	0.3599
9	PER	105.257	29.575	0.605	0.523	-18.096	3.237	0.738	0.764	-3.278	0.837	0.0182	0.0048	-1.285	0.191	3.1533	0.1660	0.7497	0.6707
9	PRY	-168.030	121.121	0.273	0.299	48.584	45.139	-0.023	0.715	6.179	4.907	-0.0318	0.0251	-0.999	0.331	0.5394	0.0599	0.5844	0.3073
9	URY	114.596	305.520	-0.192	0.372	-133.779	231.758	-0.390	0.695	-9.154	18.070	0.0451	0.0891	-1.543	0.664	0.1545	0.0386	0.7158	0.2896
9	VEN	42.639	23.026	0.066	0.250	-5.790	1.646	0.318	0.525	-1.295	0.603	0.0077	0.0034	-0.730	0.175	1.4065	0.0703	0.6054	0.4870
10	BRB	-88.723	36.065	-0.411	0.170	12.235	7.403	0.097	0.486	2.401	1.152	-0.0119	0.0061	-0.968	0.249	0.6180	0.0441	0.5597	0.3710
10	CRI	-27.294	33.820	-0.010	0.077	5.349	6.906	-0.164	0.540	0.831	1.092	-0.0040	0.0059	-0.705	0.239	1.0290	0.0686	0.3864	0.1409
10	GTM	100.385	49.402	0.081	0.219	-8.857	5.275	-0.823	0.695	-2.869	1.395	0.0169	0.0079	-0.999	0.285	1.7621	0.1037	0.4914	0.3119
10	HND	188.557	191.183	-1.107	0.798	-139.744	115.217	-0.843	0.657	-11.164	9.860	0.0565	0.0493	-1.240	0.367	0.2723	0.0454	0.7725	0.5449
10	JAM	-3.756	27.159	-0.246	0.412	-0.122	3.849	0.091	0.513	0.031	0.821	0.0002	0.0046	-0.542	0.224	1.2286	0.0723	0.5025	0.3269
10	NIC	-22.522	31.352	-0.067	0.051	1.248	3.869	0.106	0.493	0.526	0.894	-0.0024	0.0049	-0.683	0.223	1.1366	0.0669	0.5398	0.3773
10	PAN	33.181	21.814	-0.867	0.347	-15.441	4.344	-0.033	0.523	-1.557	0.631	0.0088	0.0036	-0.717	0.225	1.3217	0.0734	0.4695	0.2927
10	SLV	-27.056	68.298	0.751	0.174	19.117	25.454	-0.314	0.425	1.502	2.758	-0.0074	0.0141	-0.509	0.203	0.2068	0.0230	0.8233	0.7055
10	TTO	-14.522	34.378	0.434	0.450	5.013	3.973	0.783	0.949	0.473	0.984	-0.0020	0.0055	-0.660	0.234	0.8694	0.0543	0.4947	0.3052

Table M.9: Stock adjustment results, variable λ (equation 5.17); first traffic demand predicted results (equation 5.6); All manufacturers price index, model 3 (table 3.3).

	Country	ω	S. Err	a_0	S. Err	a_1	S. Err	a_2	S. Err	a_3	S. Err	a_4	S. Err	a_5	S. Err	a_6	S. Err	SSE	MSE	R^2	Adj R^2
1	CAN	0.126	0.132	30.753	35.011	-0.017	0.344	0.147	0.487	-4.606	9.105	-0.887	1.097	0.0051	0.0060	-0.540	0.342	0.5785	0.0526	0.9475	0.9141
1	DEU	-0.079	0.288	59.595	48.904	0.204	0.310	-0.386	0.558	-4.127	5.361	-1.672	1.421	0.0100	0.0082	-0.498	0.278	0.8583	0.0715	0.6711	0.4792
1	ESP	0.003	0.318	2.233	31.468	0.411	0.385	-0.334	0.465	-1.081	3.944	-0.123	0.914	0.0008	0.0052	-0.532	0.243	0.5278	0.0440	0.7133	0.5460
1	FRA	-0.251	0.325	26.082	38.677	0.028	0.255	-0.294	0.457	-1.332	4.600	-0.726	1.135	0.0047	0.0065	-0.468	0.266	0.7342	0.0612	0.6769	0.4885
1	GBR	-0.025	0.398	3.745	31.580	-0.119	0.161	-0.225	0.442	-0.115	3.816	-0.140	0.925	0.0015	0.0053	-0.543	0.286	0.5469	0.0456	0.7028	0.5295
1	ITA	-0.547	0.405	104.175	46.122	0.159	0.305	-0.241	0.478	-8.773	5.063	-2.980	1.342	0.0178	0.0077	-0.727	0.254	1.3832	0.1153	0.6637	0.4675
1	JPN	1.146	0.682	110.187	67.596	0.182	0.470	-0.811	0.681	-7.339	6.531	-3.060	1.926	0.0184	0.0113	-0.636	0.258	2.5308	0.2109	0.6766	0.4879
1	LUX	-0.400	0.327	-5.170	34.231	-0.064	0.402	-0.152	0.403	2.923	4.043	0.179	1.003	-0.0003	0.0058	-0.340	0.277	0.6548	0.0595	0.5723	0.3002
1	NOR	0.151	0.268	33.587	28.937	0.752	0.399	-0.484	0.367	-2.377	3.381	-0.916	0.848	0.0049	0.0049	-0.396	0.247	0.3553	0.0296	0.7631	0.6249
1	SWE	0.047	0.328	17.367	35.330	0.032	0.151	-0.260	0.395	0.357	3.858	-0.441	1.027	0.0031	0.0059	-0.409	0.275	0.4412	0.0368	0.7280	0.5694
1	USA	-0.383	0.205	-52.265	27.466	-0.268	0.085	-0.792	0.239	7.137	1.738	1.596	0.722	-0.0085	0.0041	-0.169	0.110	0.0646	0.0092	0.9843	0.9686
2	AUS	3.640	1.809	-63.259	38.734	0.281	0.341	0.357	0.255	8.229	5.470	1.891	1.195	-0.0107	0.0070	-0.079	0.109	1.4460	0.1205	0.5623	0.3070
2	BRA	-0.545	0.469	-20.533	31.027	0.268	0.334	-0.388	0.519	3.307	3.380	0.659	0.884	-0.0037	0.0051	-0.198	0.206	0.8197	0.0683	0.6534	0.4512
2	IDN	3.248	1.016	-40.806	35.312	-0.045	0.277	0.183	0.121	6.298	4.925	1.233	1.103	-0.0064	0.0064	-0.242	0.083	1.2997	0.1083	0.5477	0.2838
2	IND	-0.272	0.250	-167.205	108.923	-0.350	0.361	0.185	1.011	31.292	20.177	5.303	3.452	-0.0276	0.0188	-0.473	0.251	1.6234	0.1623	0.5003	0.1505
2	KOR	2.883	1.217	-75.434	23.992	0.066	0.087	0.446	0.176	8.893	2.734	2.172	0.690	-0.0118	0.0038	-0.309	0.097	1.4996	0.1250	0.5331	0.2607
2	MEX	0.084	0.519	-23.677	123.999	0.063	0.139	-0.877	1.800	6.536	15.071	0.845	3.545	-0.0041	0.0194	-0.318	0.272	6.7771	0.6161	0.3224	-0.109
2	MYS	0.490	0.357	-30.958	26.224	0.566	0.154	-0.151	0.485	4.300	2.783	1.027	0.739	-0.0061	0.0042	-0.566	0.183	0.7566	0.0631	0.7280	0.5693
2	SAU	-0.427	0.364	-29.576	27.161	0.058	0.074	0.399	0.604	5.391	3.260	0.929	0.776	-0.0047	0.0044	-0.262	0.180	0.9498	0.0792	0.5940	0.3572
2	THA	0.108	0.465	-87.922	148.800	0.061	0.151	0.741	1.018	9.852	24.130	2.527	4.565	-0.0138	0.0246	-0.508	0.333	2.2092	0.2209	0.3885	-0.040
2	TUR	-0.375	0.329	-15.772	27.356	0.188	0.196	0.000	0.382	2.774	3.068	0.513	0.769	-0.0028	0.0042	-0.266	0.150	0.5143	0.0429	0.7552	0.6124
3	BFA	0.008	0.400	-77.451	162.585	0.301	0.277	-0.319	0.541	13.408	54.534	2.450	6.315	-0.0129	0.0326	-0.825	0.407	0.4126	0.0590	0.5472	0.0944
3	CAF	-0.246	0.289	-28.057	40.265	-6.512	3.061	-1.307	0.704	-0.503	8.951	0.506	1.361	-0.0018	0.0074	-0.373	0.198	0.2949	0.0328	0.6000	0.2889
3	CIV	-0.257	0.344	-18.000	30.125	-0.296	0.200	-0.476	0.392	0.847	3.542	0.434	0.857	-0.0019	0.0048	-0.615	0.229	0.4010	0.0365	0.6427	0.4154
3	COG	-0.602	0.520	-101.316	220.563	0.148	0.228	-0.333	0.623	21.313	73.930	3.367	8.593	-0.0177	0.0444	-0.710	0.515	0.3883	0.0555	0.5155	0.0309
3	DZA	-0.374	0.307	-9.431	27.433	-0.230	0.249	-0.496	0.523	2.996	2.937	0.356	0.776	-0.0017	0.0044	-0.039	0.296	0.6113	0.0509	0.7362	0.5824
3	ETH	-0.896	0.631	-24.825	20.900	0.114	0.124	0.266	0.255	3.125	3.368	0.736	0.637	-0.0038	0.0036	-0.416	0.195	0.5716	0.0476	0.7433	0.5936
3	GAB	-0.433	0.290	-48.257	37.273	0.244	0.233	-0.318	0.496	11.749	8.066	1.686	1.244	-0.0088	0.0067	-0.542	0.232	0.4323	0.0432	0.5343	0.2082
3	GHA	-0.471	0.377	-38.873	42.132	0.012	0.247	-0.402	0.709	8.611	7.934	1.301	1.334	-0.0066	0.0072	-0.511	0.409	0.4793	0.0479	0.4839	0.1226
3	GIN	1.719	0.892	605.923	286.842	-0.023	0.311	-0.616	0.493	-337.542	136.340	-30.259	13.020	0.1536	0.0662	-2.450	0.666	0.0785	0.0196	0.8782	0.6650
3	KEN	-0.712	0.545	-14.001	18.057	0.019	0.089	0.116	0.304	0.738	2.831	0.361	0.528	-0.0018	0.0030	-0.420	0.201	0.5597	0.0466	0.7470	0.5994

Table M.9: Continued.

	Country	ω	S. Err	a_0	S. Err	a_1	S. Err	a_2	S. Err	a_3	S. Err	a_4	S. Err	a_5	S. Err	a_6	S. Err	SSE	MSE	R^2	Adj R^2
3	LBY	-0.364	0.333	-25.811	21.729	0.000	0.000	-0.073	0.360	3.687	2.609	0.779	0.626	-0.0041	0.0036	-0.273	0.176	0.5752	0.0479	0.7348	0.5800
3	MAR	-0.292	0.413	8.637	29.158	0.001	0.124	-0.381	0.483	-0.203	3.989	-0.230	0.874	0.0017	0.0050	-0.427	0.242	0.6390	0.0533	0.6900	0.5092
3	MDG	-2.038	2.432	-59.184	47.441	0.984	0.913	0.788	0.666	7.366	10.275	1.712	1.575	-0.0091	0.0085	-0.586	0.231	0.8230	0.0823	0.5025	0.1542
3	MRT	-3.546	1.716	21.675	2.009	0.858	0.166	0.028	0.169	-9.858	1.517	-0.822	0.000	0.0038	0.0002	-0.952	0.174	0.3100	0.0310	0.6988	0.4880
3	NER	0.328	0.296	326.728	213.797	-0.093	0.155	-0.394	0.431	-300.917	138.986	-21.885	11.021	0.1072	0.0549	-2.028	0.801	0.1296	0.0324	0.8059	0.4662
3	NGA	-0.448	0.358	-8.929	23.074	-0.105	0.256	-0.105	0.345	2.531	4.091	0.318	0.694	-0.0014	0.0039	-0.274	0.305	0.5677	0.0473	0.7524	0.6079
3	SEN	-0.859	0.779	16.106	35.664	-0.493	0.410	-0.633	0.378	-7.429	9.892	-0.777	1.246	0.0048	0.0068	-0.817	0.289	0.3626	0.0363	0.6000	0.3201
3	TCD	-0.085	0.328	-106.459	159.030	-1.197	0.642	-0.208	0.466	50.203	59.609	4.652	6.394	-0.0219	0.0325	-0.594	0.315	0.2921	0.0417	0.6041	0.2082
3	TUN	-0.371	0.288	-24.883	22.232	0.464	0.269	-0.307	0.367	3.302	2.707	0.737	0.649	-0.0041	0.0037	-0.350	0.189	0.5250	0.0438	0.7735	0.6413
3	TZA	-0.117	0.308	-8.775	20.994	3.556	1.704	-0.406	0.456	1.691	2.461	0.077	0.596	0.0003	0.0034	-0.335	0.167	0.4450	0.0371	0.7989	0.6815
3	UGA	-0.746	0.541	-14.065	17.896	0.000	0.000	0.077	0.252	0.925	2.561	0.360	0.520	-0.0018	0.0029	-0.422	0.201	0.5609	0.0467	0.7464	0.5985
3	ZAF	-0.739	0.553	-18.434	26.519	0.063	0.277	0.086	0.257	1.069	2.575	0.489	0.714	-0.0026	0.0042	-0.435	0.208	0.5606	0.0467	0.7466	0.5988
3	ZMB	-1.128	1.042	-8.188	33.632	-0.174	0.368	-0.159	0.755	0.964	8.013	0.225	1.147	-0.0008	0.0061	-0.520	0.241	0.4535	0.0454	0.4466	0.0593
4	ARE	-0.783	0.465	-244.431	298.959	1.973	0.757	-1.598	1.126	39.304	81.974	7.498	10.735	-0.0415	0.0558	-1.016	0.417	0.8066	0.1008	0.6591	0.3608
4	EGY	-0.511	0.472	-28.011	36.839	0.140	0.455	0.039	0.363	2.617	2.758	0.781	0.978	-0.0041	0.0058	-0.405	0.254	0.6261	0.0522	0.7230	0.5614
4	IRN	0.292	0.370	77.526	90.582	-0.848	0.644	0.414	0.766	-8.476	8.799	-2.229	2.528	0.0132	0.0144	-0.471	0.245	1.9488	0.1624	0.3872	0.0298
4	ISR	-0.632	0.535	-20.614	22.836	-0.128	0.230	0.043	0.275	2.160	3.465	0.542	0.677	-0.0026	0.0037	-0.383	0.204	0.5450	0.0454	0.7538	0.6102
4	JOR	-0.460	0.410	-20.154	21.563	0.024	0.142	0.016	0.432	2.449	2.713	0.562	0.628	-0.0028	0.0036	-0.369	0.220	0.6280	0.0523	0.7221	0.5600
4	KWT	0.076	0.526	-26.916	67.436	0.194	0.580	0.471	1.067	0.413	4.993	0.576	1.718	-0.0029	0.0098	-0.509	0.348	2.5012	0.2084	0.2791	-0.142
4	LBN	-0.316	0.333	9.219	35.919	0.011	0.010	-0.409	0.516	1.239	2.932	-0.233	0.990	0.0019	0.0058	-0.361	0.187	0.5821	0.0485	0.7424	0.5922
4	OMN	0.007	0.232	221.147	291.266	0.802	0.296	0.244	0.695	-77.021	80.412	-8.654	10.479	0.0438	0.0544	-0.293	0.310	0.7495	0.0937	0.6877	0.4145
4	QAT	-0.209	0.258	-143.034	211.090	0.763	0.471	-0.096	0.723	34.120	56.914	4.886	7.513	-0.0259	0.0390	-0.552	0.353	0.6210	0.0776	0.5795	0.2115
4	SYR	-0.879	0.898	-21.345	20.007	0.166	0.146	0.294	0.262	1.587	2.818	0.554	0.593	-0.0028	0.0033	-0.428	0.186	0.6800	0.0567	0.7209	0.5580
4	YEM	-0.282	0.388	-44.366	43.027	0.204	0.409	0.265	0.682	2.251	4.827	1.140	1.056	-0.0063	0.0063	-0.349	0.261	1.2760	0.1063	0.4797	0.1761
5	BGD	-0.449	0.633	66.206	343.947	-0.043	0.466	1.044	1.500	-30.834	94.353	-3.039	12.335	0.0158	0.0644	-0.350	0.428	1.9393	0.2424	0.3756	-0.171
5	CYP	-0.447	0.397	-68.715	119.318	-0.111	0.305	-0.105	0.548	18.590	35.311	2.445	4.405	-0.0123	0.0228	-0.505	0.316	0.3778	0.0472	0.4574	-0.017
5	LKA	0.538	0.423	-104.461	111.280	-0.398	0.274	0.647	0.803	0.248	17.188	2.363	3.333	-0.0131	0.0182	-0.459	0.294	1.9592	0.1959	0.4580	0.0786
5	PAK	0.086	0.187	-7.786	46.647	-0.349	0.109	-0.164	0.765	-6.257	4.625	-0.097	1.282	0.0006	0.0071	-0.821	0.232	1.5376	0.1281	0.6801	0.4935
5	PHL	0.362	0.579	-20.404	44.643	0.410	0.413	0.571	0.859	0.122	4.738	0.516	1.236	-0.0031	0.0068	-0.393	0.264	1.8215	0.1518	0.4337	0.1034
5	SGP	0.394	0.735	-5.489	184.688	0.801	1.151	0.713	0.958	-6.670	31.257	-0.187	5.663	0.0000	0.0298	-0.258	0.417	2.2407	0.2241	0.3837	-0.048
5	VNM	0.189	0.441	-68.170	42.855	0.001	0.004	-0.184	0.535	9.946	3.956	2.066	1.151	-0.0111	0.0064	-0.368	0.225	0.6458	0.0587	0.7696	0.6229

Table M.9: Continued.

