

Essays on Product Quality, International Trade and Welfare



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Balliol College

University of Oxford

A Thesis Submitted for the Degree of

Doctor of Philosophy in Economics

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Abstract

This dissertation consists of four related, sole-authored chapters. It considers the microeconomic mechanisms for gains from trade in the presence of quality investments by firms. It shows within the framework of a quality-augmented heterogeneous firms model that the quality dimension matters for welfare gains from trade. It also provides novel empirical evidence on adjustment mechanisms of aggregate quality as a consequence of globalization. To the best of my knowledge, this is the first contribution to provide a comprehensive analysis of the role of endogenous product quality in the determination of gains from trade.

I first offer an explanation for observed industry heterogeneity in trade-induced productivity gains and show that results depend on whether or not firms have the option to invest in quality. I then take a broader view of welfare gains from trade, looking beyond productivity improvements. I find that globalization can imply a quality-variety trade-off when consumer quality preference is strong - a finding which holds under firm heterogeneity and symmetry. Nevertheless, overall gains from trade are positive. With quality being itself an important channel for gains from trade, I also investigate the detailed mechanisms by which aggregate quality changes as a consequence of globalization. This is done within the same theoretical heterogeneous firms framework as well as empirically using firm-level export data matched with firm-level quality ratings. I argue that firm heterogeneity matters for gains from trade by giving rise to an additional welfare channel in the presence of variable elasticity of demand preferences: high quality firms expand sales disproportionately in a larger market, thereby raising aggregate quality. This theoretical prediction is confirmed by the data. Furthermore, I study the mechanisms for gains from trade in a symmetric firms version of the baseline model. This allows me to isolate the role of firm heterogeneity in driving earlier results. In addition, I analyse the efficiency properties of the market equilibrium for the symmetric firms case. (Thesis word count: ~47,000)

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Contents

1	Introduction	12
2	Heterogeneous Industries, Quality and Trade	24
2.1	Introduction	24
2.1.1	Literature	27
2.2	Theory	31
2.2.1	Set-Up	31
2.2.1.1	Closed Economy	31
2.2.1.2	Open Economy	37
2.3	Productivity, Quality and Product Differentiation	37
2.3.1	No-Quality Benchmark	39
2.3.1.1	Closed Economy: Market Size Effect	40
2.3.1.2	Open Economy: Trade and Bilateral Liberalization	42
2.3.2	Introducing Quality	46
2.3.2.1	Differentiation and Productivity	47
2.3.2.2	Differentiation and Firm-Level Quality Upgrading	48
2.3.2.3	Closed Economy: Market Size Effect	52
2.3.2.4	Open Economy: Trade and Bilateral Liberalization	53
2.3.3	Product Differentiation and Fixed Costs	58
2.3.3.1	Closed Economy	58
2.3.3.2	Open Economy	59

2.3.4	Interaction Between Differentiation and Fixed Costs	60
2.4	Conclusion	61
2.5	Appendix	69
2.5.1	Derivations and Proofs Relating to the Benchmark Model without Quality	69
2.5.1.1	Closed Economy	69
2.5.1.2	Open Economy	70
2.5.2	Derivations and Proofs Relating to the Model with Quality	71
2.5.2.1	Closed Economy	71
2.5.2.2	Open Economy	74
2.5.3	Derivations and Proofs Relating to Fixed Costs	75
2.5.3.1	Closed Economy	75
2.5.3.2	Open Economy	75
2.5.4	Derivations and Proofs Relating to FC- γ Interaction	76
3	Does Product Quality Matter for Gains from Trade?	77
3.1	Introduction	77
3.2	Set-Up	81
3.2.1	Consumers	81
3.2.2	Firms	83
3.3	Quality and Product Market Competition	88
3.3.1	Divergence of Competition Measures	89
3.3.1.1	Selection	89
3.3.1.2	Market Power	91
3.3.1.3	Competitive Toughness	91
3.4	Welfare and Gains from Trade	93
3.4.1	Quality	94
3.4.2	Quality-Adjusted Prices	97