	Country	ω	S. Err	a_0	S. Err	a_1	S. Err	a_2	S. Err	a_3	S. Err	a_4	S. Err	a_5	S. Err	a_6	S. Err	SSE	MSE	R^2	Adj R^2
6	FJI	-0.063	0.703	-641.624	374.859	0.178	0.250	0.145	0.889	203.818	130.009	24.516	14.725	-0.1272	0.0757	-1.132	0.493	0.5266	0.0878	0.7033	0.3572
6	NZL	1.401	0.867	-66.941	32.920	0.331	0.283	1.393	0.852	3.357	3.968	1.707	0.884	-0.0094	0.0050	-0.621	0.315	1.5341	0.1278	0.5270	0.2511
6	PNG	-1.111	0.103	268.601	65.907	0.428	0.095	0.476	0.118	-664.733	52.409	-38.204	3.935	0.1780	0.0193	-2.026	0.097	0.0006	0.0006	0.9993	0.9941
7	AUT	-0.450	0.332	-10.499	24.801	0.150	0.346	-0.072	0.314	1.966	3.030	0.295	0.726	-0.0013	0.0042	-0.361	0.221	0.5001	0.0417	0.7618	0.6228
7	BEL	-0.238	0.362	-10.550	29.796	0.077	0.344	-0.014	0.445	1.761	4.248	0.277	0.916	-0.0011	0.0052	-0.384	0.371	0.5769	0.0481	0.7109	0.5423
7	CHE	-0.482	0.348	-3.022	28.814	0.493	0.365	-0.625	0.644	1.470	3.294	0.099	0.840	-0.0006	0.0046	-0.294	0.180	0.5424	0.0452	0.7549	0.6119
7	DNK	-0.466	0.352	-3.661	23.509	0.104	0.121	0.172	0.390	1.371	2.993	0.102	0.703	-0.0002	0.0040	-0.335	0.193	0.4554	0.0380	0.7776	0.6479
7	FIN	0.020	0.385	-107.951	99.467	-0.740	0.963	-0.224	0.685	24.927	25.304	3.621	3.439	-0.0181	0.0173	-0.522	0.463	0.7004	0.0778	0.4095	-0.050
7	GRC	-0.389	0.325	-20.703	22.764	-0.031	0.176	0.060	0.338	2.638	2.634	0.577	0.643	-0.0028	0.0036	-0.348	0.205	0.4763	0.0397	0.7614	0.6222
7	IRL	-0.172	0.361	2.563	30.855	0.231	0.395	-0.239	0.439	-0.666	4.010	-0.141	0.914	0.0011	0.0053	-0.494	0.248	0.5501	0.0458	0.7012	0.5269
7	ISL	0.071	0.294	-117.886	50.648	-0.069	0.453	-0.819	0.529	30.706	12.244	4.128	1.702	-0.0211	0.0090	-0.589	0.377	0.4411	0.0490	0.6092	0.3052
7	NLD	-0.204	0.326	-18.134	29.349	-0.058	0.083	-0.221	0.485	2.343	3.349	0.494	0.849	-0.0023	0.0048	-0.356	0.215	0.5578	0.0465	0.7205	0.5574
7	PRT	-0.196	0.361	4.762	34.986	0.005	0.266	-0.172	0.442	0.110	3.823	-0.155	0.992	0.0014	0.0058	-0.437	0.270	0.5656	0.0471	0.6926	0.5134
8	YUG	-0.149	0.204	18.166	39.512	0.495	0.184	-0.249	0.363	-1.205	7.585	-0.492	1.265	0.0027	0.0067	-0.331	0.180	0.2386	0.0239	0.6647	0.4299
9	ARG	-0.363	0.396	13.610	25.014	0.467	0.299	-0.385	0.419	-2.182	3.285	-0.386	0.728	0.0021	0.0041	-0.548	0.197	0.5719	0.0477	0.8276	0.7270
9	BOL	-0.602	0.561	-116.834	137.793	-0.435	0.873	-0.784	0.878	49.813	39.847	5.009	4.776	-0.0245	0.0252	-0.845	0.363	0.4929	0.0616	0.6036	0.2568
9	CHL	-0.869	0.539	25.275	38.530	0.038	0.590	-0.340	0.190	-3.405	3.665	-0.755	1.077	0.0045	0.0066	-0.639	0.208	0.6946	0.0579	0.9314	0.8914
9	COL	-0.866	0.560	24.257	23.077	0.064	0.100	-0.581	0.467	-2.399	3.500	-0.667	0.696	0.0039	0.0039	-0.529	0.222	0.6563	0.0547	0.8496	0.7619
9	ECU	-0.741	0.550	15.636	85.612	0.102	0.430	-0.717	0.576	0.492	13.460	-0.341	2.584	0.0023	0.0137	-0.619	0.281	0.6662	0.0666	0.5660	0.2622
9	PER	-0.962	0.588	29.076	20.835	0.117	0.212	-0.481	0.284	-4.228	3.811	-0.860	0.650	0.0050	0.0036	-0.673	0.212	0.6774	0.0565	0.9331	0.8941
9	PRY	-0.454	0.423	-69.303	156.308	0.004	0.308	-0.543	0.697	9.120	54.901	2.011	6.178	-0.0104	0.0317	-0.821	0.364	0.4529	0.0647	0.6319	0.2639
9	URY	-3.817	6.190	676.011	48.071	-0.887	0.579	-0.176	0.554	-466.096	25.449	-38.040	0.218	0.1893	0.0000	-0.412	0.692	0.0805	0.0268	0.8488	0.5465
9	VEN	-0.860	0.616	9.595	23.582	-0.154	0.153	-0.352	0.208	-2.015	3.066	-0.324	0.684	0.0022	0.0039	-0.544	0.214	0.6365	0.0530	0.7303	0.5730
10	BRB	-0.202	0.276	-3.316	44.385	-0.293	0.141	-0.814	0.508	4.405	8.334	0.131	1.420	0.0002	0.0078	-0.796	0.227	0.4335	0.0434	0.6547	0.4129
10	CRI	-0.639	0.548	6.536	47.036	-0.178	0.310	-0.869	0.630	1.865	9.306	-0.110	1.540	0.0012	0.0085	-0.556	0.284	0.6509	0.0651	0.5760	0.2792
10	GTM	0.424	0.418	161.206	62.160	-0.416	0.267	-1.090	0.773	-16.759	7.274	-4.693	1.810	0.0273	0.0102	-1.155	0.302	0.9985	0.0908	0.6776	0.4725
10	HND	0.305	0.461	421.208	264.731	-0.629	0.370	-0.898	0.379	-237.278	152.604	-21.170	13.372	0.1074	0.0671	-1.479	0.447	0.1340	0.0335	0.8854	0.6849
10	JAM	-1.683	1.066	5.330	25.800	0.392	0.281	-0.624	0.183	-1.507	4.034	-0.266	0.796	0.0016	0.0045	-0.657	0.262	0.6338	0.0576	0.6537	0.4333
10	NIC	-0.811	0.540	18.474	28.914	-0.023	0.046	-0.234	0.294	-2.947	4.129	-0.610	0.857	0.0038	0.0048	-0.649	0.227	0.6911	0.0628	0.6224	0.3821
10	PAN	-0.875	0.644	27.206	27.078	0.012	0.250	-0.344	0.356	-3.712	3.957	-0.851	0.806	0.0051	0.0045	-0.632	0.233	0.7043	0.0640	0.6146	0.3693
10	SLV	-0.528	0.555	63.546	134.665	0.213	0.259	-0.571	0.607	-21.042	47.120	-2.526	5.287	0.0134	0.0272	-0.566	0.432	0.4224	0.0603	0.6354	0.2707
10	TTO	-0.577	0.415	-16.718	47.191	-0.149	0.229	-1.143	0.701	5.105	10.438	0.586	1.580	-0.0028	0.0085	-0.501	0.238	0.5434	0.0543	0.5671	0.2641

Table M.10: Stock adjustment results, variable λ (equation 5.17); first traffic demand predicted results (equation 5.6); US manufacturers price index, model 3 (table 3.12).

	Country	ω	S. Err	a_0	S. Err	a_1	S. Err	a_2	S. Err	a_3	S. Err	a_4	S. Err	a_5	S. Err	a_6	S. Err	SSE	MSE	R^2	Adj R^2
1	CAN	0.118	0.124	30.346	31.251	-0.026	0.340	0.326	0.495	-4.546	8.508	-0.874	0.981	0.0051	0.0054	-0.529	0.330	0.5613	0.0510	0.9491	0.9167
1	DEU	-0.042	0.266	45.800	49.488	0.158	0.305	0.011	0.591	-2.904	5.423	-1.300	1.443	0.0080	0.0083	-0.493	0.281	0.8942	0.0745	0.6574	0.4575
1	ESP	0.032	0.321	-7.812	28.945	0.387	0.409	-0.157	0.509	0.107	3.612	0.164	0.843	-0.0008	0.0049	-0.490	0.243	0.5466	0.0456	0.7031	0.5298
1	FRA	-0.208	0.314	14.617	36.763	-0.012	0.258	0.110	0.525	-0.322	4.470	-0.419	1.088	0.0031	0.0063	-0.480	0.276	0.7565	0.0630	0.6672	0.4730
1	GBR	-0.057	0.377	-2.422	28.661	-0.097	0.158	-0.041	0.469	0.558	3.590	0.034	0.848	0.0005	0.0049	-0.499	0.273	0.5580	0.0465	0.6968	0.5200
1	ITA	-0.659	0.497	112.258	41.574	-0.018	0.317	-0.676	0.449	-9.409	4.627	-3.200	1.217	0.0192	0.0070	-0.748	0.240	1.2182	0.1015	0.7038	0.5311
1	JPN	0.984	0.707	110.487	73.487	0.323	0.580	-0.605	0.952	-7.956	7.064	-3.117	2.094	0.0188	0.0123	-0.718	0.284	2.7565	0.2297	0.6477	0.4422
1	LUX	-0.259	0.303	-3.355	34.462	-0.323	0.514	0.395	0.710	2.741	4.055	0.119	1.013	0.0002	0.0059	-0.308	0.265	0.6469	0.0588	0.5775	0.3086
1	NOR	0.245	0.279	25.029	24.718	0.984	0.410	-0.765	0.402	-0.891	2.976	-0.629	0.734	0.0031	0.0043	-0.246	0.249	0.3199	0.0267	0.7867	0.6622
1	SWE	0.068	0.300	2.965	33.368	0.026	0.150	0.141	0.404	1.573	3.690	-0.050	0.977	0.0009	0.0057	-0.371	0.271	0.4531	0.0378	0.7207	0.5578
1	USA	-0.259	0.187	-89.715	26.214	-0.163	0.112	-0.611	0.316	9.634	1.654	2.582	0.687	-0.0140	0.0039	-0.272	0.126	0.1024	0.0146	0.9751	0.9503
2	AUS	2.882	1.026	-61.184	36.443	-0.218	0.441	1.230	0.594	4.681	5.328	1.654	1.123	-0.0089	0.0067	-0.280	0.163	1.2299	0.1025	0.6277	0.4106
2	BRA	-2.775	1.607	-32.903	21.313	0.913	0.325	-1.417	0.430	4.829	2.644	1.056	0.631	-0.0068	0.0037	0.204	0.120	0.7665	0.0639	0.6759	0.4868
2	IDN	0.830	0.743	-66.175	32.556	-0.849	0.421	2.322	0.974	-0.488	4.090	1.427	0.882	-0.0072	0.0051	-0.261	0.188	1.1744	0.0979	0.5913	0.3529
2	IND	-0.275	0.242	-162.174	114.132	-0.363	0.343	0.244	1.134	30.375	21.606	5.142	3.653	-0.0267	0.0199	-0.481	0.246	1.6212	0.1621	0.5010	0.1516
2	KOR	4.086	0.776	-105.755	21.959	0.086	0.029	0.919	0.202	10.929	2.263	3.003	0.623	-0.0167	0.0035	-0.303	0.066	0.9237	0.0770	0.7124	0.5446
2	MEX	0.251	0.689	-43.414	124.251	0.046	0.166	0.289	2.460	8.268	15.512	1.336	3.557	-0.0065	0.0194	-0.394	0.343	6.8676	0.6243	0.3134	-0.124
2	MYS	0.495	0.359	-36.204	25.156	0.559	0.162	0.044	0.592	4.509	2.700	1.154	0.706	-0.0068	0.0040	-0.594	0.195	0.7625	0.0635	0.7259	0.5659
2	SAU	-0.390	0.358	-25.454	27.340	0.045	0.068	0.320	0.721	4.574	3.198	0.800	0.784	-0.0041	0.0045	-0.288	0.221	0.9659	0.0805	0.5871	0.3463
2	THA	0.695	0.715	-36.994	137.533	0.351	0.394	-0.549	0.984	3.663	19.975	1.152	4.077	-0.0070	0.0218	-0.512	0.292	2.2551	0.2255	0.3758	-0.061
2	TUR	-0.405	0.348	-13.737	24.698	0.216	0.198	-0.149	0.433	2.745	2.857	0.471	0.700	-0.0026	0.0039	-0.242	0.168	0.5089	0.0424	0.7577	0.6164
3	BFA	-0.057	0.501	-102.507	199.195	0.243	0.330	-0.196	0.827	21.536	68.254	3.404	7.809	-0.0178	0.0402	-0.787	0.409	0.4296	0.0614	0.5286	0.0571
3	CAF	-0.367	0.363	-45.828	44.263	-3.123	2.398	-0.804	0.658	5.485	9.824	1.260	1.486	-0.0062	0.0080	-0.338	0.210	0.3417	0.0380	0.5365	0.1760
3	CIV	-0.270	0.320	-35.366	33.037	-0.392	0.233	-0.669	0.532	3.007	4.051	0.934	0.951	-0.0046	0.0053	-0.554	0.231	0.3970	0.0361	0.6463	0.4213
3	COG	-0.563	0.501	-126.129	229.402	0.108	0.237	-0.257	0.800	28.606	76.658	4.277	8.931	-0.0223	0.0462	-0.706	0.522	0.3980	0.0569	0.5033	0.0066
3	DZA	-0.385	0.341	-20.574	24.065	-0.146	0.228	-0.337	0.567	4.079	3.037	0.665	0.698	-0.0034	0.0040	-0.075	0.333	0.6382	0.0532	0.7246	0.5640
3	ETH	-0.815	0.669	-18.692	20.785	0.055	0.124	0.089	0.319	2.673	3.504	0.568	0.640	-0.0029	0.0036	-0.347	0.222	0.6212	0.0518	0.7210	0.5583
3	GAB	-0.427	0.296	-53.614	42.573	0.259	0.231	-0.322	0.635	12.646	9.601	1.852	1.441	-0.0097	0.0078	-0.508	0.233	0.4382	0.0438	0.5279	0.1974
3	GHA	-0.448	0.363	-45.804	45.001	0.060	0.212	-0.300	0.799	9.144	9.682	1.487	1.491	-0.0077	0.0080	-0.534	0.409	0.4889	0.0489	0.4736	0.1052
3	GIN	0.764	0.638	821.210	374.509	0.375	0.309	0.278	0.722	-394.581	174.008	-37.868	16.875	0.1929	0.0858	-2.055	0.634	0.0957	0.0239	0.8513	0.5912
3	KEN	0.006	0.411	1.576	23.683	0.110	0.092	-0.284	0.508	-0.446	3.497	-0.041	0.687	0.0003	0.0038	-0.335	0.208	0.5761	0.0480	0.7396	0.5877

Table M.10: Continued.

	Country	ω	S. Err	a_0	S. Err	a_1	S. Err	a_2	S. Err	a_3	S. Err	a_4	S. Err	a_5	S. Err	a_6	S. Err	SSE	MSE	R^2	Adj R^2
3	LBY	-0.368	0.335	-26.843	20.675	0.000	0.000	-0.105	0.439	3.914	2.739	0.813	0.606	-0.0042	0.0035	-0.256	0.202	0.5744	0.0479	0.7351	0.5806
3	MAR	-0.199	0.446	6.049	31.543	-0.041	0.133	-0.061	0.644	-0.568	4.786	-0.200	0.972	0.0016	0.0056	-0.468	0.306	0.6706	0.0559	0.6747	0.4849
3	MDG	-1.642	1.757	-143.276	62.220	0.187	0.808	-1.111	0.894	30.873	13.256	4.802	2.082	-0.0254	0.0113	-0.521	0.248	0.7854	0.0785	0.5252	0.1929
3	MRT	-3.998	1.920	-31.195	0.630	0.683	0.164	-0.748	0.145	3.742	1.440	1.031	0.032	-0.0059	0.0000	-0.752	0.177	0.2991	0.0299	0.7094	0.5060
3	NER	0.335	0.265	209.192	205.425	-0.162	0.127	-0.623	0.465	-277.856	127.523	-18.046	10.331	0.0867	0.0516	-2.257	0.743	0.1081	0.0270	0.8380	0.5546
3	NGA	-0.442	0.367	-10.705	22.442	-0.074	0.239	-0.010	0.392	2.292	4.109	0.347	0.688	-0.0015	0.0039	-0.306	0.304	0.5722	0.0477	0.7504	0.6048
3	SEN	-0.172	0.387	-10.804	43.252	-0.281	0.285	-0.475	0.575	1.116	8.921	0.248	1.396	-0.0006	0.0076	-0.866	0.302	0.4114	0.0411	0.5462	0.2285
3	TCD	-0.089	0.332	-168.107	178.730	-1.285	0.638	-0.421	0.594	71.779	66.532	7.089	7.189	-0.0343	0.0366	-0.644	0.319	0.2796	0.0399	0.6211	0.2422
3	TUN	-0.387	0.315	-30.671	21.460	0.468	0.277	-0.332	0.456	4.160	2.889	0.912	0.642	-0.0051	0.0037	-0.303	0.215	0.5323	0.0444	0.7703	0.6364
3	TZA	-0.424	0.367	-8.738	15.401	2.444	1.213	-0.739	0.405	2.352	2.226	0.171	0.443	-0.0003	0.0025	-0.256	0.181	0.3934	0.0328	0.8222	0.7184
3	UGA	-0.793	0.606	-12.411	16.648	0.000	0.000	-0.050	0.253	1.458	2.657	0.348	0.494	-0.0017	0.0028	-0.353	0.219	0.5648	0.0471	0.7447	0.5957
3	ZAF	-0.786	0.613	-14.686	25.917	0.035	0.281	-0.047	0.259	1.542	2.667	0.421	0.698	-0.0021	0.0042	-0.361	0.227	0.5662	0.0472	0.7441	0.5948
3	ZMB	-1.478	0.988	-54.829	36.672	-0.204	0.184	-1.068	0.588	12.918	8.479	1.881	1.259	-0.0096	0.0068	-0.466	0.199	0.3452	0.0345	0.5788	0.2839
4	ARE	-0.663	0.440	-413.795	282.407	1.544	0.658	-1.185	1.097	87.418	76.603	13.666	10.117	-0.0732	0.0528	-1.024	0.406	0.8639	0.1080	0.6349	0.3154
4	EGY	-0.410	0.423	-20.072	34.586	0.008	0.444	-0.173	0.515	2.937	2.930	0.606	0.917	-0.0031	0.0055	-0.310	0.298	0.6224	0.0519	0.7246	0.5640
4	IRN	0.322	0.409	88.420	96.065	-0.863	0.664	0.084	0.895	-9.313	9.113	-2.515	2.673	0.0148	0.0153	-0.478	0.252	1.9934	0.1661	0.3732	0.0076
4	ISR	-0.627	0.569	-19.924	22.637	-0.143	0.230	-0.094	0.297	2.730	3.401	0.557	0.669	-0.0027	0.0036	-0.326	0.212	0.5417	0.0451	0.7553	0.6126
4	JOR	-0.381	0.388	-20.159	20.523	-0.021	0.140	-0.246	0.582	3.054	2.987	0.596	0.612	-0.0030	0.0035	-0.279	0.272	0.6209	0.0517	0.7253	0.5650
4	KWT	0.014	0.459	-28.612	55.810	0.139	0.510	0.889	1.098	0.094	4.634	0.591	1.440	-0.0029	0.0083	-0.594	0.358	2.4130	0.2011	0.3045	-0.101
4	LBN	-0.368	0.358	-7.329	27.075	0.006	0.008	-0.265	0.470	2.368	2.984	0.223	0.782	-0.0008	0.0046	-0.321	0.221	0.5949	0.0496	0.7367	0.5832
4	OMN	-0.023	0.228	242.742	286.496	0.810	0.299	0.031	0.834	-82.763	79.123	-9.419	10.313	0.0478	0.0536	-0.278	0.310	0.7596	0.0950	0.6835	0.4066
4	QAT	-0.262	0.251	-156.343	190.737	0.832	0.470	-0.611	0.828	38.723	51.623	5.427	6.804	-0.0288	0.0354	-0.504	0.335	0.5855	0.0732	0.6035	0.2566
4	SYR	-0.611	0.694	-23.002	20.678	0.118	0.163	0.100	0.469	2.549	3.200	0.645	0.627	-0.0034	0.0036	-0.361	0.228	0.7234	0.0603	0.7030	0.5298
4	YEM	-0.282	0.383	-38.981	37.727	0.168	0.378	0.283	0.792	2.130	4.985	1.006	0.956	-0.0055	0.0057	-0.361	0.286	1.2790	0.1066	0.4784	0.1742
5	BGD	-0.436	0.695	-41.836	397.045	-0.288	0.451	-0.354	1.695	3.491	110.171	1.062	14.316	-0.0053	0.0747	-0.377	0.437	2.0454	0.2557	0.3414	-0.235
5	CYP	-0.570	0.446	-118.717	120.407	-0.102	0.293	-0.668	0.642	32.687	35.075	4.277	4.430	-0.0219	0.0230	-0.541	0.297	0.3313	0.0414	0.5242	0.1078
5	LKA	0.554	0.476	-113.809	114.845	-0.374	0.285	-0.399	0.959	5.106	17.900	2.824	3.446	-0.0155	0.0188	-0.536	0.293	2.0516	0.2052	0.4325	0.0352
5	PAK	0.093	0.177	14.322	44.667	-0.401	0.108	-1.024	0.845	-7.864	4.200	-0.683	1.221	0.0039	0.0068	-0.787	0.217	1.3755	0.1146	0.7138	0.5469
5	PHL	0.464	0.733	-33.920	46.283	0.299	0.381	0.980	0.845	0.756	5.151	0.857	1.286	-0.0050	0.0070	-0.492	0.278	1.7014	0.1418	0.4710	0.1625
5	SGP	1.919	1.098	-11.233	110.620	0.868	0.835	-0.115	0.592	-5.405	17.522	0.053	3.341	-0.0016	0.0176	-0.153	0.198	2.0609	0.2061	0.4332	0.0364
5	VNM	0.265	0.456	-73.268	43.894	0.001	0.004	0.001	0.588	10.121	3.931	2.187	1.167	-0.0118	0.0065	-0.399	0.254	0.6529	0.0594	0.7670	0.6188

Table M.10: Continued.

	Country	ω	S. Err	a_0	S. Err	a_1	S. Err	a_2	S. Err	a_3	S. Err	a_4	S. Err	a_5	S. Err	a_6	S. Err	SSE	MSE	R^2	Adj R^2
6	FJI	-0.237	0.570	-598.938	273.696	0.305	0.272	-0.845	1.076	195.128	99.580	23.166	10.934	-0.1203	0.0562	-1.019	0.404	0.4810	0.0802	0.7290	0.4128
6	NZL	0.311	0.578	-67.178	35.848	0.441	0.244	1.617	0.882	0.027	3.787	1.600	0.971	-0.0093	0.0055	-0.855	0.320	1.3709	0.1142	0.5773	0.3308
6	PNG	-1.888	0.148	964.011	228.369	1.833	0.397	3.573	1.173	-1422.2	276.404	-90.592	18.533	0.4311	0.0891	-4.741	0.929	0.0007	0.0007	0.9992	0.9932
7	AUT	-0.466	0.347	-11.715	23.574	0.159	0.346	-0.122	0.340	2.215	3.017	0.335	0.697	-0.0015	0.0040	-0.345	0.228	0.4968	0.0414	0.7633	0.6252
7	BEL	-0.203	0.362	-10.500	28.887	0.116	0.352	0.103	0.510	1.439	4.567	0.254	0.918	-0.0010	0.0052	-0.430	0.413	0.5749	0.0479	0.7119	0.5439
7	CHE	-0.384	0.329	-18.507	23.886	0.330	0.314	-0.300	0.598	3.183	2.984	0.542	0.712	-0.0029	0.0041	-0.249	0.204	0.5710	0.0476	0.7420	0.5914
7	DNK	-0.451	0.344	-0.508	23.156	0.095	0.128	0.137	0.463	0.952	3.113	0.009	0.703	0.0003	0.0040	-0.358	0.202	0.4593	0.0383	0.7757	0.6449
7	FIN	0.001	0.388	-110.471	103.031	-0.684	0.934	-0.251	0.779	25.046	25.887	3.688	3.559	-0.0185	0.0180	-0.486	0.428	0.7005	0.0778	0.4094	-0.050
7	GRC	-0.407	0.337	-21.448	22.011	-0.076	0.206	-0.127	0.442	2.710	2.615	0.600	0.628	-0.0029	0.0035	-0.350	0.204	0.4741	0.0395	0.7625	0.6239
7	IRL	-0.147	0.363	-4.431	28.601	0.199	0.414	-0.077	0.502	0.185	3.731	0.060	0.854	0.0000	0.0050	-0.463	0.248	0.5626	0.0469	0.6944	0.5161
7	ISL	0.138	0.290	-147.742	56.418	-0.197	0.481	-0.916	0.705	37.338	14.854	5.139	1.968	-0.0265	0.0104	-0.401	0.423	0.4752	0.0528	0.5789	0.2514
7	NLD	-0.189	0.333	-22.749	28.828	-0.052	0.088	-0.125	0.548	2.915	3.323	0.627	0.839	-0.0030	0.0048	-0.333	0.225	0.5649	0.0471	0.7169	0.5517
7	PRT	-0.166	0.365	-2.535	30.327	0.036	0.255	0.006	0.468	0.560	3.722	0.035	0.881	0.0003	0.0051	-0.443	0.284	0.5727	0.0477	0.6888	0.5073
8	YUG	-0.200	0.194	2.608	38.823	0.489	0.175	-0.565	0.415	2.554	7.828	0.050	1.264	-0.0002	0.0067	-0.284	0.169	0.2092	0.0209	0.7060	0.5001
9	ARG	-0.135	0.353	9.680	26.245	0.616	0.306	-0.063	0.564	-2.239	3.575	-0.300	0.770	0.0015	0.0043	-0.585	0.207	0.5886	0.0491	0.8226	0.7191
9	BOL	-3.413	2.445	-271.040	0.177	-1.563	0.139	-2.117	0.640	127.913	0.000	12.132	0.000	-0.0590	0.0001	-1.015	0.177	0.4042	0.0449	0.6750	0.4583
9	CHL	-0.804	0.512	13.025	39.777	0.214	0.621	-0.316	0.290	-3.068	3.847	-0.439	1.119	0.0026	0.0068	-0.688	0.202	0.7459	0.0622	0.9263	0.8834
9	COL	-0.593	0.421	12.211	26.280	-0.028	0.107	-0.061	0.588	-1.890	3.738	-0.387	0.780	0.0026	0.0044	-0.598	0.223	0.7196	0.0600	0.8351	0.7390
9	ECU	-2.458	1.872	-88.895	75.019	-0.417	0.315	-0.767	0.809	16.126	14.057	2.781	2.386	-0.0142	0.0127	-0.687	0.365	0.6244	0.0624	0.5932	0.3084
9	PER	-0.861	0.568	26.343	23.048	0.089	0.277	-0.452	0.490	-3.954	4.032	-0.794	0.708	0.0047	0.0039	-0.683	0.209	0.7466	0.0622	0.9263	0.8833
9	PRY	-0.568	0.511	-163.955	162.070	0.011	0.307	-0.693	0.899	38.774	56.076	5.600	6.363	-0.0290	0.0328	-0.910	0.338	0.4530	0.0647	0.6318	0.2636
9	URY	-4.265	7.696	657.200	43.997	-0.887	0.694	-0.176	0.770	-461.891	26.263	-37.411	0.301	0.1860	0.0000	-0.463	0.593	0.0816	0.0408	0.8467	0.3102
9	VEN	-0.646	0.510	1.603	24.809	-0.103	0.174	-0.222	0.379	-0.838	3.139	-0.086	0.717	0.0009	0.0041	-0.509	0.221	0.6910	0.0576	0.7072	0.5364
10	BRB	0.002	0.275	-13.328	55.201	-0.288	0.158	-0.016	0.629	3.266	10.692	0.285	1.785	-0.0006	0.0097	-0.822	0.256	0.5313	0.0531	0.5767	0.2804
10	CRI	-1.165	1.110	6.837	60.463	0.134	0.262	-0.420	0.926	0.181	13.268	-0.193	2.048	0.0015	0.0111	-0.716	0.294	0.7524	0.0752	0.5099	0.1668
10	GTM	0.595	0.563	123.064	62.933	-0.564	0.267	-0.367	0.824	-12.778	7.247	-3.625	1.839	0.0215	0.0105	-0.985	0.313	1.1436	0.1040	0.6308	0.3958
10	HND	-0.064	0.506	161.496	371.717	-0.730	0.513	-0.798	0.723	-112.382	207.869	-9.211	18.468	0.0469	0.0927	-1.265	0.502	0.2112	0.0528	0.8194	0.5034
10	JAM	-3.582	1.041	-4.343	2.384	0.475	0.215	-0.780	0.203	-0.417	1.042	0.008	0.017	0.0001	0.0000	-0.647	0.202	0.5680	0.0473	0.6897	0.5345
10	NIC	-0.617	0.433	2.640	33.461	-0.044	0.054	0.032	0.480	-1.811	4.352	-0.194	0.971	0.0015	0.0054	-0.652	0.228	0.7208	0.0655	0.6061	0.3555
10	PAN	-1.854	1.422	18.063	23.756	-0.181	0.161	-0.224	0.299	-2.788	4.357	-0.602	0.764	0.0038	0.0043	-0.581	0.278	0.7087	0.0644	0.6122	0.3654
10	SLV	-0.727	0.774	-10.115	141.228	0.223	0.260	-0.553	0.876	2.831	48.880	0.297	5.517	-0.0011	0.0285	-0.624	0.446	0.4511	0.0644	0.6105	0.2211
10	TTO	-0.506	0.438	-39.794	56.941	0.055	0.202	-0.460	0.850	9.398	13.045	1.298	1.937	-0.0065	0.0104	-0.533	0.266	0.6640	0.0664	0.4710	0.1007

Table M.11: Stock adjustment results, variable λ (equation 5.17); second traffic demand predicted results (equation 5.7); All manufacturers price index, model 3 (table 3.3).

	Country	ω	S. Err	a_0	S. Err	a_1	S. Err	a_2	S. Err	a_3	S. Err	a_4	S. Err	a_5	S. Err	a_6	S. Err	SSE	MSE	R^2	Adj R^2
1	CAN	0.137	0.126	36.473	45.094	-0.108	0.455	0.161	0.490	-6.306	10.863	-1.106	1.528	0.0064	0.0086	-0.538	0.291	0.5760	0.0524	0.9478	0.9145
1	DEU	0.645	0.449	37.940	40.045	-0.163	0.190	-0.473	0.412	-4.402	5.774	-1.177	1.151	0.0075	0.0066	-0.553	0.221	0.8573	0.0714	0.6715	0.4799
1	ESP	-0.124	0.356	9.528	31.830	-0.212	0.288	-0.154	0.429	-1.408	4.346	-0.331	0.950	0.0025	0.0055	-0.500	0.247	0.5410	0.0451	0.7061	0.5346
1	FRA	-0.211	0.253	2.966	37.605	-0.382	0.240	-0.348	0.415	-2.713	4.142	-0.273	1.057	0.0027	0.0060	-0.755	0.287	0.6074	0.0506	0.7328	0.5769
1	GBR	-0.052	0.347	-3.837	31.802	-0.049	0.049	-0.168	0.423	-1.356	4.103	-0.021	0.914	0.0006	0.0052	-0.524	0.244	0.5295	0.0441	0.7123	0.5445
1	ITA	-0.524	0.453	101.073	47.384	-0.039	0.654	-0.325	0.638	-8.734	5.361	-2.899	1.378	0.0174	0.0080	-0.737	0.260	1.4153	0.1179	0.6559	0.4552
1	JPN	1.171	0.650	132.641	66.824	-0.380	0.335	-1.057	0.691	-10.757	6.961	-3.806	1.934	0.0234	0.0114	-0.745	0.264	2.3135	0.1928	0.7043	0.5319
1	LUX	-0.141	0.232	26.853	34.135	-1.489	0.664	-0.117	0.404	-3.013	4.615	-0.865	1.032	0.0063	0.0060	-0.404	0.192	0.4755	0.0432	0.6895	0.4918
1	NOR	-0.192	0.319	38.718	31.118	0.307	0.240	-0.354	0.353	-2.531	3.566	-1.090	0.913	0.0066	0.0052	-0.551	0.239	0.3954	0.0330	0.7363	0.5826
1	SWE	0.047	0.316	16.719	35.246	0.014	0.119	-0.250	0.398	0.596	4.259	-0.417	1.029	0.0030	0.0060	-0.421	0.258	0.4424	0.0369	0.7273	0.5682
1	USA	-0.412	0.277	-69.194	34.309	-0.408	0.270	-0.816	0.331	7.039	2.666	1.984	0.922	-0.0106	0.0053	-0.168	0.152	0.1202	0.0172	0.9708	0.9416
2	AUS	2.191	1.088	-54.091	27.839	0.106	0.118	0.807	0.425	5.232	2.631	1.510	0.768	-0.0081	0.0044	-0.355	0.217	1.3792	0.1149	0.5825	0.3390
2	BRA	-2.147	1.232	-23.235	21.475	0.867	0.289	-1.951	0.573	7.526	2.798	0.999	0.641	-0.0066	0.0038	0.246	0.148	0.6864	0.0572	0.7098	0.5405
2	IDN	0.150	0.526	-3.186	45.435	-0.462	0.340	0.541	0.768	-4.956	6.649	-0.225	1.363	0.0019	0.0078	-0.369	0.252	1.6714	0.1393	0.4184	0.0791
2	IND	-0.523	0.256	-378.147	136.469	-1.866	0.915	-0.541	1.107	84.201	36.662	12.400	4.744	-0.0622	0.0236	-0.747	0.253	1.0988	0.1099	0.6618	0.4250
2	KOR	0.545	0.463	14.723	53.450	-0.693	0.455	0.428	0.666	-1.784	5.189	-0.503	1.513	0.0038	0.0088	-0.412	0.219	1.5642	0.1304	0.5129	0.2288
2	MEX	0.090	0.537	-16.731	120.188	0.085	0.138	-1.046	1.904	6.132	13.807	0.684	3.396	-0.0034	0.0186	-0.302	0.274	6.6696	0.6063	0.3332	-0.091
2	MYS	0.121	0.535	-85.207	37.097	0.636	0.183	-0.118	0.642	11.798	4.468	2.685	1.085	-0.0156	0.0062	-0.418	0.204	0.8898	0.0742	0.6801	0.4935
2	SAU	-0.418	0.351	-23.297	27.176	0.077	0.074	0.190	0.450	5.370	3.062	0.791	0.762	-0.0040	0.0044	-0.238	0.176	0.9177	0.0765	0.6077	0.3789
2	THA	0.539	0.224	294.225	89.452	-1.438	0.252	1.300	0.447	-46.116	12.850	-9.212	2.713	0.0521	0.0151	-0.416	0.156	0.5518	0.0552	0.8473	0.7404
2	TUR	-0.360	0.330	-29.654	30.462	-0.019	0.213	0.147	0.364	4.482	3.540	0.883	0.862	-0.0045	0.0047	-0.246	0.162	0.5549	0.0462	0.7358	0.5817
3	BFA	-7.679	7.879	187.893	0.063	-0.316	0.056	-0.049	0.217	-75.991	0.000	-7.969	0.000	0.0407	0.0000	0.217	0.023	0.3015	0.0431	0.6691	0.3383
3	CAF	-0.424	0.511	-32.634	40.653	-2.144	3.870	-0.311	0.592	0.903	11.297	0.767	1.404	-0.0039	0.0076	-0.320	0.302	0.3975	0.0442	0.4609	0.0415
3	CIV	-0.324	0.373	-13.401	32.354	-0.358	0.323	-0.485	0.421	-0.545	3.442	0.258	0.882	-0.0009	0.0049	-0.681	0.272	0.4268	0.0388	0.6197	0.3777
3	COG	-0.608	0.499	48.254	201.371	-0.239	0.475	-0.430	0.681	-33.743	76.006	-2.753	8.242	0.0140	0.0424	-0.431	0.405	0.4011	0.0573	0.4994	-0.001
3	DZA	-0.621	0.391	25.878	38.080	0.112	0.073	-0.673	0.486	1.182	3.094	-0.503	0.999	0.0028	0.0055	-0.081	0.208	0.5587	0.0466	0.7590	0.6183
3	ETH	-0.672	0.504	-9.225	21.117	0.109	0.193	0.346	0.444	1.882	2.918	0.316	0.567	-0.0015	0.0032	-0.366	0.214	0.5960	0.0497	0.7323	0.5762
3	GAB	-0.304	0.300	-77.759	49.047	-0.647	0.530	-0.553	0.481	5.751	8.329	2.042	1.374	-0.0107	0.0074	-0.638	0.256	0.4193	0.0419	0.5482	0.2319
3	GHA	-0.353	0.191	66.831	35.121	0.650	0.151	-0.989	0.345	7.375	4.834	-1.095	0.974	0.0066	0.0053	-0.967	0.169	0.1694	0.0169	0.8176	0.6900
3	GIN	0.643	0.493	647.485	264.484	0.300	0.441	-0.224	0.447	-314.851	117.886	-30.033	11.545	0.1530	0.0587	-1.929	0.497	0.0787	0.0197	0.8778	0.6640
3	KEN	-0.709	0.563	-12.718	21.796	0.012	0.112	0.090	0.281	0.842	2.864	0.335	0.619	-0.0016	0.0034	-0.413	0.213	0.5613	0.0468	0.7463	0.5983

Table M.11: Continued.

	Country	ω	S. Err	a_0	S. Err	a_1	S. Err	a_2	S. Err	a_3	S. Err	a_4	S. Err	a_5	S. Err	a_6	S. Err	SSE	MSE	R^2	Adj R^2
3	LBY	-0.364	0.333	-25.811	21.729	0.000	0.000	-0.073	0.360	3.687	2.609	0.779	0.626	-0.0041	0.0036	-0.273	0.176	0.5752	0.0479	0.7348	0.5800
3	MAR	-0.273	0.393	-11.393	29.091	-0.653	0.429	-0.410	0.411	-4.046	4.192	0.054	0.787	0.0003	0.0045	-0.708	0.297	0.5308	0.0442	0.7425	0.5923
3	MDG	-1.417	1.568	-66.438	53.401	0.473	1.812	0.414	0.785	11.712	10.809	2.080	1.753	-0.0108	0.0095	-0.641	0.245	0.8880	0.0888	0.4632	0.0874
3	MRT	-0.467	0.381	-47.360	54.375	-0.006	0.412	-1.049	0.553	14.089	12.417	1.773	1.799	-0.0090	0.0095	-0.426	0.335	0.4700	0.0470	0.5433	0.2236
3	NER	0.228	0.275	200.573	325.593	-0.090	0.147	-0.491	0.391	-219.694	161.913	-15.085	15.026	0.0732	0.0763	-1.783	0.628	0.1290	0.0322	0.8068	0.4687
3	NGA	-0.560	0.405	-1.287	28.195	-0.021	0.054	-0.114	0.338	0.589	3.605	0.053	0.821	0.0000	0.0046	-0.325	0.232	0.5688	0.0474	0.7519	0.6072
3	SEN	-0.378	0.392	16.733	39.149	0.153	0.356	-0.596	0.455	2.436	8.625	-0.301	1.232	0.0023	0.0068	-0.727	0.274	0.4035	0.0404	0.5549	0.2434
3	TCD	-0.002	0.295	-184.590	154.925	-1.436	0.593	-0.244	0.427	78.523	57.823	7.772	6.231	-0.0376	0.0316	-0.783	0.313	0.2505	0.0358	0.6605	0.3209
3	TUN	-0.410	0.326	-10.781	28.111	0.681	0.913	-0.287	0.396	6.150	4.525	0.566	0.717	-0.0033	0.0040	-0.107	0.263	0.6259	0.0522	0.7300	0.5724
3	TZA	-0.388	0.407	-26.397	19.260	6.991	4.418	0.408	0.359	0.007	2.468	0.189	0.519	0.0002	0.0031	-0.481	0.184	0.4699	0.0392	0.7876	0.6637
3	UGA	-0.746	0.541	-14.065	17.896	0.000	0.000	0.077	0.252	0.925	2.561	0.360	0.520	-0.0018	0.0029	-0.422	0.201	0.5609	0.0467	0.7464	0.5985
3	ZAF	-0.643	0.470	16.456	36.979	0.116	0.131	0.192	0.290	-0.068	2.716	-0.382	0.956	0.0024	0.0053	-0.360	0.203	0.5267	0.0439	0.7619	0.6230
3	ZMB	-0.772	0.469	-80.013	59.346	0.392	0.288	0.090	0.462	19.348	15.520	2.811	2.132	-0.0149	0.0115	-0.556	0.213	0.4004	0.0400	0.5114	0.1694
4	ARE	-0.255	0.431	-312.794	304.882	0.187	0.628	0.363	1.042	66.476	84.626	10.319	10.989	-0.0544	0.0570	-0.715	0.438	1.3743	0.1718	0.4192	-0.089
4	EGY	-0.640	0.406	11.610	27.748	0.027	0.018	-0.537	0.470	1.354	2.504	-0.183	0.732	0.0012	0.0041	-0.235	0.197	0.5282	0.0440	0.7663	0.6300
4	IRN	0.147	0.380	57.389	75.156	0.077	0.056	0.857	0.809	-14.766	12.323	-2.042	2.300	0.0110	0.0124	-0.182	0.282	1.9161	0.1597	0.3975	0.0461
4	ISR	-0.891	0.567	-20.127	16.634	0.087	0.073	0.008	0.225	1.863	2.528	0.525	0.492	-0.0027	0.0028	-0.493	0.199	0.5025	0.0419	0.7730	0.6406
4	JOR	-0.495	0.387	-3.346	22.987	0.227	0.154	0.331	0.374	1.079	2.673	0.128	0.652	-0.0006	0.0036	-0.456	0.189	0.5303	0.0442	0.7653	0.6284
4	KWT	0.055	0.508	-28.544	59.435	0.323	0.647	0.560	1.064	0.343	4.856	0.615	1.556	-0.0032	0.0089	-0.510	0.307	2.4716	0.2060	0.2876	-0.128
4	OMN	-0.225	0.309	-453.181	255.311	0.895	0.568	0.410	0.870	100.771	67.928	15.304	9.101	-0.0814	0.0477	-1.049	0.402	1.0523	0.1315	0.5616	0.1780
4	QAT	-0.365	0.366	-272.061	236.908	0.132	0.640	0.131	0.855	63.895	64.999	9.240	8.488	-0.0484	0.0441	-0.668	0.444	0.8164	0.1021	0.4471	-0.037
4	SYR	-1.179	0.955	-6.968	16.137	0.537	0.236	0.135	0.210	0.585	2.277	0.204	0.475	-0.0012	0.0026	-0.384	0.164	0.5364	0.0447	0.7798	0.6514
4	YEM	-0.681	0.379	15.292	31.890	0.439	0.198	-0.591	0.549	-1.217	3.420	-0.330	0.879	0.0014	0.0048	-0.253	0.169	0.9609	0.0801	0.6082	0.3796
5	BGD	-0.408	0.591	42.005	334.886	-0.223	0.876	0.932	1.432	-26.624	83.037	-2.321	11.571	0.0122	0.0605	-0.366	0.433	1.9274	0.2409	0.3794	-0.164
5	CYP	-0.440	0.375	-72.023	118.620	0.257	0.513	-0.148	0.536	20.435	35.371	2.641	4.399	-0.0137	0.0228	-0.476	0.317	0.3719	0.0465	0.4659	-0.002
5	LKA	0.064	0.503	-147.345	158.453	-0.056	0.108	0.978	1.002	17.301	25.561	4.199	4.849	-0.0227	0.0262	-0.526	0.347	2.1809	0.2181	0.3967	-0.026
5	PAK	0.230	0.428	-17.985	91.035	0.014	0.121	0.695	1.031	0.502	6.067	0.430	2.334	-0.0022	0.0130	-0.400	0.364	2.9410	0.2451	0.3881	0.0312
5	PHL	2.504	1.057	-66.662	23.606	0.033	0.231	0.416	0.211	7.980	2.791	1.930	0.682	-0.0105	0.0038	-0.287	0.099	1.5378	0.1282	0.5219	0.2430
5	SGP	1.195	1.210	-307.773	134.693	-7.508	4.020	0.750	0.632	39.927	18.419	8.495	3.787	-0.0388	0.0180	-0.955	0.392	1.8422	0.1842	0.4933	0.1387
5	VNM	0.175	0.474	-65.159	32.658	0.000	0.001	-0.202	0.544	9.717	3.943	1.987	0.921	-0.0107	0.0051	-0.358	0.200	0.6463	0.0588	0.7694	0.6226

Table M.11: Continued.