3.4.3	Mass of Varieties	97
3.4.4	Price and Quality Variance	99
3.4.5	Summary	99
3.4.6	Overall Welfare Impact	100
3.5	Variable Quality Cost	101
3.5.1	Gains from Trade	103
3.6	Quality and the Macroeconomic Gains from Trade	106
3.7	Conclusion	108
3.8	Appendix	115
3.8.1	Fixed Cost of Quality: Closed Economy	115
3.8.2	Introducing Vertical Differentiation	120
3.8.3	Preferences Nesting both Antoniades (2008) and this Chapter	124
3.8.4	Divergence of Competition Measures	126
3.8.5	Welfare Derivation	129
3.8.6	Trade Integration and Gains from Trade	138
3.8.6.1	Welfare Comparative Statics	145
3.8.7	Variable Cost of Quality: Closed Economy	146
3.8.7.1	Variable Cost Comparative Statics	149
3.8.8	Open Economy	151

4	Sparkling Trade Flows: Does Export Market Size Amplify Quality Advantage?	156
4.1	Introduction	156
4.1.1	Literature	158
4.2	Theoretical Background and Baseline Specification	163
4.3	Data	168
4.4	Estimations	174
4.4.1	Results	174

4.4.2	Robustness	181
4.4.2.1	Quantity Effects	181
4.4.2.2	Heckman Selection Model	181
4.4.2.3	GDP per Capita	182
4.4.3	Other Margins of Adjustment	183
4.5	Conclusion	184
4.6	Appendix	191
4.6.1	Theory - Submodularity of Optimized Export Revenues	191
4.6.2	Definition of Gravity Variables	194
4.6.3	Market Size, Unit Values and Quality Upgrading	194
4.6.3.1	Price Decomposition	196
4.6.3.2	Price Effects	197
4.6.4	Additional Results	198

5 Quality vs Variety: Efficiency and Welfare under Monopolistic Competition with Endogenous Quality 203

5.1	Introduction	203
5.2	Set-Up	206
5.2.1	Consumers	206
5.2.2	Firms	207
5.2.3	Monopolistic Competition, Demand and Efficiency	208
5.3	Market Equilibrium and Social Planner's Outcome	209
5.3.1	Market Equilibrium	210
5.3.2	Social Planner's Outcome	211
5.3.2.1	Unconstrained Optimum	212
5.3.2.2	Constrained Optimum	213
5.3.3	Market vs Social Planner without Quality	214
5.3.4	Adding Quality	215

5.3.5	Market vs Social Planner with Quality	217
5.4	Globalization	219
5.4.1	Can Market Size Address Distortions?	219
5.4.2	The Added Value of Firm Heterogeneity	222
5.5	Conclusion	223
5.6	Appendix	228
5.6.1	Market Equilibrium	228
5.6.2	Unconstrained Social Planner	230
5.6.3	Constrained Social Planner	233
6	Conclusion	236

List of Figures

2.1	Optimal Quality vs Cost	35
2.2	Market Size Effect without Quality	42
2.3	Cut-off and Product Differentiation with Quality	48
2.4	Optimal Quality vs Cost for Different Values of γ	51
2.5	Market Size Effect with Quality	54
2.6	Partial Liberalization with Quality	56
3.1	Cost Cut-off for Different Degrees of Product Differentiation	90
3.2	Selection and Competitive Toughness	92
3.3	Variety and Market Size	98
4.1	Number of Exporters by Star Rating	169
4.2	Average Exports per Firm by Star Rating (in million euros)	171

List of Tables

3.1	Channels for Gains from Trade	100
4.1	Quality-Market Size Relationship in the Literature	163
4.2	Summary Statistics: Export Destinations per Firm	171
4.3	Summary Statistics: Firm Destination Export Value (in euro)	172
4.4	Export Values (OLS)	176
4.5	Export Values (OLS)	177
4.6	Export Values (Tobit EK censored)	179
4.7	Export Values (Tobit EK censored)	180
4.8	Definition of Gravity Variables from CEPII Gravity Dataset	195
4.9	Price Decomposition	197
4.10	Export Quantities (Tobit EK censored)	199
4.11	3-Stage Heckman Selection Model with Export Values	200
4.12	3-Stage Heckman Selection Model with Export Quantities	201
4.13	Export Values (Tobit EK censored)	202
4.14	FOB Export Prices	202