	Country	ω	S. Err	a_0	S. Err	a_1	S. Err	a_2	S. Err	a_3	S. Err	a_4	S. Err	a_5	S. Err	a_6	S. Err	SSE	MSE	R^2	Adj R^2
6	FJI	0.096	0.607	-644.380	382.434	0.233	0.259	0.225	0.828	200.444	136.447	24.423	15.240	-0.1269	0.0782	-1.170	0.481	0.5005	0.0834	0.7180	0.3890
6	NZL	1.923	0.678	-57.039	23.211	0.493	0.232	0.695	0.293	2.278	3.282	1.474	0.668	-0.0085	0.0037	-0.614	0.195	1.2022	0.1002	0.6293	0.4131
6	PNG	-0.772	0.028	613.538	25.979	-0.247	0.018	0.524	0.045	-976.528	20.713	-61.247	1.554	0.2909	0.0076	-1.697	0.032	0.0001	0.0001	0.9999	0.9991
7	AUT	-0.418	0.307	-8.113	24.678	-0.125	0.509	-0.027	0.321	2.075	3.060	0.257	0.728	-0.0009	0.0042	-0.296	0.213	0.5049	0.0421	0.7595	0.6192
7	BEL	-0.185	0.344	-16.040	28.911	-0.037	0.073	-0.002	0.418	2.456	3.394	0.442	0.846	-0.0020	0.0048	-0.342	0.212	0.5702	0.0475	0.7142	0.5475
7	CHE	-0.234	0.269	-11.749	25.753	-1.222	0.685	0.110	0.378	2.108	3.010	0.408	0.742	-0.0012	0.0043	-0.232	0.175	0.4995	0.0416	0.7743	0.6426
7	DNK	-0.423	0.313	-5.698	24.519	-0.057	0.114	-0.267	0.508	1.301	3.077	0.155	0.727	-0.0004	0.0042	-0.362	0.201	0.4751	0.0396	0.7680	0.6327
7	FIN	0.014	0.226	-59.548	54.018	-0.875	0.399	-0.651	0.626	15.299	13.065	2.086	1.829	-0.0102	0.0096	-0.273	0.269	0.5049	0.0561	0.5743	0.2433
7	GRC	-0.400	0.325	-19.819	22.447	-0.015	0.137	0.051	0.390	2.607	2.687	0.556	0.637	-0.0027	0.0036	-0.338	0.193	0.4771	0.0398	0.7610	0.6216
7	IRL	-0.142	0.297	20.801	27.833	-0.530	0.246	-0.190	0.391	-4.278	3.851	-0.836	0.855	0.0058	0.0050	-0.632	0.217	0.4085	0.0340	0.7781	0.6486
7	ISL	-0.108	0.267	-77.996	56.299	0.255	0.355	-0.883	0.538	21.368	12.169	2.780	1.856	-0.0142	0.0098	-0.687	0.253	0.4304	0.0478	0.6186	0.3219
7	NLD	-0.352	0.365	-16.605	30.578	-0.114	0.291	-0.017	0.377	1.578	3.768	0.410	0.843	-0.0017	0.0048	-0.401	0.301	0.5737	0.0478	0.7125	0.5448
7	PRT	-0.173	0.350	5.665	30.830	-0.172	0.205	-0.135	0.414	-0.561	3.808	-0.221	0.911	0.0019	0.0052	-0.418	0.240	0.5319	0.0443	0.7110	0.5424
8	YUG	-0.191	0.230	8.747	40.633	0.401	0.183	-0.060	0.385	1.406	7.609	-0.165	1.295	0.0012	0.0069	-0.386	0.185	0.2683	0.0268	0.6228	0.3588
9	ARG	-0.992	0.659	18.740	19.931	0.780	0.419	-0.312	0.128	-0.917	3.066	-0.430	0.609	0.0021	0.0035	-0.464	0.208	0.5305	0.0442	0.8401	0.7468
9	BOL	-0.641	0.652	-224.395	194.511	0.388	0.711	-0.555	0.681	86.370	87.530	9.366	8.693	-0.0482	0.0451	-0.611	0.523	0.4791	0.0599	0.6147	0.2776
9	CHL	-1.183	0.768	2.952	42.669	0.295	0.411	-0.182	0.306	-1.155	4.751	-0.102	1.243	0.0006	0.0074	-0.511	0.230	0.6805	0.0567	0.9328	0.8936
9	COL	-0.830	0.545	22.562	23.455	0.060	0.124	-0.510	0.470	-2.244	3.564	-0.623	0.709	0.0037	0.0040	-0.539	0.222	0.6643	0.0554	0.8478	0.7590
9	ECU	-0.854	0.634	-3.767	92.381	-0.021	0.389	-0.657	0.616	3.181	15.677	0.224	2.849	-0.0007	0.0151	-0.657	0.310	0.6678	0.0668	0.5650	0.2604
9	PER	-1.431	0.860	8.995	24.898	0.300	0.220	-0.210	0.163	-1.816	3.742	-0.264	0.758	0.0015	0.0044	-0.578	0.223	0.6295	0.0525	0.9378	0.9016
9	PRY	-0.452	0.392	-134.490	182.285	0.277	0.439	-0.255	0.782	35.733	67.488	4.795	7.394	-0.0247	0.0380	-1.002	0.444	0.4280	0.0612	0.6521	0.3042
9	URY	0.752	0.033	-326.074	42.546	-0.691	0.038	-0.740	0.035	243.101	31.829	19.112	2.502	-0.0923	0.0123	-2.435	0.067	0.0006	0.0003	0.9989	0.9949
9	VEN	-0.918	0.687	-3.216	30.243	-0.202	0.201	-0.374	0.195	-1.010	3.030	0.030	0.838	0.0002	0.0048	-0.521	0.214	0.6456	0.0538	0.7265	0.5669
10	BRB	-0.249	0.297	-76.178	45.481	-0.270	0.193	-0.638	0.521	14.959	8.602	2.282	1.422	-0.0113	0.0076	-0.872	0.287	0.5027	0.0503	0.5995	0.3192
10	CRI	-0.818	0.596	3.646	59.738	-0.018	0.157	-0.708	0.600	0.872	17.231	-0.082	2.198	0.0009	0.0117	-0.641	0.250	0.6674	0.0667	0.5652	0.2609
10	GTM	-0.577	0.835	218.843	61.654	0.433	0.285	-1.698	0.839	-16.296	6.706	-5.988	1.745	0.0344	0.0099	-1.221	0.316	1.0518	0.0956	0.6604	0.4443
10	HND	0.083	0.488	465.028	280.941	-0.991	0.730	-0.923	0.427	-257.988	163.517	-23.188	14.262	0.1178	0.0714	-1.311	0.478	0.1452	0.0363	0.8759	0.6587
10	JAM	-1.209	0.839	27.074	20.934	0.257	0.291	-0.778	0.481	-3.366	3.944	-0.855	0.691	0.0050	0.0039	-0.614	0.242	0.6674	0.0607	0.6353	0.4033
10	NIC	-1.230	0.870	41.876	30.056	0.028	0.055	-0.635	0.515	-4.512	4.134	-1.199	0.857	0.0069	0.0046	-0.548	0.275	0.6985	0.0635	0.6184	0.3755
10	PAN	0.388	0.495	-0.394	33.671	-0.813	0.321	-0.636	0.472	-8.773	5.348	-0.448	0.978	0.0027	0.0055	-0.676	0.196	0.7061	0.0642	0.6137	0.3678
10	SLV	0.122	0.284	22.496	76.290	0.760	0.171	-0.476	0.336	5.086	26.476	-0.309	2.994	0.0020	0.0154	-0.536	0.203	0.1523	0.0218	0.8685	0.7370
10	TTO	-0.605	0.437	-33.855	41.349	0.014	0.379	-0.832	0.586	9.595	11.444	1.180	1.453	-0.0059	0.0078	-0.556	0.245	0.5659	0.0566	0.5492	0.2336

Table M.12: Stock adjustment results, variable λ (equation 5.17); second traffic demand predicted results (equation 5.7); US manufacturers price index, model 3 (table 3.12).

	Country	ω	S. Err	a_0	S. Err	a_1	S. Err	a_2	S. Err	a_3	S. Err	a_4	S. Err	a_5	S. Err	a_6	S. Err	SSE	MSE	R^2	Adj R^2
1	CAN	0.149	0.121	48.036	42.712	-0.334	0.513	0.509	0.575	-9.498	10.745	-1.541	1.480	0.0089	0.0084	-0.505	0.279	0.5423	0.0493	0.9508	0.9195
1	DEU	0.006	0.295	42.586	49.114	-0.072	0.222	0.023	0.611	-4.004	7.231	-1.281	1.451	0.0082	0.0084	-0.568	0.281	0.9073	0.0756	0.6523	0.4495
1	ESP	-0.010	0.345	3.896	28.773	-0.305	0.309	0.236	0.510	-1.708	4.376	-0.226	0.879	0.0021	0.0051	-0.551	0.267	0.5380	0.0448	0.7077	0.5372
1	FRA	-0.206	0.253	-7.155	36.710	-0.378	0.256	-0.104	0.488	-1.723	4.050	0.006	1.033	0.0011	0.0059	-0.722	0.288	0.6403	0.0534	0.7183	0.5539
1	GBR	-0.052	0.344	-9.045	28.922	-0.049	0.051	-0.036	0.458	-0.819	3.883	0.124	0.838	-0.0002	0.0048	-0.506	0.246	0.5363	0.0447	0.7086	0.5387
1	ITA	-0.429	0.374	120.406	40.996	-0.859	0.626	-1.414	0.685	-10.776	4.654	-3.425	1.196	0.0210	0.0070	-0.742	0.229	1.0690	0.0891	0.7401	0.5885
1	JPN	1.058	0.721	131.009	75.314	-0.314	0.381	-0.668	0.885	-10.284	7.559	-3.780	2.178	0.0235	0.0129	-0.811	0.303	2.6798	0.2233	0.6575	0.4577
1	LUX	-0.186	0.231	20.902	31.293	-1.422	0.656	0.125	0.417	-2.435	4.370	-0.702	0.956	0.0053	0.0056	-0.397	0.193	0.4748	0.0432	0.6899	0.4926
1	NOR	-0.175	0.326	28.310	28.809	0.266	0.239	-0.295	0.368	-1.351	3.431	-0.791	0.856	0.0050	0.0050	-0.494	0.245	0.4059	0.0338	0.7293	0.5714
1	SWE	0.062	0.298	3.181	33.553	0.021	0.120	0.137	0.406	1.858	3.993	-0.043	0.976	0.0009	0.0057	-0.379	0.254	0.4531	0.0378	0.7207	0.5578
1	USA	-0.325	0.211	-101.513	27.382	-0.063	0.281	-0.753	0.338	10.121	2.057	2.887	0.729	-0.0158	0.0042	-0.308	0.146	0.1304	0.0186	0.9683	0.9366
2	AUS	2.798	1.093	-74.739	31.360	0.008	0.063	1.058	0.515	7.060	2.480	2.103	0.859	-0.0116	0.0049	-0.232	0.142	1.2533	0.1044	0.6207	0.3994
2	BRA	-0.619	0.513	-41.288	31.736	0.309	0.288	-0.727	0.752	7.465	4.526	1.346	0.966	-0.0076	0.0058	0.034	0.323	0.8038	0.0670	0.6601	0.4618
2	IDN	0.322	0.654	-10.506	43.761	-0.439	0.328	1.155	0.753	-4.798	6.959	-0.041	1.354	0.0008	0.0078	-0.455	0.243	1.4688	0.1224	0.4888	0.1907
2	IND	-0.395	0.196	-288.395	88.881	-1.666	0.649	0.811	0.945	59.901	21.377	9.190	2.992	-0.0456	0.0154	-0.661	0.188	1.0505	0.1051	0.6766	0.4503
2	KOR	0.529	0.413	2.132	50.869	-0.688	0.428	0.979	0.745	-1.753	4.860	-0.205	1.437	0.0021	0.0084	-0.512	0.232	1.4121	0.1177	0.5603	0.3038
2	MEX	0.243	0.650	-36.112	114.838	0.075	0.164	-0.077	2.614	7.747	13.380	1.169	3.248	-0.0057	0.0178	-0.356	0.350	6.7827	0.6166	0.3219	-0.110
2	MYS	0.565	0.577	-89.942	31.691	0.566	0.179	0.623	0.602	10.645	3.911	2.714	0.936	-0.0156	0.0054	-0.553	0.191	0.8509	0.0709	0.6941	0.5156
2	SAU	-0.411	0.347	-20.181	27.362	0.081	0.077	0.269	0.599	4.960	3.147	0.699	0.773	-0.0035	0.0045	-0.271	0.208	0.9153	0.0763	0.6087	0.3805
2	THA	0.389	0.226	287.720	119.149	-1.441	0.334	0.831	0.708	-44.147	18.105	-8.942	3.653	0.0506	0.0202	-0.544	0.191	0.8417	0.0842	0.7670	0.6039
2	TUR	-0.381	0.341	-25.635	28.636	-0.004	0.214	0.042	0.405	4.135	3.543	0.778	0.823	-0.0040	0.0045	-0.247	0.181	0.5627	0.0469	0.7321	0.5758
3	BFA	-6.081	7.115	64.126	6.439	-0.265	0.111	-0.254	0.251	-13.885	2.710	-2.138	0.000	0.0113	0.0000	0.155	0.135	0.2761	0.0395	0.6970	0.3940
3	CAF	-0.542	0.586	-43.913	43.851	-1.172	3.133	-0.453	0.637	5.697	12.779	1.272	1.590	-0.0066	0.0085	-0.344	0.291	0.3865	0.0430	0.4757	0.0680
3	CIV	-0.270	0.339	-29.540	37.008	-0.479	0.389	-0.565	0.584	0.852	3.768	0.690	1.008	-0.0032	0.0055	-0.676	0.271	0.4379	0.0398	0.6099	0.3616
3	COG	-0.574	0.510	-45.412	194.778	-0.137	0.446	-0.414	0.799	-1.694	70.836	0.943	7.832	-0.0051	0.0404	-0.529	0.390	0.4056	0.0579	0.4938	-0.012
3	DZA	-0.663	0.467	11.806	32.633	0.108	0.078	-0.748	0.617	3.104	2.757	-0.091	0.842	0.0005	0.0046	0.019	0.279	0.5769	0.0481	0.7511	0.6059
3	ETH	-0.840	0.652	-17.656	21.517	-0.082	0.203	-0.174	0.575	1.300	2.817	0.462	0.568	-0.0023	0.0032	-0.365	0.227	0.6246	0.0521	0.7195	0.5559
3	GAB	-0.307	0.305	-86.004	54.610	-0.627	0.536	-0.568	0.611	7.357	9.503	2.305	1.572	-0.0121	0.0085	-0.569	0.254	0.4359	0.0436	0.5303	0.2015
3	GHA	-0.252	0.232	35.097	46.526	0.494	0.173	-0.491	0.487	7.125	7.508	-0.410	1.373	0.0028	0.0074	-0.791	0.207	0.2829	0.0283	0.6954	0.4822
3	GIN	0.737	0.492	844.398	312.918	0.619	0.388	0.257	0.575	-385.633	140.007	-37.904	13.767	0.1933	0.0700	-2.045	0.525	0.0801	0.0200	0.8756	0.6578
3	KEN	-0.011	0.360	14.554	26.538	0.134	0.092	-0.437	0.491	-0.483	3.218	-0.338	0.746	0.0019	0.0041	-0.244	0.201	0.5447	0.0454	0.7538	0.6101

Table M.12: Continued.

	Country	ω	S. Err	a_0	S. Err	a_1	S. Err	a_2	S. Err	a_3	S. Err	a_4	S. Err	a_5	S. Err	a_6	S. Err	SSE	MSE	R^2	Adj R^2
3	LBY	-0.368	0.335	-26.843	20.675	0.000	0.000	-0.105	0.439	3.914	2.739	0.813	0.606	-0.0042	0.0035	-0.256	0.202	0.5744	0.0479	0.7351	0.5806
3	MAR	-0.225	0.450	-19.409	29.499	-0.704	0.446	-0.285	0.604	-3.662	4.705	0.253	0.827	-0.0008	0.0048	-0.714	0.349	0.5562	0.0464	0.7302	0.5728
3	MDG	-1.224	1.308	-125.623	67.296	-0.458	1.528	-1.084	0.897	27.885	14.600	4.237	2.270	-0.0222	0.0124	-0.535	0.233	0.7832	0.0783	0.5266	0.1952
3	MRT	-1.107	0.761	-196.306	103.790	-0.541	0.603	-2.650	1.053	48.060	24.436	6.765	3.489	-0.0355	0.0183	0.321	0.478	0.4703	0.0470	0.5431	0.2233
3	NER	0.161	0.283	169.906	348.635	-0.054	0.162	-0.538	0.578	-197.959	171.276	-13.361	16.012	0.0648	0.0814	-1.655	0.628	0.1454	0.0363	0.7822	0.4011
3	NGA	-0.508	0.380	-5.923	25.007	-0.013	0.050	-0.031	0.393	1.017	3.428	0.179	0.738	-0.0007	0.0042	-0.346	0.245	0.5737	0.0478	0.7498	0.6038
3	SEN	-0.339	0.383	6.983	45.807	0.118	0.363	-0.529	0.629	3.256	10.477	-0.045	1.489	0.0010	0.0081	-0.713	0.286	0.4402	0.0440	0.5145	0.1746
3	TCD	-0.023	0.279	-284.275	172.254	-1.604	0.571	-0.621	0.545	114.137	63.958	11.743	6.934	-0.0579	0.0352	-0.881	0.309	0.2194	0.0313	0.7027	0.4055
3	TUN	-0.445	0.346	-12.872	26.319	0.910	1.055	-0.412	0.525	8.011	5.630	0.716	0.675	-0.0042	0.0039	0.004	0.344	0.6222	0.0519	0.7315	0.5749
3	TZA	-0.030	0.368	-24.335	22.193	11.836	6.442	0.345	0.585	-1.742	3.179	-0.223	0.623	0.0031	0.0039	-0.530	0.223	0.4762	0.0397	0.7848	0.6592
3	UGA	-0.793	0.606	-12.411	16.648	0.000	0.000	-0.050	0.253	1.458	2.657	0.348	0.494	-0.0017	0.0028	-0.353	0.219	0.5648	0.0471	0.7447	0.5957
3	ZAF	-0.612	0.523	13.185	44.115	0.099	0.162	0.063	0.388	0.411	3.256	-0.281	1.147	0.0018	0.0064	-0.329	0.214	0.5499	0.0458	0.7514	0.6064
3	ZMB	-1.003	0.607	-92.480	56.494	0.264	0.328	-0.620	0.676	22.451	14.768	3.245	2.029	-0.0172	0.0109	-0.485	0.221	0.3693	0.0369	0.5494	0.2341
4	ARE	-0.298	0.446	-282.477	312.774	0.177	0.652	0.095	1.290	58.482	87.624	9.248	11.324	-0.0489	0.0587	-0.688	0.438	1.3927	0.1741	0.4114	-0.104
4	EGY	-0.715	0.407	8.611	21.789	0.031	0.016	-0.819	0.519	2.957	2.440	-0.040	0.577	0.0004	0.0032	-0.084	0.240	0.4912	0.0409	0.7827	0.6559
4	IRN	0.180	0.398	62.604	76.026	0.077	0.057	0.815	0.922	-15.579	12.601	-2.188	2.330	0.0117	0.0125	-0.234	0.289	1.9616	0.1635	0.3832	0.0234
4	ISR	-1.134	0.801	-17.923	14.075	0.107	0.075	-0.152	0.227	2.696	2.553	0.519	0.429	-0.0027	0.0024	-0.409	0.209	0.4836	0.0403	0.7815	0.6541
4	JOR	-0.431	0.372	-3.841	24.347	0.190	0.156	0.194	0.510	1.073	3.212	0.141	0.708	-0.0006	0.0040	-0.448	0.234	0.5516	0.0460	0.7559	0.6135
4	KWT	-0.018	0.454	-35.289	51.788	0.339	0.595	1.082	1.151	-0.153	4.475	0.737	1.357	-0.0039	0.0078	-0.637	0.340	2.3610	0.1968	0.3195	-0.078
4	OMN	-0.241	0.316	-411.788	250.634	0.896	0.578	0.228	1.039	89.635	66.872	13.827	8.950	-0.0737	0.0470	-1.023	0.404	1.0749	0.1344	0.5522	0.1603
4	QAT	-0.550	0.458	-265.151	235.112	0.308	0.759	-0.560	1.073	63.112	64.711	9.082	8.441	-0.0479	0.0439	-0.538	0.486	0.8002	0.1000	0.4581	-0.016
4	SYR	-1.214	0.945	-6.333	15.910	0.549	0.230	0.148	0.271	0.501	2.605	0.188	0.487	-0.0012	0.0027	-0.383	0.195	0.5456	0.0455	0.7760	0.6453
4	YEM	-1.057	0.583	19.711	24.625	0.562	0.208	-1.491	0.773	-0.440	2.747	-0.350	0.681	0.0011	0.0038	-0.006	0.222	0.9164	0.0764	0.6263	0.4084
5	BGD	3.804	3.845	98.773	247.026	-1.639	0.910	-1.792	1.390	-76.933	71.100	-6.346	9.214	0.0340	0.0499	0.043	0.198	1.5370	0.1921	0.5051	0.0721
5	CYP	-0.502	0.414	-126.476	119.283	0.285	0.502	-0.667	0.613	36.012	35.360	4.647	4.421	-0.0242	0.0230	-0.509	0.298	0.3239	0.0405	0.5348	0.1277
5	LKA	0.258	0.916	-133.577	155.557	-0.042	0.107	-0.311	1.140	18.287	25.699	3.953	4.786	-0.0214	0.0259	-0.527	0.336	2.3591	0.2359	0.3474	-0.109
5	PAK	0.254	0.483	-15.766	92.684	0.005	0.125	0.401	1.196	-0.119	6.243	0.360	2.381	-0.0019	0.0133	-0.443	0.360	3.0213	0.2518	0.3714	0.0047
5	PHL	5.166	0.979	-98.429	0.092	0.201	0.030	0.874	0.022	9.821	0.053	2.799	0.000	-0.0157	0.0000	-0.280	0.014	0.7752	0.0596	0.7590	0.6478
5	SGP	0.965	1.225	-254.784	150.497	-5.783	4.344	0.050	0.892	33.853	21.117	7.090	4.267	-0.0329	0.0205	-0.897	0.441	2.1101	0.2110	0.4197	0.0135
5	VNM	2.372	0.815	-66.641	21.365	-0.001	0.000	0.429	0.295	12.212	2.274	2.138	0.578	-0.0115	0.0033	-0.159	0.133	0.5605	0.0510	0.8000	0.6727

Table M.12: Continued.

	Country	ω	S. Err	a_0	S. Err	a_1	S. Err	a_2	S. Err	a_3	S. Err	a_4	S. Err	a_5	S. Err	a_6	S. Err	SSE	MSE	R^2	Adj R^2
6	FJI	0.002	0.574	-579.427	304.966	0.256	0.254	-0.126	0.855	176.710	110.649	21.811	12.237	-0.1136	0.0628	-1.085	0.415	0.5044	0.0841	0.7158	0.3842
6	NZL	1.697	0.639	-80.207	26.947	0.490	0.223	1.193	0.444	3.219	3.263	2.087	0.757	-0.0122	0.0043	-0.643	0.204	1.0142	0.0845	0.6873	0.5049
6	PNG	-1.038	0.089	1923.03	372.238	-0.812	0.163	2.564	0.794	-2189.6	373.606	-149.92	26.588	0.7238	0.1293	-2.647	0.393	0.0010	0.0010	0.9988	0.9901
7	AUT	-0.427	0.318	-8.380	23.310	-0.109	0.508	-0.078	0.355	2.191	3.035	0.269	0.695	-0.0010	0.0040	-0.288	0.218	0.5030	0.0419	0.7603	0.6205
7	BEL	-0.180	0.339	-16.868	26.096	-0.038	0.071	0.084	0.450	2.423	3.241	0.458	0.775	-0.0021	0.0045	-0.350	0.220	0.5685	0.0474	0.7151	0.5489
7	CHE	-0.200	0.274	-10.067	23.674	-1.298	0.687	0.249	0.443	1.629	2.945	0.347	0.689	-0.0008	0.0041	-0.266	0.186	0.4888	0.0407	0.7791	0.6502
7	DNK	-0.457	0.333	-12.301	25.044	-0.073	0.108	-0.412	0.558	2.290	3.196	0.361	0.752	-0.0016	0.0043	-0.305	0.213	0.4637	0.0386	0.7736	0.6415
7	FIN	0.031	0.253	-68.182	63.432	-0.743	0.385	-0.359	0.689	14.816	15.738	2.259	2.184	-0.0113	0.0115	-0.230	0.274	0.5491	0.0610	0.5371	0.1770
7	GRC	-0.472	0.353	-22.789	22.723	-0.087	0.169	-0.249	0.565	2.562	2.598	0.627	0.643	-0.0031	0.0037	-0.347	0.189	0.4701	0.0392	0.7645	0.6271
7	IRL	-0.343	0.387	23.916	24.217	-0.719	0.307	-0.642	0.490	-4.719	3.557	-0.944	0.765	0.0066	0.0045	-0.588	0.205	0.3735	0.0311	0.7971	0.6788
7	ISL	-0.055	0.289	-107.146	68.184	0.244	0.398	-0.849	0.684	26.138	15.211	3.683	2.278	-0.0191	0.0121	-0.588	0.266	0.4774	0.0530	0.5770	0.2480
7	NLD	-0.350	0.378	-17.872	27.308	-0.124	0.286	0.035	0.407	1.547	3.778	0.436	0.771	-0.0019	0.0044	-0.411	0.309	0.5734	0.0478	0.7127	0.5450
7	PRT	-0.128	0.344	-0.121	28.008	-0.177	0.198	0.031	0.448	-0.106	3.613	-0.068	0.838	0.0010	0.0048	-0.421	0.248	0.5361	0.0447	0.7087	0.5388
8	YUG	-0.211	0.239	-0.519	47.091	0.375	0.195	-0.206	0.489	3.431	9.199	0.147	1.525	-0.0005	0.0081	-0.379	0.178	0.2637	0.0264	0.6293	0.3698
9	ARG	-0.854	0.598	13.234	21.741	0.739	0.462	-0.282	0.233	-0.410	3.234	-0.283	0.655	0.0013	0.0038	-0.462	0.216	0.5981	0.0498	0.8197	0.7146
9	BOL	-0.847	1.075	-326.198	304.904	0.404	1.037	-0.811	0.862	117.289	137.924	13.185	13.751	-0.0680	0.0714	-0.711	0.560	0.4684	0.0586	0.6233	0.2938
9	CHL	-1.332	0.896	-8.982	35.138	0.428	0.319	-0.106	0.284	-0.118	4.299	0.238	1.036	-0.0015	0.0061	-0.461	0.226	0.6897	0.0575	0.9319	0.8922
9	COL	-0.578	0.410	12.464	26.259	-0.052	0.127	-0.002	0.562	-2.072	3.782	-0.405	0.784	0.0027	0.0045	-0.609	0.221	0.7141	0.0595	0.8364	0.7410
9	ECU	-2.229	1.837	-95.895	83.793	-0.350	0.276	-0.844	0.817	19.771	16.252	3.117	2.700	-0.0159	0.0143	-0.724	0.383	0.6382	0.0638	0.5842	0.2932
9	PER	-1.704	0.995	3.808	22.877	0.342	0.181	-0.213	0.146	-1.139	3.706	-0.109	0.707	0.0006	0.0040	-0.535	0.237	0.6151	0.0513	0.9393	0.9038
9	PRY	-0.501	0.447	-182.661	152.592	0.287	0.400	-0.377	0.877	50.896	55.008	6.627	6.101	-0.0342	0.0315	-1.048	0.379	0.4234	0.0605	0.6558	0.3117
9	URY	0.902	0.279	-1156.4	675.946	-0.873	0.384	-1.571	0.772	805.494	467.589	65.273	37.984	-0.3210	0.1879	-2.624	0.641	0.0456	0.0228	0.9144	0.6146
9	VEN	-0.618	0.551	-3.302	33.782	-0.091	0.267	-0.211	0.437	-0.233	3.219	0.059	0.933	0.0001	0.0053	-0.492	0.222	0.7024	0.0585	0.7024	0.5288
10	BRB	-0.110	0.296	-78.260	50.090	-0.311	0.220	-0.059	0.685	12.393	10.080	2.185	1.603	-0.0108	0.0086	-0.895	0.310	0.5714	0.0571	0.5448	0.2261
10	CRI	-2.012	1.672	-56.807	78.691	0.138	0.122	-0.905	0.854	20.927	20.621	2.284	2.817	-0.0115	0.0150	-0.618	0.307	0.7041	0.0704	0.5413	0.2202
10	GTM	0.110	0.462	115.410	71.268	0.149	0.323	-0.834	0.970	-9.351	8.151	-3.257	2.031	0.0192	0.0115	-1.011	0.365	1.4356	0.1305	0.5365	0.2416
10	HND	-1.354	1.430	-18.415	216.331	-2.053	0.812	-0.320	0.815	15.798	141.652	1.010	11.705	-0.0028	0.0585	-0.647	0.595	0.1662	0.0416	0.8579	0.6094
10	JAM	-0.748	0.556	20.156	26.652	-0.039	0.299	-0.190	0.669	-3.439	4.123	-0.705	0.820	0.0043	0.0046	-0.630	0.235	0.7586	0.0690	0.5855	0.3217
10	NIC	-0.579	0.487	2.224	34.932	-0.036	0.046	0.130	0.570	-2.120	4.242	-0.208	0.987	0.0016	0.0055	-0.709	0.254	0.7262	0.0660	0.6032	0.3507
10	PAN	0.336	0.533	-15.604	32.600	-0.803	0.350	-0.390	0.581	-6.959	5.419	-0.016	0.953	0.0004	0.0054	-0.635	0.211	0.7833	0.0712	0.5714	0.2987
10	SLV	0.208	0.353	9.552	96.809	0.805	0.191	-0.109	0.499	8.504	33.231	0.151	3.790	-0.0004	0.0195	-0.489	0.223	0.1948	0.0278	0.8319	0.6637
10	TTO	-0.169	0.310	-31.833	54.117	0.568	0.527	0.690	1.150	12.754	10.728	1.209	1.714	-0.0056	0.0093	-0.793	0.309	0.6181	0.0618	0.5076	0.1628

Table M.13: Stock adjustment results, pooled, variable λ (equation 5.17); first traffic demand predicted results (equation 5.6); All manufacturers price indices, model 3 (table 3.3).

SSE	138.9544		MSE	0.0832		R^2	0.4368		Adj R^2	0.3896	
Parameter	Estimate	Std Err	Parameter	Estimate	Std Err	Parameter	Estimate	Std Err	Parameter	Estimate	Std Err
ω	-0.0111	0.0094	3 BBEN	-3.1882	2.5681	4 BARE	-3.3470	2.5664	7 BIRL	-3.5286	2.5665
a_0	-18.7731	4.1605 ***	3 BBFA	-2.8410	2.5643	4 BBHR	-5.1322	2.5759 **	7 BISL	-3.1432	2.5655
a_1	0.0032	0.0014 **	3 BCAF	-2.5663	2.5646	4 BDJI	-3.9973	2.5704	7 BMLT	-5.1729	2.5767 **
a_2	-0.0606	0.0592	3 BCIV	-2.8053	2.5645	4 BEGY	-2.3709	2.5635	7 BNLD	-3.3795	2.5660
a_3	3.1718	0.3658 ***	3 BCOG	-2.7593	2.5640	4 BIRN	-2.5144	2.5638	7 BPRT	-3.1402	2.5653
a_4	0.6375	0.0949 ***	3 BDZA	-2.0792	2.5628	4 BISR	-3.6813	2.5670	8 BPOL	-3.1490	2.5802
a_5	-0.0032	0.0005 ***	3 BETH	-2.3739	2.5635	4 BJOR	-3.1433	2.5654	8 BROM	-2.6828	2.5721
a_6	-0.3201	0.0159 ***	3 BGAB	-2.8378	2.5645	4 BKWT	-3.5120	2.5665	8 BYUG	-2.7892	2.5645
1 BCAN	-1.3434	2.5624	3 BGHA	-2.8709	2.5646	4 BLBN	-3.9089	2.5678	9 BARG	-2.1966	2.5631
1 BDEU	-2.6034	2.5640	3 BGIN	-2.9120	2.5655	4 BOMN	-3.0448	2.5654	9 BBOL	-2.5038	2.5639
1 BESP	-2.5978	2.5639	3 BKEN	-2.6069	2.5640	4 BQAT	-3.9351	2.5686	9 BCHL	-2.5744	2.5640
1 BFRA	-2.4951	2.5637	3 BLBR	-5.1491	2.5774 **	4 BSYR	-2.9467	2.5649	9 BCOL	-2.4762	2.5637
1 BGBR	-2.8346	2.5645	3 BLBY	-2.1715	2.5631	4 BYEM	-2.7176	2.5643	9 BECU	-2.9603	2.5649
1 BITA	-2.6511	2.5642	3 BMAR	-2.6272	2.5640	5 BBGD	-3.4134	2.5665	9 BPER	-2.4034	2.5636
1 BJPN	-2.2376	2.5633	3 BMDG	-2.6489	2.5642	5 BCYP	-2.4668	2.5638	9 BPRY	-2.8231	2.5643
1 BLUX	-4.1982	2.5691	3 BMRT	-2.3571	2.5635	5 BLKA	-3.6298	2.5672	9 BURY	-3.0629	2.5660
1 BNOR	-2.8264	2.5645	3 BMUS	-2.5740	2.5654	5 BNPL	-3.6343	2.5723	9 BVEN	-2.5541	2.5638
1 BSWE	-2.6867	2.5642	3 BNER	-2.3251	2.5638	5 BPAK	-2.8144	2.5646	10 BBHS	-4.0110	2.5704
1 BUSA	-1.1891	2.5619	3 BNGA	-2.4358	2.5635	5 BPHL	-2.6102	2.5639	10 BBRB	-5.0076	2.5723 *
2 BAUS	-1.5382	2.5628	3 BRWA	-3.7460	2.5697	5 BSGP	-5.1553	2.5734 **	10 BCRI	-3.5114	2.5665
2 BBRA	-1.7489	2.5622	3 BSEN	-2.9804	2.5650	5 BVNM	-2.8682	2.5649	10 BGTM	-3.4516	2.5663
2 BHKG	-5.3321	2.5866 **	3 BSWZ	-3.8506	2.5713	6 BFJI	-3.5686	2.5678	10 BHND	-3.2452	2.5664
2 BIDN	-1.9494	2.5626	3 BTCD	-2.3252	2.5622	6 BNZL	-2.7115	2.5641	10 BJAM	-4.0042	2.5682
2 BIND	-2.1914	2.5631	3 BTGO	-3.4105	2.5691	6 BPNG	-2.5319	2.5639	10 BNIC	-3.1600	2.5654
2 BKOR	-2.9688	2.5647	3 BTUN	-2.9354	2.5647	7 BAUT	-3.1564	2.5653	10 BPAN	-3.3828	2.5661
2 BMEX	-2.2250	2.5631	3 BTZA	-2.4512	2.5637	7 BBEL	-3.4742	2.5663	10 BSLV	-3.8512	2.5693
2 BMYS	-2.5978	2.5638	3 BUGA	-2.8964	2.5647	7 BCHE	-3.3595	2.5659	10 BTTO	-4.2141	2.5690
2 BSAU	-2.1885	2.5631	3 BZAF	-2.3773	2.5635	7 BDNK	-3.3753	2.5660			
2 BTHA	-2.9743	2.5652	3 BZMB	-2.5345	2.5639	7 BFIN	-2.8753	2.5648			
2 BTUR	-2.4534	2.5637	3 BZWE	-2.8255	2.5693	7 BGRC	-2.9925	2.5650			

Table M.14: Stock adjustment results, pooled, variable λ (equation 5.17); first traffic demand predicted results (equation 5.6); US manufacturers price index, model 3 (table 3.12).