Chapter 1

Introduction

This dissertation consists of four related, sole-authored chapters. It asks how endogenous product quality changes what we know about the microeconomic mechanisms for gains from trade. The analysis is conducted in light of three strands of the recent trade and IO literature: (i) the heterogeneous firms trade literature which examines the micro-structure of international trade flows based on highly disaggregated trade datasets at the product-, firm- and plant-level;¹ (ii) a large recent literature examining the systematic links between product quality and the trade environment;² and (iii) a classic IO literature which studies the relationship between market size and endogenous product quality.³ Ultimately, the combination of results from these literatures constitutes another important piece in the puzzle of understanding growth processes and modern industrialization experiences.⁴

I show within the framework of a quality-augmented heterogeneous firms model that the quality dimension matters for welfare gains from trade. I first offer an explanation for observed industry heterogeneity in trade-induced productivity gains and show that results depend on whether or not firms have the option to invest in quality. I then take a broader

¹Pavcnik, 2002; Bernard, Jensen and Schott, 2006; Bernard, Jensen, Redding and Schott, 2007; Fernandes, 2007; Melitz, 2003; Melitz and Ottaviano, 2008.

²Schott, 2004; Hummels and Klenow, 2005; Hallak, 2006; Verhoogen, 2008; Eckel, Iacovone, Javorcik and Neary, 2011; Khandelwal, 2010; Baldwin and Harrigan, 2011; Iacovone and Javorcik, 2012; Kugler and Verhoogen, 2012; Crozet, Head and Mayer, 2012.

³Shaked and Sutton, 1983; Sutton, 1989, 1991; Berry and Waldfogel, 2004.

⁴Grossman and Helpman 1991; Sutton 2012.

view of welfare gains from trade, looking beyond productivity improvements. I find that globalization can imply a quality-variety trade-off when consumer quality preference is strong - a finding which holds under firm heterogeneity and symmetry. Nevertheless, overall gains from trade are positive. With quality being itself an important channel for gains from trade, I also investigate the detailed mechanisms by which aggregate quality changes as a consequence of globalization. This is done within the same theoretical heterogeneous firms framework as well as empirically using firm-level export data. I argue that firm heterogeneity matters for gains from trade by giving rise to an additional welfare channel in the presence of variable elasticity of demand preferences: the existence of a “Matthew Effect” (Mrazova and Neary, 2011) for market size means that globalization skews sales towards the best firms, thereby raising aggregate quality. Furthermore, I study the efficiency of the quality-augmented market equilibrium in a symmetric firms version of the baseline model. To the best of my knowledge, this dissertation is the first contribution to provide a comprehensive analysis of the role of endogenous product quality in the determination of gains from trade.

For the purpose of this dissertation, I take a very broad view of quality. Following Sutton (2012), I define “quality (as) refer(ring) to anything that shifts the demand schedule outwards: technical characteristics, after sales service, brand image, and so on... ” (Sutton 2012, p.10). I thus do not differentiate between real quality and perceived quality, that is whether a product is objectively better or whether consumers simply perceive it to be better.⁵

In the theoretical models presented in this thesis, product quality is a choice variable for firms along with output. I consider two types of quality investment: firms can raise quality either through fixed cost investment or by incurring additional variable costs. For the empirical analysis, I make use of a unique dataset containing firm-level quality ratings

⁵As Dixit and Norman (1978) have argued, the difference is immaterial for a positive analysis; for a normative analysis, the welfare assessment of changes in “quality” achieved by marketing will to a certain extent depend on whether one believes that marketing adds value or not (the literature differentiates between informative vs persuasive marketing: does marketing carry information/signal quality or does it simply change preferences).

matched with firm-level exports, which allows me to test one of the key predictions implied by the theoretical framework in Chapter 3.

This dissertation was inspired by a large empirical literature pointing to an important role for product quality in international competition. Schott's (2004) initial observation that product quality is an important factor in explaining trade patterns has been substantiated by a wave of recent evidence. In line with the rest of the empirical trade literature over the last decade, contributions have moved from showing a quality-trade relationship at the country level to more disaggregated analyses at the product- and firm-level.