SSE	138.9871		MSE	0.0832		R^2	0.4367		Adj R^2	0.3894	
Parameter	Estimate	Std Err	Parameter	Estimate	Std Err	Parameter	Estimate	Std Err	Parameter	Estimate	Std Err
ω	-0.0114	0.0094	3 BBEN	-3.0865	2.4305	4 BARE	-3.2446	2.4286	7 BIRL	-3.4253	2.4287
a_0	-19.7449	3.8881 ***	3 BBFA	-2.7427	2.4266	4 BBHR	-5.0191	2.4385 **	7 BISL	-3.0425	2.4277
a_1	0.0032	0.0014 **	3 BCAF	-2.4696	2.4269	4 BDJI	-3.8918	2.4328	7 BMLT	-5.0580	2.4392 **
a_2	-0.0515	0.0636	3 BCIV	-2.7069	2.4267	4 BEGY	-2.2754	2.4258	7 BNLD	-3.2773	2.4282
a_3	3.2737	0.3563 ***	3 BCOG	-2.6615	2.4262	4 BIRN	-2.4180	2.4260	7 BPRT	-3.0395	2.4275
a_4	0.6617	0.0895 ***	3 BDZA	-1.9856	2.4251	4 BISR	-3.5771	2.4292	8 BPOL	-3.0561	2.4434
a_5	-0.0033	0.0005 ***	3 BETH	-2.2784	2.4258	4 BJOR	-3.0426	2.4276	8 BROM	-2.5900	2.4349
a_6	-0.3179	0.0164 ***	3 BGAB	-2.7392	2.4267	4 BKWT	-3.4087	2.4287	8 BYUG	-2.6908	2.4267
1 BCAN	-1.2536	2.4248	3 BGHA	-2.7720	2.4268	4 BLBN	-3.8037	2.4300	9 BARG	-2.1024	2.4253
1 BDEU	-2.5060	2.4262	3 BGIN	-2.8128	2.4277	4 BOMN	-2.9444	2.4276	9 BBOL	-2.4076	2.4261
1 BESP	-2.5008	2.4261	3 BKEN	-2.5099	2.4263	4 BQAT	-3.8289	2.4308	9 BCHL	-2.4771	2.4262
1 BFRA	-2.3986	2.4259	3 BLBR	-5.0334	2.4399 **	4 BSYR	-2.8473	2.4271	9 BCOL	-2.3800	2.4259
1 BGBR	-2.7361	2.4267	3 BLBY	-2.0773	2.4253	4 BYEM	-2.6196	2.4265	9 BECU	-2.8611	2.4271
1 BITA	-2.5532	2.4264	3 BMAR	-2.5301	2.4262	5 BBGD	-3.3109	2.4287	9 BPER	-2.3072	2.4259
1 BJPN	-2.1422	2.4256	3 BMDG	-2.5515	2.4264	5 BCYP	-2.3706	2.4261	9 BPRY	-2.7250	2.4265
1 BLUX	-4.0902	2.4313 *	3 BMRT	-2.2615	2.4258	5 BLKA	-3.5256	2.4294	9 BURY	-2.9625	2.4282
1 BNOR	-2.7278	2.4267	3 BMUS	-2.4775	2.4278	5 BNPL	-3.5305	2.4348	9 BVEN	-2.4576	2.4260
1 BSWE	-2.5889	2.4264	3 BNER	-2.2300	2.4260	5 BPAK	-2.7157	2.4269	10 BBHS	-3.9043	2.4328
1 BUSA	-1.1019	2.4244	3 BNGA	-2.3399	2.4258	5 BPHL	-2.5134	2.4261	10 BBRB	-4.8946	2.4347 **
2 BAUS	-1.4484	2.4252	3 BRWA	-3.6416	2.4320	5 BSGP	-5.0410	2.4358 **	10 BCRI	-3.4084	2.4287
2 BBRA	-1.6576	2.4246	3 BSEN	-2.8808	2.4272	5 BVNM	-2.7697	2.4271	10 BGTM	-3.3489	2.4285
2 BHKG	-5.2236	2.4500 **	3 BSWZ	-3.7424	2.4337	6 BFJI	-3.4659	2.4300	10 BHND	-3.1440	2.4287
2 BIDN	-1.8568	2.4249	3 BTCD	-2.2304	2.4245	6 BNZL	-2.6142	2.4263	10 BJAM	-3.8980	2.4304
2 BIND	-2.0965	2.4254	3 BTGO	-3.3073	2.4314	6 BPNG	-2.4354	2.4262	10 BNIC	-3.0593	2.4276
2 BKOR	-2.8697	2.4269	3 BTUN	-2.8361	2.4269	7 BAUT	-3.0556	2.4276	10 BPAN	-3.2807	2.4283
2 BMEX	-2.1298	2.4253	3 BTZA	-2.3553	2.4259	7 BBEL	-3.3713	2.4285	10 BSLV	-3.7463	2.4315
2 BMYS	-2.5011	2.4260	3 BUGA	-2.7974	2.4269	7 BCHE	-3.2573	2.4281	10 BTTO	-4.1064	2.4312 *
2 BSAU	-2.0941	2.4254	3 BZAF	-2.2819	2.4258	7 BDNK	-3.2731	2.4282			
2 BTHA	-2.8745	2.4274	3 BZMB	-2.4379	2.4262	7 BFIN	-2.7762	2.4270			
2 BTUR	-2.3572	2.4259	3 BZWE	-2.7268	2.4318	7 BGRC	-2.8928	2.4272			

Table M.15: Stock adjustment results, pooled, variable λ (equation 5.17); second traffic demand predicted results (equation 5.7); All manufacturers price index, model 3 (table 3.3).

SSE	138.3581		MSE	0.0839		R^2	0.4340		Adj R^2	0.3860	
Parameter	Estimate	Std Err	Parameter	Estimate	Std Err	Parameter	Estimate	Std Err	Parameter	Estimate	Std Err
ω	-0.0114	0.0095	2 BTUR	-2.3887	2.4776	3 BZMB	-2.4729	2.4779	7 BFIN	-2.8077	2.4788
a_0	-18.7473	4.1348 ***	3 BBEN	-3.1259	2.4824	3 BZWE	-2.7603	2.4836	7 BGRC	-2.9246	2.4790
a_1	0.0016	0.0007 **	3 BBFA	-2.7802	2.4784	4 BARE	-3.2780	2.4805	7 BIRL	-3.4606	2.4806
a_2	-0.0602	0.0597	3 BCAF	-2.5065	2.4786	4 BBHR	-5.0601	2.4904 **	7 BISL	-3.0786	2.4796
a_3	3.1616	0.3694 ***	3 BCIV	-2.7419	2.4785	4 BDJI	-3.9327	2.4847	7 BMLT	-5.1031	2.4912 **
a_4	0.6350	0.0958 ***	3 BCOG	-2.6983	2.4781	4 BEGY	-2.2988	2.4775	7 BNLD	-3.3102	2.4800
a_5	-0.0032	0.0005 ***	3 BDZA	-2.0128	2.4768	4 BIRN	-2.4531	2.4778	7 BPRT	-3.0727	2.4793
a_6	-0.3193	0.0160 ***	3 BETH	-2.3130	2.4775	4 BISR	-3.6126	2.4812	8 BPOL	-3.0804	2.4949
1 BCAN	-1.2775	2.4763	3 BGAB	-2.7746	2.4785	4 BJOR	-3.0779	2.4795	8 BROM	-2.6173	2.4864
1 BDEU	-2.5306	2.4780	3 BGHA	-2.8087	2.4787	4 BKWT	-3.4437	2.4806	8 BYUG	-2.7228	2.4785
1 BESP	-2.5293	2.4779	3 BGIN	-2.8497	2.4795	4 BOMN	-2.9811	2.4794	9 BARG	-2.1322	2.4770
1 BFRA	-2.4239	2.4776	3 BKEN	-2.5432	2.4780	4 BQAT	-3.8674	2.4827	9 BBOL	-2.4415	2.4779
1 BGBR	-2.7606	2.4785	3 BLBR	-5.0810	2.4919 **	4 BSYR	-2.8827	2.4789	9 BCHL	-2.5103	2.4780
1 BITA	-2.5818	2.4782	3 BLBY	-2.1073	2.4770	4 BYEM	-2.6527	2.4783	9 BCOL	-2.4121	2.4777
1 BJPN	-2.1697	2.4773	3 BMAR	-2.5619	2.4780	5 BBGD	-3.3508	2.4806	9 BECU	-2.8966	2.4789
1 BLUX	-4.1281	2.4833 *	3 BMDG	-2.5876	2.4782	5 BCYP	-2.4026	2.4778	9 BPER	-2.3404	2.4776
1 BNOR	-2.7585	2.4785	3 BMRT	-2.2982	2.4775	5 BLKA	-3.5655	2.4813	9 BPRY	-2.7603	2.4783
1 BSWE	-2.6175	2.4782	3 BMUS	-2.5112	2.4795	5 BNPL	-3.5689	2.4867	9 BURY	-2.9975	2.4801
1 BUSA	-1.1206	2.4758	3 BNER	-2.2581	2.4777	5 BPAK	-2.7437	2.4787	9 BVEN	-2.4886	2.4778
2 BAUS	-1.4736	2.4767	3 BNGA	-2.3710	2.4775	5 BPHL	-2.5456	2.4778	10 BBHS	-3.9425	2.4847
2 BBRA	-1.6848	2.4761	3 BRWA	-3.6831	2.4839	5 BSGP	-5.0825	2.4878 **	10 BBRB	-4.9369	2.4867 **
2 BHKG	-5.2546	2.5016 **	3 BSEN	-2.9169	2.4790	5 BVNM	-2.7509	2.4788	10 BCRI	-3.4451	2.4806
2 BIDN	-1.8870	2.4765	3 BSWZ	-3.7844	2.4857	6 BFJI	-3.5054	2.4820	10 BGTM	-3.3855	2.4804
2 BIND	-2.1276	2.4771	3 BTCD	-2.2672	2.4762	6 BNZL	-2.6459	2.4781	10 BHND	-3.1796	2.4805
2 BKOR	-2.9021	2.4787	3 BTGO	-3.3463	2.4834	6 BPNG	-2.4684	2.4780	10 BJAM	-3.9355	2.4823
2 BMEX	-2.1619	2.4771	3 BTUN	-2.8696	2.4787	7 BAUT	-3.0866	2.4794	10 BNIC	-3.0983	2.4795
2 BMYS	-2.5345	2.4778	3 BTZA	-2.3891	2.4777	7 BBEL	-3.4034	2.4803	10 BPAN	-3.3170	2.4801
2 BSAU	-2.1243	2.4771	3 BUGA	-2.8330	2.4788	7 BCHE	-3.2879	2.4799	10 BSLV	-3.7841	2.4835
2 BTHA	-2.9137	2.4792	3 BZAF	-2.3092	2.4775	7 BDNK	-3.3060	2.4801	10 BTTO	-4.1462	2.4832 *

Table M.16: Stock adjustment results, pooled, variable λ (equation 5.17); second traffic demand predicted results (equation 5.7); US manufacturers price index, model 3 (table 3.12).

SSE	138.3930		MSE	0.0839		R^2	0.4338		Adj R^2	0.3858	
Parameter	Estimate	Std Err	Parameter	Estimate	Std Err	Parameter	Estimate	Std Err	Parameter	Estimate	Std Err
ω	-0.0117	0.0096	2 BTUR	-2.2951	2.3453	3 BZMB	-2.3790	2.3456	7 BFIN	-2.7114	2.3464
a_0	-19.7256	3.8635 ***	3 BBEN	-3.0271	2.3501	3 BZWE	-2.6643	2.3515	7 BGRC	-2.8277	2.3466
a_1	0.0016	0.0007 **	3 BBFA	-2.6846	2.3460	4 BARE	-3.1785	2.3481	7 BIRL	-3.3603	2.3482
a_2	-0.0498	0.0642	3 BCAF	-2.4124	2.3463	4 BBHR	-4.9506	2.3584 **	7 BISL	-2.9806	2.3472
a_3	3.2625	0.3598 ***	3 BCIV	-2.6462	2.3461	4 BDJI	-3.8303	2.3525	7 BMLT	-4.9918	2.3591 **
a_4	0.6594	0.0904 ***	3 BCOG	-2.6032	2.3457	4 BEGY	-2.2058	2.3452	7 BNLD	-3.2109	2.3476
a_5	-0.0033	0.0005 ***	3 BDZA	-1.9217	2.3445	4 BIRN	-2.3592	2.3454	7 BPRT	-2.9749	2.3469
a_6	-0.3173	0.0165 ***	3 BETH	-2.2201	2.3452	4 BISR	-3.5115	2.3488	8 BPOL	-2.9900	2.3635
1 BCAN	-1.1900	2.3441	3 BGAB	-2.6787	2.3462	4 BJOR	-2.9801	2.3471	8 BROM	-2.5271	2.3546
1 BDEU	-2.4358	2.3456	3 BGHA	-2.7126	2.3463	4 BKWT	-3.3434	2.3482	8 BYUG	-2.6271	2.3461
1 BESP	-2.4350	2.3455	3 BGIN	-2.7534	2.3472	4 BOMN	-2.8835	2.3471	9 BARG	-2.0404	2.3447
1 BFRA	-2.3301	2.3453	3 BKEN	-2.4489	2.3457	4 BQAT	-3.7644	2.3504	9 BBOL	-2.3479	2.3455
1 BGBR	-2.6648	2.3461	3 BLBR	-4.9690	2.3599 **	4 BSYR	-2.7861	2.3465	9 BCHL	-2.4157	2.3456
1 BJTA	-2.4867	2.3458	3 BLBY	-2.0156	2.3447	4 BYEM	-2.5574	2.3459	9 BCOL	-2.3185	2.3453
1 BJPN	-2.0769	2.3449	3 BMAR	-2.4674	2.3456	5 BBGD	-3.2512	2.3482	9 BECU	-2.8001	2.3465
1 BLUX	-4.0234	2.3509 *	3 BMDG	-2.4929	2.3458	5 BCYP	-2.3090	2.3455	9 BPER	-2.2468	2.3453
1 BNOR	-2.6626	2.3461	3 BMRT	-2.2052	2.3452	5 BLKA	-3.4643	2.3489	9 BPRY	-2.6649	2.3460
1 BSWE	-2.5224	2.3458	3 BMUS	-2.4174	2.3473	5 BNPL	-3.4681	2.3545	9 BURY	-2.9000	2.3477
1 BUSA	-1.0355	2.3437	3 BNER	-2.1655	2.3454	5 BPAK	-2.6478	2.3463	9 BVEN	-2.3947	2.3454
2 BAUS	-1.3861	2.3445	3 BNGA	-2.2777	2.3452	5 BPHL	-2.4514	2.3455	10 BBHS	-3.8390	2.3524
2 BBRA	-1.5958	2.3439	3 BRWA	-3.5819	2.3517	5 BSGP	-4.9717	2.3556 **	10 BBRB	-4.8274	2.3545 **
2 BHKG	-5.1495	2.3704 **	3 BSEN	-2.8201	2.3466	5 BVNM	-2.6552	2.3464	10 BCRI	-3.3451	2.3482
2 BIDN	-1.7969	2.3443	3 BSWZ	-3.6794	2.3534	6 BFJI	-3.4057	2.3496	10 BGTM	-3.2858	2.3480
2 BIND	-2.0353	2.3448	3 BTCD	-2.1749	2.3439	6 BNZL	-2.5513	2.3457	10 BHND	-3.0812	2.3482
2 BKOR	-2.8058	2.3464	3 BTGO	-3.2461	2.3511	6 BPNG	-2.3745	2.3457	10 BJAM	-3.8324	2.3500
2 BMEX	-2.0692	2.3447	3 BTUN	-2.7730	2.3464	7 BAUT	-2.9887	2.3470	10 BNIC	-3.0004	2.3471
2 BMYS	-2.4404	2.3454	3 BTZA	-2.2958	2.3453	7 BBEL	-3.3035	2.3479	10 BPAN	-3.2178	2.3478
2 BSAU	-2.0324	2.3447	3 BUGA	-2.7368	2.3464	7 BCHE	-3.1887	2.3476	10 BSLV	-3.6822	2.3512
2 BTHA	-2.8166	2.3468	3 BZAF	-2.2164	2.3451	7 BDNK	-3.2067	2.3477	10 BTTO	-4.0417	2.3508 *

Table M.17: Stock adjustment results, grouped, variable λ (equation 5.17); first traffic demand predicted results (equation 5.6); All manufacturers price indices, model 3 (table 3.3).

SSE	MSE	SSE	MSE	SSE	MSE	SSE	MSE	SSE	MSE	SSE	MSE	SSE	MSE	SSE	MSE	SSE	MSE	SSE	MSE
19.6	0.101	26.4	0.149	16.8	0.041	15.6	0.079	16.8	0.130	2.98	0.090	6.62	0.036	0.26	0.026	6.17	0.043	8.08	0.055
R^2	$AdjR^2$	R^2	$AdjR^2$	R^2	$AdjR^2$	R^2	$AdjR^2$	R^2	$AdjR^2$	R^2	$AdjR^2$	R^2	$AdjR^2$	R^2	$AdjR^2$	R^2	$AdjR^2$	R^2	$AdjR^2$
0.52	0.48	0.27	0.19	0.56	0.52	0.43	0.37	0.32	0.25	0.50	0.36	0.65	0.61	0.70	0.40	0.83	0.81	0.49	0.43
1	**Est**	**2**	**Est**	**3**	**Est**	**4**	**Est**	**5**	**Est**	**6**	**Est**	**7**	**Est**	**8**	**Est**	**9**	**Est**	**10**	**Est**
ω	-0.013	ω	0.075	ω	-0.071 ***	ω	-0.011	ω	0.010	ω	0.000	ω	-0.062	ω	-0.105	ω	-0.064 **	ω	-0.008
a_0	3.721	a_0	-32.40 **	a_0	-13.52 ***	a_0	-30.65 ***	a_0	-45.18 ***	a_0	132.98	a_0	-20.83 ***	a_0	-4.863	a_0	-4.856	a_0	11.27
a_1	0.101 *	a_1	0.049 **	a_1	0.012	a_1	0.001	a_1	0.002	a_1	0.280 ***	a_1	-0.013	a_1	0.423 *	a_1	0.027	a_1	-0.032
a_2	-0.140	a_2	0.073	a_2	-0.112	a_2	0.169	a_2	0.616 **	a_2	-0.081	a_2	-0.048	a_2	-0.286	a_2	-0.385 ***	a_2	-0.491 ***
a_3	1.276	a_3	3.940 ***	a_3	2.330 ***	a_3	3.994 ***	a_3	3.124 *	a_3	1.710	a_3	3.504 ***	a_3	3.127	a_3	0.971	a_3	0.295
a_4	-0.051	a_4	0.953 **	a_4	0.436 ***	a_4	0.934 ***	a_4	1.221 ***	a_4	1.363 *	a_4	0.625 ***	a_4	0.247	a_4	0.187	a_4	-0.108
a_5	0.001	a_5	-0.005 **	a_5	-0.002 ***	a_5	-0.005 ***	a_5	-0.007 **	a_5	-0.008 **	a_5	-0.003 **	a_5	-0.001	a_5	-0.001	a_5	0.001
a_6	-0.315 ***	a_6	-0.264 ***	a_6	-0.360 ***	a_6	-0.302 ***	a_6	-0.449 ***	a_6	-0.533 ***	a_6	-0.305 ***	a_6	-0.418 *	a_6	-0.625 ***	a_6	-0.579 ***
CAN	0.845	AUS	0.436	BEN	-1.382 ***	ARE	-2.536	BGD	-2.231 ***	FJI	-186.4 ***	AUT	-0.340	POL	-0.860	ARG	-0.693	BHS	-8.821
DEU	-0.591	BRA	0.303	BFA	-1.012 ***	BHR	-4.235	CYP	-0.903 ***	NZL	-185.7 ***	BEL	-0.645	ROM	0.399	BOL	-1.192	BRB	-10.73
ESP	-0.406	HKG	-2.622 ***	CAF	-0.720 **	DJI	-3.170	LKA	-2.556 ***	PNG	-184.9 ***	CHE	-0.522	YUG	-0.190	CHL	-1.496 **	CRI	-8.026
FRA	-0.449	IDN	0.202	CIV	-1.013 ***	EGY	-1.616	NPL	-2.360 ***			DNK	-0.561			COL	-1.247 *	GTM	-7.942
GBR	-0.759	IND	-0.009	COG	-0.924 **	IRN	-1.750	PAK	-1.393 ***			FIN	-0.092			ECU	-2.107 ***	HND	-7.533
ITA	-0.520	KOR	-0.705	DZA	-0.210	ISR	-2.852	PHL	-1.075 ***			GRC	-0.200			PER	-1.149	JAM	-8.881
JPN	-0.046	MEX	0.000	ETH	-0.514	JOR	-2.346	SGP	-4.683 ***			IRL	-0.731			PRY	-1.809 **	NIC	-7.486
LUX	-1.879	MYS	-0.323	GAB	-1.045 ***	KWT	-2.690	VNM	-1.412 ***			ISL	-0.387			URY	-2.293 ***	PAN	-7.794
NOR	-0.588	SAU	-0.035	GHA	-1.071 ***	LBN	-3.029					MLT	-2.382 ***			VEN	-1.384 *	SLV	-8.609
SWE	-0.489	THA	-0.598	GIN	-1.101 ***	OMN	-2.256					NLD	-0.559					TTO	-9.284
USA	0.773	TUR	-0.242	KEN	-0.790 **	QAT	-3.095					PRT	-0.352						
				LBR	-3.613 ***	SYR	-2.161												
				LBY	-0.314	YEM	-1.944												
				MAR	-0.828 **														
				MDG	-0.823 **														
				MRT	-0.485	NGA	-0.607 *	SWZ	-2.159 ***	TUN	-1.177 ***	ZAF	-0.550						
				MUS	-0.702 *	RWA	-2.003 ***	TCD	-0.429	TZA	-0.612 *	ZMB	-0.694 *						
				NER	-0.474	SEN	-1.205 ***	TGO	-1.638 ***	UGA	-1.117 ***	ZWE	-1.011 ***						

Table M.18: Stock adjustment results, grouped, variable λ (equation 5.17); first traffic demand predicted results (equation 5.6); North American manufacturers price indices, model 3 (table 3.12).

SSE	MSE	SSE	MSE	SSE	MSE	SSE	MSE	SSE	MSE	SSE	MSE	SSE	MSE	SSE	MSE	SSE	MSE	SSE	MSE
19.6	0.101	26.3	0.149	16.4	0.040	15.7	0.079	17.4	0.135	2.93	0.092	6.63	0.036	0.23	0.023	6.48	0.046	8.63	0.059
R^2	$AdjR^2$	R^2	$AdjR^2$	R^2	$AdjR^2$	R^2	$AdjR^2$	R^2	$AdjR^2$	R^2	$AdjR^2$	R^2	$AdjR^2$	R^2	$AdjR^2$	R^2	$AdjR^2$	R^2	$AdjR^2$
0.52	0.48	0.27	0.20	0.57	0.53	0.43	0.37	0.30	0.22	0.50	0.35	0.65	0.61	0.74	0.48	0.82	0.80	0.45	0.39
1	**Est**	**2**	**Est**	**3**	**Est**	**4**	**Est**	**5**	**Est**	**6**	**Est**	**7**	**Est**	**8**	**Est**	**9**	**Est**	**10**	**Est**
ω	-0.013	ω	0.073	ω	-0.078 ***	ω	-0.009	ω	0.009	ω	0.062	ω	-0.064	ω	-0.148	ω	-0.059 *	ω	-0.010
a_0	-0.840	a_0	-33.74 ***	a_0	-14.62 ***	a_0	-27.11 *	a_0	-33.95 **	a_0	-59.56 **	a_0	-22.02 ***	a_0	-26.02	a_0	-12.68	a_0	-1.618
a_1	0.098	a_1	0.049 **	a_1	0.009	a_1	0.002	a_1	0.002	a_1	0.281 ***	a_1	-0.012	a_1	0.400 *	a_1	0.037	a_1	-0.028
a_2	0.038	a_2	0.200	a_2	-0.333 ***	a_2	0.081	a_2	0.217	a_2	0.304	a_2	-0.022	a_2	-0.625	a_2	0.054	a_2	-0.009
a_3	1.601	a_3	3.905 ***	a_3	2.906 ***	a_3	3.760 ***	a_3	2.227	a_3	1.927	a_3	3.623 ***	a_3	7.954	a_3	1.325	a_3	1.016
a_4	0.064	a_4	0.983 ***	a_4	0.489 ***	a_4	0.859 ***	a_4	0.930 **	a_4	1.540 **	a_4	0.657 ***	a_4	0.969	a_4	0.377	a_4	0.175
a_5	0.000	a_5	-0.005 ***	a_5	-0.002 ***	a_5	-0.004 ***	a_5	-0.005 *	a_5	-0.009 **	a_5	-0.003 ***	a_5	-0.005	a_5	-0.002	a_5	0.000
a_6	-0.313 ***	a_6	-0.275 ***	a_6	-0.317 ***	a_6	-0.302 ***	a_6	-0.456 ***	a_6	-0.604 ***	a_6	-0.301 ***	a_6	-0.381 *	a_6	-0.640 ***	a_6	-0.569 ***
CAN	0.973	AUS	0.443	BEN	-1.275 ***	ARE	-3.195	BGD	-2.273 ***	FJI	-1.490	AUT	-0.328	POL	-0.874 *	ARG	-0.698	BHS	-7.073
DEU	-0.450	BRA	0.301	BFA	-0.955 ***	BHR	-4.889	CYP	-0.922 ***	NZL	-0.670	BEL	-0.629	ROM	0.334	BOL	-1.182	BRB	-8.942
ESP	-0.271	HKG	-2.719 ***	CAF	-0.698 **	DJI	-3.824	LKA	-2.600 ***	PNG	0.253	CHE	-0.507	YUG	-0.185	CHL	-1.512 *	CRI	-6.287
FRA	-0.309	IDN	0.192	CIV	-0.952 ***	EGY	-2.275	NPL	-2.411 ***			DNK	-0.545			COL	-1.259	GTM	-6.203
GBR	-0.618	IND	-0.031	COG	-0.876 **	IRN	-2.409	PAK	-1.418 ***			FIN	-0.082			ECU	-2.131 **	HND	-5.806
ITA	-0.381	KOR	-0.748	DZA	-0.239	ISR	-3.510	PHL	-1.093 ***			GRC	-0.189			PER	-1.154	JAM	-7.129
JPN	0.088	MEX	-0.023	ETH	-0.514	JOR	-3.004	SGP	-4.764 ***			IRL	-0.712			PRY	-1.820 **	NIC	-5.749
LUX	-1.736	MYS	-0.355	GAB	-0.980 ***	KWT	-3.348	VNM	-1.435 ***			ISL	-0.373			URY	-2.324 ***	PAN	-6.058
NOR	-0.453	SAU	-0.053	GHA	-1.005 ***	LBN	-3.694					MLT	-2.341 ***			VEN	-1.406 *	SLV	-6.861
SWE	-0.353	THA	-0.647	GIN	-1.027 ***	OMN	-2.914					NLD	-0.544					TTO	-7.525
USA	0.903	TUR	-0.270	KEN	-0.756 **	QAT	-3.753					PRT	-0.339						
				LBR	-3.228 ***	SYR	-2.819												
				LBY	-0.331	YEM	-2.602												
				MAR	-0.787 **														
				MDG	-0.784 **														
				MRT	-0.486	NGA	-0.592 *	SWZ	-1.957 ***	TUN	-1.094 ***	ZAF	-0.541						
				MUS	-0.675 *	RWA	-1.826 ***	TCD	-0.442	TZA	-0.599 *	ZMB	-0.672 **						
				NER	-0.468	SEN	-1.122 ***	TGO	-1.500 ***	UGA	-1.046 ***	ZWE	-0.950 ***						

Table M.19: Stock adjustment results, grouped, variable λ (equation 5.17); second traffic demand predicted results (equation 5.7); All manufacturers price indices, model 3 (table 3.3).

SSE	MSE	SSE	MSE	SSE	MSE	SSE	MSE	SSE	MSE	SSE	MSE	SSE	MSE	SSE	MSE	SSE	MSE	SSE	MSE
19.8	0.102	26.0	0.147	16.9	0.041	14.9	0.083	16.6	0.129	2.78	0.084	6.60	0.036	0.33	0.033	6.11	0.043	8.12	0.056
R^2	$AdjR^2$	R^2	$AdjR^2$	R^2	$AdjR^2$	R^2	$AdjR^2$	R^2	$AdjR^2$	R^2	$AdjR^2$	R^2	$AdjR^2$	R^2	$AdjR^2$	R^2	$AdjR^2$	R^2	$AdjR^2$
0.51	0.47	0.28	0.21	0.56	0.52	0.41	0.34	0.33	0.25	0.53	0.40	0.65	0.62	0.63	0.26	0.83	0.81	0.48	0.42
1	**Est**	**2**	**Est**	**3**	**Est**	**4**	**Est**	**5**	**Est**	**6**	**Est**	**7**	**Est**	**8**	**Est**	**9**	**Est**	**10**	**Est**
ω	-0.011	ω	0.076	ω	-0.070 **	ω	-0.011	ω	0.009	ω	0.000	ω	-0.054	ω	-0.145	ω	-0.064 *	ω	-0.008
a_0	2.665	a_0	-33.85 **	a_0	-13.10 ***	a_0	-32.67 **	a_0	-44.55 ***	a_0	250.97	a_0	-21.02 ***	a_0	-37.89	a_0	-3.309	a_0	11.18
a_1	-0.006	a_1	0.064 ***	a_1	0.006	a_1	-0.005	a_1	0.002	a_1	0.452 ***	a_1	-0.027	a_1	0.219	a_1	0.056	a_1	-0.018
a_2	-0.124	a_2	0.056	a_2	-0.116	a_2	0.197	a_2	0.605 **	a_2	-0.086	a_2	-0.051	a_2	-0.215	a_2	-0.396 ***	a_2	-0.486 ***
a_3	1.490	a_3	4.246 ***	a_3	2.342 ***	a_3	4.172 ***	a_3	2.948 *	a_3	1.101	a_3	3.418 ***	a_3	9.650	a_3	0.936	a_3	0.168
a_4	-0.017	a_4	1.004 ***	a_4	0.427 ***	a_4	0.987 ***	a_4	1.199 ***	a_4	1.396 **	a_4	0.626 ***	a_4	1.311	a_4	0.153	a_4	-0.109
a_5	0.001	a_5	-0.005 **	a_5	-0.002 ***	a_5	-0.005 ***	a_5	-0.006 **	a_5	-0.008 **	a_5	-0.003 **	a_5	-0.007	a_5	0.000	a_5	0.001
a_6	-0.316 ***	a_6	-0.268 ***	a_6	-0.357 ***	a_6	-0.299 ***	a_6	-0.450 ***	a_6	-0.603 ***	a_6	-0.311 ***	a_6	-0.518 **	a_6	-0.616 ***	a_6	-0.587 ***
CAN	0.650	AUS	0.415	BEN	-1.403 ***	ARE	-2.448	BGD	-2.241 ***	FJI	-305.8 ***	AUT	-0.402	POL	-0.787	ARG	-0.752	BHS	-8.992
DEU	-0.575	BRA	0.300	BFA	-1.036 ***	BHR	-4.143	CYP	-0.907 ***	NZL	-305.5 ***	BEL	-0.717	ROM	0.086	BOL	-1.144	BRB	-10.93
ESP	-0.582	HKG	-2.657 ***	CAF	-0.747 **	DJI	-3.105	LKA	-2.567 ***	PNG	-304.2 ***	CHE	-0.573	YUG	-0.221	CHL	-1.522 **	CRI	-8.185
FRA	-0.469	IDN	0.218	CIV	-1.026 ***	EGY	-1.570	NPL	-2.365 ***			DNK	-0.639			COL	-1.286 *	GTM	-8.096
GBR	-0.816	IND	-0.004	COG	-0.947 **	IRN	-1.659	PAK	-1.391 ***			FIN	-0.169			ECU	-2.102 ***	HND	-7.681
ITA	-0.626	KOR	-0.722 *	DZA	-0.212	ISR	-2.767	PHL	-1.077 ***			GRC	-0.277			PER	-1.165	JAM	-9.058
JPN	-0.226	MEX	0.029	ETH	-0.538	JOR	-2.276	SGP	-4.700 ***			IRL	-0.842			PRY	-1.791 **	NIC	-7.603
LUX	-2.176	MYS	-0.309	GAB	-1.059 ***	KWT	-2.603	VNM	-1.390 ***			ISL	-0.509			URY	-2.291 ***	PAN	-7.945
NOR	-0.810	SAU	-0.045	GHA	-1.089 ***	OMN	-2.186					MLT	-2.545 ***			VEN	-1.448 *	SLV	-8.771
SWE	-0.672	THA	-0.681	GIN	-1.120 ***	QAT	-3.012					NLD	-0.621					TTO	-9.455
USA	0.811	TUR	-0.248	KEN	-0.803 **	SYR	-2.090					PRT	-0.447						
				LBR	-3.615 ***	YEM	-1.879												
				LBY	-0.324														
				MAR	-0.835 **														
				MDG	-0.844 **														
				MRT	-0.515	NGA	-0.616 *	SWZ	-2.167 ***	TUN	-1.182 ***	ZAF	-0.546						
				MUS	-0.719 *	RWA	-2.023 ***	TCD	-0.463	TZA	-0.631 *	ZMB	-0.714 *						
				NER	-0.472	SEN	-1.219 ***	TGO	-1.652 ***	UGA	-1.132 ***	ZWE	-1.021 ***						

Table M.20: Stock adjustment results, grouped, variable λ (equation 5.17); second traffic demand predicted results (equation 5.7); North American manufacturers price indices, model 3 (table 3.12).

SSE	MSE	SSE	MSE	SSE	MSE	SSE	MSE	SSE	MSE	SSE	MSE	SSE	MSE	SSE	MSE	SSE	MSE	SSE	MSE
19.9	0.102	25.9	0.15	16.4	0.040	14.9	0.083	17.2	0.134	2.76	0.084	6.61	0.036	0.30	0.030	6.44	0.045	8.66	0.059
R^2	$AdjR^2$	R^2	$AdjR^2$	R^2	$AdjR^2$	R^2	$AdjR^2$	R^2	$AdjR^2$	R^2	$AdjR^2$	R^2	$AdjR^2$	R^2	$AdjR^2$	R^2	$AdjR^2$	R^2	$AdjR^2$
0.51	0.47	0.28	0.21	0.57	0.53	0.40	0.34	0.31	0.22	0.53	0.40	0.65	0.62	0.66	0.32	0.82	0.80	0.45	0.38
1	**Est**	**2**	**Est**	**3**	**Est**	**4**	**Est**	**5**	**Est**	**6**	**Est**	**7**	**Est**	**8**	**Est**	**9**	**Est**	**10**	**Est**
ω	-0.011	ω	0.072	ω	-0.077 **	ω	-0.009	ω	0.007	ω	0.000	ω	-0.055	ω	-0.181	ω	-0.057 *	ω	-0.010
a_0	-1.882	a_0	-35.63 ***	a_0	-14.24 ***	a_0	-28.72 *	a_0	-33.42 **	a_0	353.04	a_0	-22.25 ***	a_0	-61.66	a_0	-11.32	a_0	-1.832
a_1	-0.006	a_1	0.064 ***	a_1	0.005	a_1	-0.005	a_1	0.002	a_1	0.457 ***	a_1	-0.027	a_1	0.160	a_1	0.054	a_1	-0.017
a_2	0.060	a_2	0.201	a_2	-0.337 ***	a_2	0.112	a_2	0.203	a_2	0.287	a_2	-0.027	a_2	-0.536	a_2	0.045	a_2	-0.017
a_3	1.799	a_3	4.235 ***	a_3	2.918 ***	a_3	3.896 ***	a_3	2.065	a_3	1.153	a_3	3.548 ***	a_3	14.65	a_3	1.313	a_3	0.904
a_4	0.097	a_4	1.045 ***	a_4	0.481 ***	a_4	0.904 ***	a_4	0.912 **	a_4	1.544 **	a_4	0.660 ***	a_4	2.102	a_4	0.348	a_4	0.173
a_5	0.000	a_5	-0.006 ***	a_5	-0.002 ***	a_5	-0.005 ***	a_5	-0.005 *	a_5	-0.009 **	a_5	-0.003 ***	a_5	-0.011	a_5	-0.001	a_5	0.000
a_6	-0.313 ***	a_6	-0.280 ***	a_6	-0.315 ***	a_6	-0.301 ***	a_6	-0.457 ***	a_6	-0.675 ***	a_6	-0.306 ***	a_6	-0.493 **	a_6	-0.631 ***	a_6	-0.576 ***
CAN	0.809	AUS	0.415	BEN	-1.289 ***	ARE	-3.268	BGD	-2.279 ***	FJI	-414.6 ***	AUT	-0.386	POL	-0.786	ARG	-0.793	BHS	-7.009
DEU	-0.409	BRA	0.290	BFA	-0.971 ***	BHR	-4.967	CYP	-0.924 ***	NZL	-414.0 ***	BEL	-0.697	ROM	-0.029	BOL	-1.200	BRB	-8.906
ESP	-0.416	HKG	-2.777 ***	CAF	-0.718 **	DJI	-3.924	LKA	-2.606 ***	PNG	-412.7 ***	CHE	-0.555	YUG	-0.233	CHL	-1.585 *	CRI	-6.213
FRA	-0.304	IDN	0.200	CIV	-0.963 ***	EGY	-2.385	NPL	-2.412 ***			DNK	-0.619			COL	-1.341	GTM	-6.124
GBR	-0.648	IND	-0.036	COG	-0.893 **	IRN	-2.475	PAK	-1.413 ***			FIN	-0.156			ECU	-2.180 **	HND	-5.722
ITA	-0.459	KOR	-0.777 *	DZA	-0.241	ISR	-3.588	PHL	-1.093 ***			GRC	-0.263			PER	-1.222	JAM	-7.070
JPN	-0.062	MEX	-0.005	ETH	-0.531	JOR	-3.095	SGP	-4.773 ***			IRL	-0.819			PRY	-1.864 **	NIC	-5.639
LUX	-1.999	MYS	-0.352	GAB	-0.991 ***	KWT	-3.423	VNM	-1.412 ***			ISL	-0.492			URY	-2.373 **	PAN	-5.977
NOR	-0.642	SAU	-0.073	GHA	-1.017 ***	OMN	-3.005					MLT	-2.497 ***			VEN	-1.503 *	SLV	-6.790
SWE	-0.505	THA	-0.741	GIN	-1.041 ***	QAT	-3.835					NLD	-0.601					TTO	-7.462
USA	0.965	TUR	-0.287	KEN	-0.767 **	SYR	-2.907					PRT	-0.431						
				LBR	-3.226 ***	YEM	-2.696												
				LBY	-0.341														
				MAR	-0.794 **														
				MDG	-0.800 **														
				MRT	-0.508	NGA	-0.600 *	SWZ	-1.961 ***	TUN	-1.099 ***	ZAF	-0.540						
				MUS	-0.688 *	RWA	-1.838 ***	TCD	-0.466	TZA	-0.615 *	ZMB	-0.687 **						
				NER	-0.470	SEN	-1.132 ***	TGO	-1.509 ***	UGA	-1.057 ***	ZWE	-0.958 **						

Table M.21: Stock adjustment results, pooled, variable λ (equation 5.18); first traffic demand predicted results (equation 5.6); All manufacturers price index, model 3 (table 3.3).