Focusing on the supply side, Schott (2004) and Hummels and Klenow (2005) show that (capital-)richer countries export systematically higher quality products than poorer ones. Baldwin and Harrigan (2011), Mandel (2010), and Kugler and Verhoogen (2012), present evidence that a similar pattern holds at the firm level, where the most productive firms export the highest quality products. Eckel, Iacovone, Javorcik and Neary (2011) find analogous results for multi-product firms: firms have varying competencies in producing different products and in differentiated goods sectors the "core-competency" product is of the highest quality. Crozet, Head and Mayer (2012) demonstrate the importance of quality sorting by French firms across export markets, using a unique dataset which allows them to directly capture the level of product quality. Their results provide support for a quality-interpretation of Melitz (2003). On the demand side, the literature has seen a revival of non-homothetic preferences and the Linder hypothesis in its quest to explain observed quality patterns (Hallak, 2006; Fajgelbaum et al, 2011; Fieler, 2011; Demir, 2011; Feenstra and Romalis 2012).⁶ Manova and Zhang (2012) present empirical evidence of quality heterogeneity within firms across destination markets; Demir (2011) provides a theoretical framework for these patterns.

Another set of contributions study the effect of changes in the trade environment on

⁶The Linder hypothesis states that quality plays an important role in determining the direction and volume of trade: proximity to a market with demand for high quality products is a source of comparative advantage, leading firms in high income countries to produce and export a greater fraction of high quality goods than firms in low income countries. Bilateral trade flows will be concentrated between countries with similar income levels.

firm quality choice. Verhoogen (2008) and Iacovone and Javorcik (2012), for example, consider the impact of trade liberalization on product quality. Their contributions provide evidence for liberalization-induced firm-level quality upgrading by the most productive firms, which is in line with predictions of the theoretical framework considered in this thesis. Iacovone and Javorcik (2012) investigate Mexican firm-level investment in quality around the time of the NAFTA launch. Their results are consistent with the hypothesis that firms which are about to enter the US market engage in quality upgrading. Verhoogen's (2008) contribution suggests that product quality upgrading by Mexican firms around the time of NAFTA accession had important general equilibrium effects. Most importantly, he puts it forward as an explanation for the observed widening wage gap between high and low skill workers in Mexico. While both Verhoogen (2008) and Iacovone and Javorcik (2012) study partial liberalization, this dissertation considers changes in quality provision in response to changes in market size, i.e. total integration.

Furthermore, there is an older strand of the Industrial Organization literature which is relevant when thinking about quality and globalization: Shaked and Sutton (1983) and Sutton (1989; 1991) show that the effect of market size on firms and industry outcomes will depend on an industry's scope for quality upgrading. In particular, they formulate the famous natural oligopoly result by which firms' quality investments off-set the tendency of industries to fragment as market size gets large.

All chapters of this dissertation build on the latest theoretical and empirical literature and make novel contributions to both. I discuss the individual contributions of the chapters in more detail in the subsequent section. In what follows, I provide an overview of what they have in common in terms of their conceptual framework: in my analysis of gains from trade, I focus for the most part on the consequences of globalization, modeled in a highly stylized way as an increase in market size (as in Krugman, 1979). While ultimately interested in the effect of market size, I account for trade frictions empirically in Chapter 4 and theoretically in Chapters 2 and 3. On the supply side, all settings are characterized

by a market structure of monopolistic competition; on the demand side, all have variable elasticity of demand (VED) preferences. The combination of these two assumptions means that efficiency improvements will play an important role in generating gains from trade. In particular, under VED preferences, market size will be a crucial factor in determining firms' choice of output and quality and in addressing distortions arising from imperfect competition and flexible mark-ups. I provide empirical evidence supporting the assumption of VED preferences in Chapter 4. Three of the four chapters assume heterogeneous firms (Chapters 2, 3 and 4), one works in a symmetric firms context (Chapter 5). In the case of heterogeneous firms, the assumption of VED preferences gives rise to complementarities between firm productivity and market size (the above-mentioned Matthew Effect) which I investigate theoretically in Chapter 3 and provide empirical evidence for in Chapter 4. All of the theoretical frameworks focus on industry-level equilibrium, assuming exogenous costs and an outside sector which absorbs income effects. This allows me to isolate the effect of market size in driving welfare gains. The assumption of one factor of production means I abstract from the distributional consequences of globalization - which is, of course, not to deny that they are important. Product quality is assumed to be endogenous to market size in Chapters 2, 3 and 5. Chapter 3 also considers the case where firm quality choice is independent of market size. Preferences are assumed to be quasi-homothetic throughout.

Contribution of the Thesis The subsequent section summarizes the contributions of the individual chapters. Chapter 2 represents a modified version of my MPhil thesis. It works within the theoretical frameworks developed by Melitz and Ottaviano (2008) and Antoniadis (2008). Chapters 3 and 4 form the core of the thesis; key results from these two chapters made up my Job Market Paper entitled "Product Quality, Market Size and Welfare: Theory and Evidence from French Exporters". Chapter 3 breaks new ground by conducting a systematic welfare analysis of trade with endogenous product quality; by deriving the equilibrium under variable quality cost and comparing it to the fixed cost

equilibrium in the baseline model; and by linking the analysis to recent insights on the macroeconomic gains from trade.⁷ Chapter 4 tests for a new channel for quality-related gains from trade implied by the theoretical framework in Chapter 3. Chapter 5 presents a symmetric firms version of the model in Chapter 3 in order to draw out the role of firm heterogeneity in driving results; it also studies the efficiency properties of the market equilibrium with endogenous quality.

Chapter 2 “Heterogeneous Industries, Quality and Trade” In this chapter, I offer an explanation for observed industry heterogeneity in trade-induced productivity gains. To this end, I extend a heterogeneous firms trade model to contain a continuum of industries which vary in their degree of product differentiation. In line with recent empirical evidence, I further argue that accounting for quality competition in this context is important. I compare predictions of a quality-augmented model to the no-quality benchmark and show that the quality dimension matters for results regarding average industry productivity and industries’ productivity responses to changes in the trading environment. In exploring these relationships, I separate out the effect of changes in the demand parameter representing product differentiation from changes in fixed costs associated with more differentiated industries.

Chapter 3 “Does Product Quality Matter for Gains from Trade?” This chapter presents novel theoretical insights on the welfare effects of globalization when product quality is an important dimension of competition. The setting is a heterogeneous firms trade model with competition effects. Firstly, I show that the level of “competitive toughness” in a market is an ambiguous concept in the quality-augmented model and hence not an informative welfare indicator - unlike in the standard model. Instead, I rely on a decomposition of the indirect utility function for the subsequent welfare analysis. Although overall gains from trade are positive, an increase in market size can have conflicting effects

⁷Arkolakis, Costinot and Rodriguez-Clare, 2012; Arkolakis, Costinot, Donaldson and Rodriguez-Clare, 2012; Simonovska and Waugh, 2013; Dhingra and Morrow, 2012; Mrazova and Neary, 2013; Nocco, Ottaviano and Salto, 2013; Melitz and Redding, 2013.

on welfare through different channels. In particular, when consumers have a strong preference for quality, globalization can mean that higher aggregate quality is accompanied by a loss in product variety. Secondly, with respect to gains from trade, it is necessary to distinguish between two quality cost structures: when quality is achieved via fixed cost investment, an increase in market size triggers quality upgrading by the most productive firms, leading to a polarization of the quality distribution. When quality production incurs only variable cost, firm quality choice is independent of firm scale and hence market size and the upgrading channel no longer operates. The most robust positive welfare mechanism associated with an increase in market-size is a disproportionate increase in sales for high quality firms. The chapter also derives a gravity equation for the model and links the analysis to recent insights on the macroeconomic gains from trade.

Chapter 4 “Sparkling Trade Flows: Does Export Market Size Amplify Quality Advantage?” Market size effects are an important mechanism by which countries can benefit from trade integration. The fourth chapter identifies market size effects in a quality-augmented heterogeneous firms setting. This setting gives rise to complementarities by which the high quality firms benefit disproportionately from a larger market. Using French firm-level export data and a direct measure of producer quality for the champagne industry, I present evidence that a larger export market is indeed associated with a larger expansion in export sales for the higher quality producers. Translating the result from a cross-section to a time-series context, the results suggest a positive effect of globalization on aggregate quality.