SSE	146.0967		MSE	0.0874		R^2	0.4078		Adj R^2	0.3586	
Parameter	Estimate	Std Err	Parameter	Estimate	Std Err	Parameter	Estimate	Std Err	Parameter	Estimate	Std Err
ω_1	0.0099	0.0251	2 BTUR	0.1255	0.1090	3 BZMB	0.0516	0.1114	7 BFIN	-0.2175	0.1130 *
ω_2	-0.0431	0.0116 ***	3 BBEN	-0.4819	0.1596 ***	3 BZWE	-0.1611	0.1917	7 BGRC	-0.3190	0.1100 ***
a_0	-24.0025	3.3902 ***	3 BBFA	-0.2016	0.1152 *	4 BARE	-0.5997	0.1187 ***	7 BIRL	-0.7616	0.1158 ***
a_1	0.0027	0.0014 *	3 BCAF	0.0292	0.1129	4 BBHR	-2.0946	0.1834 ***	7 BISL	-0.4406	0.1147 ***
a_2	-0.0502	0.0603	3 BCIV	-0.1704	0.1101	4 BDJI	-1.1649	0.1584 ***	7 BMLT	-2.1037	0.1827 ***
a_3	3.6860	0.3645 ***	3 BCOG	-0.1348	0.1150	4 BEGY	0.1900	0.1099 *	7 BNLD	-0.6380	0.1137 ***
a_4	0.7268	0.0955 ***	3 BDZA	0.4304	0.1124 ***	4 BIRN	0.0725	0.1092	7 BPRT	-0.4423	0.1110 ***
a_5	-0.0037	0.0005 ***	3 BETH	0.1852	0.1100 *	4 BISR	-0.8901	0.1180 ***	8 BPOL	-0.4806	0.3086
a_6	-0.2622	0.0148 ***	3 BGAB	-0.1966	0.1113 *	4 BJOR	-0.4448	0.1110 ***	8 BROM	-0.0263	0.2268
1 BCAN	1.0624	0.1219 ***	3 BGHA	-0.2237	0.1114 **	4 BKWT	-0.7438	0.1159 ***	8 BYUG	-0.1528	0.1112
1 BDEU	0.0110	0.1088	3 BGIN	-0.2490	0.1221 **	4 BLBN	-1.0772	0.1263 ***	9 BARG	0.3301	0.1114 ***
1 BESP	0.0043	0.1088	3 BKEN	-0.0067	0.1090	4 BOMN	-0.3527	0.1155 ***	9 BBOL	0.0770	0.1141
1 BFRA	0.0946	0.1090	3 BLBR	-2.0599	0.1860 ***	4 BQAT	-1.0874	0.1286 ***	9 BCHL	0.0339	0.1089
1 BGBR	-0.1895	0.1090 *	3 BLBY	0.3544	0.1114 ***	4 BSYR	-0.2834	0.1096 ***	9 BCOL	0.1033	0.1093
1 BITA	-0.0256	0.1088	3 BMAR	-0.0225	0.1090	4 BYEM	-0.0924	0.1090	9 BECU	-0.3008	0.1117 ***
1 BJPN	0.3215	0.1097 ***	3 BMDG	-0.0402	0.1112	5 BBGD	-0.6661	0.1188 ***	9 BPER	0.1745	0.1094
1 BLUX	-1.2992	0.1314 ***	3 BMRT	0.2020	0.1121 *	5 BCYP	0.1127	0.1141	9 BPRY	-0.1880	0.1151
1 BNOR	-0.1807	0.1090 *	3 BMUS	0.0145	0.1485	5 BLKA	-0.8382	0.1202 ***	9 BURY	-0.3778	0.1286 ***
1 BSWE	-0.0631	0.1087	3 BNER	0.2319	0.1225 *	5 BNPL	-0.8306	0.1971 ***	9 BVEN	0.0330	0.1092
1 BUSA	1.1648	0.1335 ***	3 BNGA	0.1349	0.1096	5 BPAK	-0.1696	0.1092	10 BBHS	-1.1620	0.1532 ***
2 BAUS	0.8655	0.1213 ***	3 BRWA	-0.9456	0.1558 ***	5 BPHL	-0.0160	0.1091	10 BBRB	-1.9822	0.1537 ***
2 BBRA	0.6966	0.1169 ***	3 BSEN	-0.3133	0.1119 ***	5 BSGP	-2.0924	0.1605 ***	10 BCRI	-0.7537	0.1170 ***
2 BIDN	0.5309	0.1139 ***	3 BSWZ	-1.0106	0.1804 ***	5 BVNM	-0.2177	0.1174 *	10 BGTM	-0.7018	0.1153 ***
2 BIND	0.3499	0.1123 ***	3 BTCD	0.2195	0.1159 *	6 BFJI	-0.8041	0.1233 ***	10 BHND	-0.5237	0.1245 ***
2 BKOR	-0.3088	0.1093 ***	3 BTGO	-0.6637	0.1614 ***	6 BNZL	-0.1021	0.1090	10 BJAM	-1.1591	0.1250 ***
2 BMEX	0.3237	0.1109 ***	3 BTUN	-0.2734	0.1096 **	7 BAUT	-0.4540	0.1112 ***	10 BNIC	-0.4649	0.1120 ***
2 BMYS	-0.0051	0.1088	3 BTZA	0.1213	0.1095	7 BBEL	-0.7158	0.1150 ***	10 BPAN	-0.6483	0.1142 ***
2 BSAU	0.3405	0.1108 ***	3 BUGA	-0.2447	0.1094 **	7 BCHE	-0.6205	0.1135 ***	10 BSLV	-1.0284	0.1271 ***
2 BTHA	-0.2987	0.1119 ***	3 BZAF	0.1818	0.1100 *	7 BDNK	-0.6342	0.1137 ***	10 BTTO	-1.3300	0.1311 ***

Table M.22: Stock adjustment results, pooled, variable λ (equation 5.18); first traffic demand predicted results (equation 5.6); US manufacturers price index, model 3 (table 3.12).

SSE	146.0546		MSE	0.0874		R^2	0.4080		Adj R^2	0.3588	
Parameter	Estimate	Std Err	Parameter	Estimate	Std Err	Parameter	Estimate	Std Err	Parameter	Estimate	Std Err
ω_1	0.0097	0.0254	2 BTUR	0.1204	0.1089	3 BZMB	0.0471	0.1112	7 BFIN	-0.2183	0.1128 *
ω_2	-0.0440	0.0118 ***	3 BBEN	-0.4782	0.1595 ***	3 BZWE	-0.1631	0.1916	7 BGRC	-0.3187	0.1098 ***
a_0	-24.4412	3.1628 ***	3 BBFA	-0.2034	0.1150 *	4 BARE	-0.5955	0.1187 ***	7 BIRL	-0.7559	0.1158 ***
a_1	0.0027	0.0014 *	3 BCAF	0.0248	0.1128	4 BBHR	-2.0724	0.1852 ***	7 BISL	-0.4387	0.1146 ***
a_2	-0.0702	0.0646	3 BCIV	-0.1721	0.1098	4 BDJI	-1.1543	0.1589 ***	7 BMLT	-2.0799	0.1846 ***
a_3	3.7754	0.3532 ***	3 BCOG	-0.1374	0.1148	4 BEGY	0.1839	0.1098 *	7 BNLD	-0.6338	0.1137 ***
a_4	0.7409	0.0900 ***	3 BDZA	0.4213	0.1125 ***	4 BIRN	0.0678	0.1091	7 BPRT	-0.4406	0.1108 ***
a_5	-0.0038	0.0005 ***	3 BETH	0.1790	0.1099	4 BISR	-0.8829	0.1182 ***	8 BPOL	-0.4898	0.3086
a_6	-0.2589	0.0152 ***	3 BGAB	-0.1979	0.1111 *	4 BJOR	-0.4430	0.1109 ***	8 BROM	-0.0358	0.2268
1 BCAN	1.0474	0.1226 ***	3 BGHA	-0.2246	0.1112 **	4 BKWT	-0.7380	0.1159 ***	8 BYUG	-0.1544	0.1110
1 BDEU	0.0077	0.1087	3 BGIN	-0.2493	0.1220 **	4 BLBN	-1.0685	0.1266 ***	9 BARG	0.3220	0.1114 ***
1 BESP	0.0004	0.1086	3 BKEN	-0.0105	0.1089	4 BOMN	-0.3516	0.1153 ***	9 BBOL	0.0717	0.1140
1 BFRA	0.0900	0.1089	3 BLBR	-2.0349	0.1881 ***	4 BQAT	-1.0774	0.1290 ***	9 BCHL	0.0305	0.1088
1 BGBR	-0.1910	0.1088 *	3 BLBY	0.3462	0.1115 ***	4 BSYR	-0.2836	0.1094 ***	9 BCOL	0.0983	0.1092
1 BITA	-0.0282	0.1086	3 BMAR	-0.0261	0.1088	4 BYEM	-0.0948	0.1087	9 BECU	-0.3010	0.1115 ***
1 BJPN	0.3152	0.1096 ***	3 BMDG	-0.0433	0.1110	5 BBGD	-0.6618	0.1188 ***	9 BPER	0.1694	0.1092
1 BLUX	-1.2860	0.1322 ***	3 BMRT	0.1960	0.1120 *	5 BCYP	0.1073	0.1140	9 BPRY	-0.1900	0.1149 *
1 BNOR	-0.1820	0.1088 *	3 BMUS	0.0112	0.1484	5 BLKA	-0.8308	0.1204 ***	9 BURY	-0.3763	0.1284 ***
1 BSWE	-0.0657	0.1085	3 BNER	0.2254	0.1224 *	5 BNPL	-0.8246	0.1971 ***	9 BVEN	0.0283	0.1091
1 BUSA	1.1463	0.1346 ***	3 BNGA	0.1293	0.1094	5 BPAK	-0.1710	0.1090	10 BBHS	-1.1507	0.1537 ***
2 BAUS	0.8504	0.1220 ***	3 BRWA	-0.9368	0.1561 ***	5 BPHL	-0.0202	0.1089	10 BBRB	-1.9614	0.1555 ***
2 BBRA	0.6839	0.1173 ***	3 BSEN	-0.3131	0.1117 ***	5 BSGP	-2.0695	0.1625 ***	10 BCRI	-0.7483	0.1171 ***
2 BIDN	0.5202	0.1141 ***	3 BSWZ	-0.9990	0.1807 ***	5 BVNM	-0.2195	0.1172 *	10 BGTM	-0.6969	0.1153 ***
2 BIND	0.3428	0.1123 ***	3 BTCD	0.2124	0.1159 *	6 BFJI	-0.7989	0.1234 ***	10 BHND	-0.5206	0.1244 ***
2 BKOR	-0.3094	0.1091 ***	3 BTGO	-0.6578	0.1614 ***	6 BNZL	-0.1055	0.1088	10 BJAM	-1.1487	0.1254 ***
2 BMEX	0.3171	0.1108 ***	3 BTUN	-0.2737	0.1094 **	7 BAUT	-0.4521	0.1111 ***	10 BNIC	-0.4630	0.1118 ***
2 BMYS	-0.0094	0.1086	3 BTZA	0.1158	0.1094	7 BBEL	-0.7107	0.1150 ***	10 BPAN	-0.6442	0.1141 ***
2 BSAU	0.3326	0.1108 ***	3 BUGA	-0.2455	0.1091 **	7 BCHE	-0.6165	0.1135 ***	10 BSLV	-1.0198	0.1274 ***
2 BTHA	-0.2981	0.1118 ***	3 BZAF	0.1755	0.1099	7 BDNK	-0.6300	0.1136 ***	10 BTTO	-1.3173	0.1318 ***

Table M.23: Stock adjustment results, pooled, variable λ (equation 5.18); second traffic demand predicted results (equation 5.7); All manufacturers price index, model 3 (table 3.3).

SSE	145.4368		MSE	0.0881		R^2	0.4050		Adj R^2	0.3549	
Parameter	Estimate	Std Err	Parameter	Estimate	Std Err	Parameter	Estimate	Std Err	Parameter	Estimate	Std Err
ω_1	0.0100	0.0253	2 BTUR	0.1181	0.1093	3 BZMB	0.0416	0.1117	7 BGRC	-0.3235	0.1102 ***
ω_2	-0.0439	0.0119 ***	3 BBEN	-0.4903	0.1601 ***	3 BZWE	-0.1674	0.1924	7 BIRL	-0.7654	0.1161 ***
a_0	-23.9357	3.4213 ***	3 BBFA	-0.2116	0.1155 *	4 BARE	-0.6029	0.1191 ***	7 BISL	-0.4474	0.1150 ***
a_1	0.0015	0.0008 *	3 BCAF	0.0179	0.1132	4 BBHR	-2.0934	0.1842 ***	7 BMLT	-2.1041	0.1835 ***
a_2	-0.0492	0.0608	3 BCIV	-0.1786	0.1103	4 BDJI	-1.1707	0.1590 ***	7 BNLD	-0.6410	0.1140 ***
a_3	3.6788	0.3680 ***	3 BCOG	-0.1448	0.1152	4 BEGY	0.1895	0.1102 *	7 BPRT	-0.4469	0.1113 ***
a_4	0.7252	0.0964 ***	3 BDZA	0.4242	0.1127 ***	4 BIRN	0.0618	0.1096	8 BPOL	-0.4844	0.3097
a_5	-0.0037	0.0005 ***	3 BETH	0.1747	0.1102	4 BISR	-0.8932	0.1184 ***	8 BROM	-0.0327	0.2275
a_6	-0.2613	0.0149 ***	3 BGAB	-0.2050	0.1116 *	4 BJOR	-0.4510	0.1113 ***	8 BYUG	-0.1586	0.1115
1 BCAN	1.0548	0.1222 ***	3 BGHA	-0.2327	0.1117 **	4 BKWT	-0.7473	0.1162 ***	9 BARG	0.3221	0.1117 ***
1 BDEU	0.0103	0.1090	3 BGIN	-0.2579	0.1225 **	4 BOMN	-0.3604	0.1158 ***	9 BBOL	0.0678	0.1144
1 BESP	0.0000	0.1090	3 BKEN	-0.0148	0.1093	4 BQAT	-1.0910	0.1291 ***	9 BCHL	0.0260	0.1092
1 BFRA	0.0924	0.1092	3 BLBR	-2.0615	0.1869 ***	4 BSYR	-0.2910	0.1099 ***	9 BCOL	0.0954	0.1096
1 BGBR	-0.1889	0.1092 *	3 BLBY	0.3462	0.1117 ***	4 BYEM	-0.0993	0.1092	9 BECU	-0.3086	0.1120 ***
1 BITA	-0.0293	0.1090	3 BMAR	-0.0294	0.1093	5 BBGD	-0.6742	0.1192 ***	9 BPER	0.1656	0.1096
1 BJPN	0.3165	0.1099 ***	3 BMDG	-0.0502	0.1114	5 BCYP	0.1048	0.1144	9 BPRY	-0.1965	0.1154 *
1 BLUX	-1.3006	0.1319 ***	3 BMRT	0.1898	0.1123 *	5 BLKA	-0.8447	0.1206 ***	9 BURY	-0.3841	0.1290 ***
1 BNOR	-0.1852	0.1092 *	3 BMUS	0.0057	0.1490	5 BNPL	-0.8360	0.1979 ***	9 BVEN	0.0261	0.1095
1 BSWE	-0.0666	0.1090	3 BNER	0.2261	0.1228 *	5 BPAK	-0.1713	0.1095	10 BBHS	-1.1647	0.1538 ***
1 BUSA	1.1590	0.1339 ***	3 BNGA	0.1275	0.1098	5 BPHL	-0.0235	0.1094	10 BBRB	-1.9823	0.1544 ***
2 BAUS	0.8568	0.1216 ***	3 BRWA	-0.9531	0.1563 ***	5 BSGP	-2.0908	0.1612 ***	10 BCRI	-0.7589	0.1174 ***
2 BBRA	0.6879	0.1172 ***	3 BSEN	-0.3213	0.1122 ***	5 BVNM	-0.1816	0.1121	10 BGTM	-0.7073	0.1157 ***
2 BIDN	0.5210	0.1142 ***	3 BSWZ	-1.0152	0.1811 ***	6 BFJI	-0.8115	0.1237 ***	10 BHND	-0.5295	0.1249 ***
2 BIND	0.3415	0.1126 ***	3 BTCD	0.2067	0.1161 *	6 BNZL	-0.1088	0.1092	10 BJAM	-1.1619	0.1254 ***
2 BKOR	-0.3143	0.1096 ***	3 BTGO	-0.6703	0.1619 ***	7 BAUT	-0.4569	0.1115 ***	10 BNIC	-0.4739	0.1122 ***
2 BMEX	0.3148	0.1112 ***	3 BTUN	-0.2795	0.1099 **	7 BBEL	-0.7175	0.1153 ***	10 BPAN	-0.6540	0.1145 ***
2 BMYS	-0.0135	0.1091	3 BTZA	0.1117	0.1098	7 BCHE	-0.6218	0.1138 ***	10 BSLV	-1.0324	0.1276 ***
2 BSAU	0.3323	0.1111 ***	3 BUGA	-0.2528	0.1096 **	7 BDNK	-0.6372	0.1140 ***	10 BTTO	-1.3333	0.1316 ***
2 BTHA	-0.3091	0.1123 ***	3 BZAF	0.1771	0.1103	7 BFIN	-0.2223	0.1133 **			

Table M.24: Stock adjustment results, pooled, variable λ (equation 5.18); second traffic demand predicted results (equation 5.7); US manufacturers price index, model 3 (table 3.12).

SSE	145.3996		MSE	0.0881		R^2	0.4052		Adj R^2	0.3551	
Parameter	Estimate	Std Err	Parameter	Estimate	Std Err	Parameter	Estimate	Std Err	Parameter	Estimate	Std Err
ω_1	0.0098	0.0256	2 BTUR	0.1129	0.1092	3 BZMB	0.0371	0.1115	7 BGRC	-0.3235	0.1101 ***
ω_2	-0.0448	0.0121 ***	3 BBEN	-0.4870	0.1600 ***	3 BZWE	-0.1696	0.1923	7 BIRL	-0.7601	0.1162 ***
a_0	-24.3786	3.1919 ***	3 BBFA	-0.2135	0.1153 *	4 BARE	-0.5991	0.1190 ***	7 BISL	-0.4459	0.1149 ***
a_1	0.0015	0.0008 *	3 BCAF	0.0135	0.1130	4 BBHR	-2.0724	0.1859 ***	7 BMLT	-2.0815	0.1854 ***
a_2	-0.0678	0.0651	3 BCIV	-0.1805	0.1101	4 BDJI	-1.1609	0.1595 ***	7 BNLD	-0.6372	0.1140 ***
a_3	3.7663	0.3567 ***	3 BCOG	-0.1475	0.1151	4 BEGY	0.1834	0.1101 *	7 BPRT	-0.4455	0.1111 ***
a_4	0.7393	0.0908 ***	3 BDZA	0.4153	0.1128 ***	4 BIRN	0.0570	0.1094	8 BPOL	-0.4935	0.3097
a_5	-0.0038	0.0005 ***	3 BETH	0.1686	0.1101	4 BISR	-0.8866	0.1186 ***	8 BROM	-0.0420	0.2276
a_6	-0.2581	0.0153 ***	3 BGAB	-0.2065	0.1114 *	4 BJOR	-0.4495	0.1112 ***	8 BYUG	-0.1604	0.1113
1 BCAN	1.0403	0.1229 ***	3 BGHA	-0.2338	0.1115 **	4 BKWT	-0.7420	0.1163 ***	9 BARG	0.3141	0.1117 ***
1 BDEU	0.0070	0.1088	3 BGIN	-0.2584	0.1223 **	4 BOMN	-0.3596	0.1156 ***	9 BBOL	0.0625	0.1143
1 BESP	-0.0040	0.1088	3 BKEN	-0.0187	0.1091	4 BQAT	-1.0817	0.1295 ***	9 BCHL	0.0225	0.1090
1 BFRA	0.0877	0.1091	3 BLBR	-2.0378	0.1890 ***	4 BSYR	-0.2914	0.1097 ***	9 BCOL	0.0903	0.1095
1 BGBR	-0.1905	0.1090 *	3 BLBY	0.3381	0.1118 ***	4 BYEM	-0.1018	0.1090	9 BECU	-0.3090	0.1118 ***
1 BITA	-0.0320	0.1088	3 BMAR	-0.0331	0.1091	5 BBGD	-0.6703	0.1192 ***	9 BPER	0.1605	0.1095
1 BJPN	0.3102	0.1098 ***	3 BMDG	-0.0534	0.1112	5 BCYP	0.0994	0.1143	9 BPRY	-0.1986	0.1152 *
1 BLUX	-1.2882	0.1327 ***	3 BMRT	0.1839	0.1122	5 BLKA	-0.8379	0.1208 ***	9 BURY	-0.3829	0.1288 ***
1 BNOR	-0.1868	0.1090 *	3 BMUS	0.0023	0.1489	5 BNPL	-0.8305	0.1979 ***	9 BVEN	0.0214	0.1094
1 BSWE	-0.0694	0.1088	3 BNER	0.2197	0.1227 *	5 BPAK	-0.1727	0.1093	10 BBHS	-1.1542	0.1543 ***
1 BUSA	1.1411	0.1349 ***	3 BNGA	0.1220	0.1097	5 BPHL	-0.0278	0.1092	10 BBRB	-1.9626	0.1561 ***
2 BAUS	0.8422	0.1223 ***	3 BRWA	-0.9449	0.1567 ***	5 BSGP	-2.0691	0.1632 ***	10 BCRI	-0.7539	0.1174 ***
2 BBRA	0.6755	0.1176 ***	3 BSEN	-0.3213	0.1120 ***	5 BVNM	-0.1835	0.1119	10 BGTM	-0.7028	0.1157 ***
2 BIDN	0.5106	0.1144 ***	3 BSWZ	-1.0042	0.1813 ***	6 BFJI	-0.8068	0.1238 ***	10 BHND	-0.5268	0.1248 ***
2 BIND	0.3345	0.1126 ***	3 BTCD	0.1998	0.1161 *	6 BNZL	-0.1122	0.1091	10 BJAM	-1.1522	0.1259 ***
2 BKOR	-0.3150	0.1094 ***	3 BTGO	-0.6649	0.1620 ***	7 BAUT	-0.4553	0.1114 ***	10 BNIC	-0.4723	0.1121 ***
2 BMEX	0.3083	0.1111 ***	3 BTUN	-0.2800	0.1097 **	7 BBEL	-0.7128	0.1154 ***	10 BPAN	-0.6503	0.1145 ***
2 BMYS	-0.0179	0.1089	3 BTZA	0.1062	0.1097	7 BCHE	-0.6181	0.1138 ***	10 BSLV	-1.0245	0.1279 ***
2 BSAU	0.3245	0.1111 ***	3 BUGA	-0.2539	0.1094 **	7 BDNK	-0.6334	0.1139 ***	10 BTTO	-1.3214	0.1323 ***
2 BTHA	-0.3087	0.1121 ***	3 BZAF	0.1708	0.1102	7 BFIN	-0.2233	0.1131 **			