Chapter 5 “Quality vs Variety: Efficiency and Welfare under Monopolistic Competition with Quality” This chapter investigates the efficiency of the market equilibrium and the welfare effects of globalization in a model with imperfect competition, variable elasticity of substitution preferences and quality investment. Firms are assumed to be symmetric. I analyse distortions in the equilibrium provision of output, quality and

variety and find that under the decentralized allocation, firms produce both too little output and too little quality, while the market as a whole may over- or underprovide variety. If fixed costs are low relative to the degree of product differentiation, the unconstrained social planner trades off variety more strongly in favour of quality than the market mechanism would and vice versa. An increase in market size can address these distortions to an extent, though the market does not converge to the competitive limit as market size gets large. The symmetric firms analysis confirms the possibility of an anti-variety effect of globalization in the presence of quality investment derived for the heterogeneous firms case in Chapter 3 of this thesis.

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Chapter 2

Heterogeneous Industries, Quality and Trade

2.1 Introduction¹

Two sets of micro evidence have been shaping an important part of the trade literature over the last decade: firstly, trade-induced productivity gains are due, to a large extent, to changes in industry composition in favour of the most productive firms.² Secondly, quality is an important factor in explaining patterns in international trade.³ This chapter notes that there is wide variation in industries' productivity responses to trade liberalization and examines one potential source of this heterogeneity: differences in the competitive environment arising from differences in the degree of product differentiation. In addition, it considers how the nature of productivity responses across industries changes in the presence of endogenous quality investment compared to a no-quality benchmark.

To this end, I extend a theoretical model by Antoniadou (2008) which incorporates

¹**Acknowledgments:** I would like to thank Peter Neary and Beata Javorcik for their guidance with this chapter and Paula Bustos, Toshihiro Okubo, Robert Ritz, Tony Venables and the participants of the Oxford trade seminar series for helpful comments and suggestions.

²Pavcnik, 2002; Bernard, Jensen and Schott, 2006; Fernandes, 2007.

³Schott, 2004; Hummels and Klenow, 2005; Hallak, 2006; Verhoogen, 2008; Khandelwal, 2010; Eckel, Iacovone, Javorcik and Neary, 2011; Baldwin and Harrigan, 2011; Iacovone and Javorcik, 2012; Manova and Zhang, 2012; Kugler and Verhoogen, 2012; Crozet, Head and Mayer, 2012.

both composition effects and product quality. In particular, I introduce industry heterogeneity in the form of differences in the degree of product and trace out the consequences of various liberalization scenarios. I contrast these results with predictions from Melitz and Ottaviano's (2008) model without quality and show that the quality dimension is important from a theoretical point of view. I further investigate the role of quality in more depth by exploring how firm-level quality choice varies for industries with different degrees of product differentiation and for firms of different productivities.

Pavcnik (2002) shows that productivity gains across industries in Chile were, to a large extent, driven by changes in industry composition. Taking a closer look at her results, it becomes evident that these reactions to changes in the trading environment vary significantly across industries. While she ascribes some of this variation to differences in pre-reform protection levels, there are still considerable differences after protection has been accounted for. According to Pavcnik's (2002) analysis, aggregate productivity gains in the seven years following Chile's liberalization ranged from 6-7% in manufacturing of machinery and equipment, and 18% in food, textiles and metals, to 33% in glass and 43% in chemicals. The analysis in the present chapter suggests an explanation for this heterogeneity across industries.

Furthermore, the analysis in this chapter offers an explanation for Schott's (2004) observation of industry-varying quality range.⁴ In his study, unit values of products are used as a proxy for their otherwise hard-to-measure level of quality. The author takes fuel oil to be the benchmark case of a homogeneous product where the price per barrel only varies between US\$9-21 from the least to the most productive producer. For a medium differentiated product like men's cotton shirts, the price range widens to US\$21-670 per dozen and, finally, for cathode ray tube (CRT) monitors, a highly differentiated product, the range is US\$162-8,143 per monitor. I show below that these predictions for industry-

⁴The context of Schott's (2004) analysis is representative firms engaging in intra-industry trade among countries of different income levels. Figure 4 in Schott (2004) plots unit values of varieties against exporters' GDP and shows that the range of unit values of US import products varies widely with the product's degree of differentiation.

varying quality range can be generated within the theoretical framework presented in this chapter.

I conduct the analysis in a monopolistic competition, heterogeneous firms setting, investigating both closed and open economy scenarios with symmetric countries. I introduce industry heterogeneity following Neary (2010): pre-entry assignment of firms to the variously differentiated industries is modeled explicitly. Product differentiation enters the model in the form of a demand parameter and is also reflected in the fixed entry cost paid by firms.

I investigate comparative statics behaviour for the long-run relationship between the degree of product differentiation and (i) average industry productivity; (ii) the industry quality range; and (iii) the productivity impact of trade (via the composition effect). I consider three situations with respect to trade: (i) an increase in market size (this can also be interpreted as a move from autarky to free trade); (ii) the move from a closed economy to an open economy setting with positive trade costs; and (iii) a reduction in trade costs.

By contrasting results for a benchmark model without quality with the quality-augmented case, I show that the quality dimension matters for predictions on the impact of liberalization on industry productivity. In the model without quality, the relationship between the degree of product differentiation and trade-induced productivity effects is monotonic: productivity effects are amplified by higher degrees of product differentiation. In the model with quality, this is not necessarily true: while the effect of total integration is also amplified by higher degrees of differentiation, the effect of partial integration is non-monotonic. It is highest at intermediate levels of product differentiation but productivity gains are negligible for very high and very low degrees of differentiation. In exploring these relationships, I separate out the effect of changes in the demand parameter representing product differentiation from changes in fixed costs associated with more differentiated industries.

The rest of this section gives an overview of the existing literature. Section 2.2 lays out the model underlying the analysis. Section 2.3 presents the comparative statics analysis of the effect of product differentiation on industry productivity and productivity responses

to trade-induced shocks as well as on firms' quality choice. This is done for the two nested models with and without quality. The section explores the impact in terms of the demand parameter representing differentiation and robustness of these results in the case where the degree of product differentiation also affects firms' entry costs. Section 2.4 concludes. Detailed proofs can be found in the Appendix.

2.1.1 Literature

The model I present in this chapter draws on several strands of the literature. The contributions I build on can be grouped under the headings of "trade and productivity" and "trade in differentiated products".

Trade and Productivity The core model on which I build is one of monopolistic competition, trade and firms that are heterogeneous in their productivity. In my analysis of differentiated products and intra-industry trade, I draw on the literature sparked by Melitz's (2003) seminal contribution on trade with heterogeneous firms which opened up a new channel for productivity gains from trade liberalization: the model predicts an intra-industry reallocation of resources to the most productive firms as a consequence of liberalization, such that average productivity in the economy increases.⁵ I am building on subsequent extensions of Melitz's (2003) model by Melitz and Ottaviano (2008), who emphasize the importance of market size in determining average industry productivity, and Antoniadis (2008), who introduces firm quality choice into the Melitz and Ottaviano (2008) framework. Since these monopolistic competition, heterogeneous firms models aim to explain different features of intra-industry trade, they focus on one sector only. In order to draw out differences in liberalization-induced productivity responses across industries, I introduce a continuum of differentiated industries which differ in the extent to which varieties are substitutable.

⁵A contemporaneous theoretical contribution which also models the stylized fact of heterogeneous firms and more productive exporters is Bernard, Eaton, Jensen and Kortum, 2003.

The models by Melitz (2003) and their subsequent variations form part of a wider debate in the micro-trade literature on the relationship between industry productivity and trade. The first strand, following Melitz (2003) and Bernard, Eaton, Jensen and Kortum (2003) emphasizes intra-industry reallocation of resources to the most productive firms post-liberalization. As the least productive firms are forced to exit and there are more firms with higher productivity in the market, the composition of the industry changes and average productivity rises in the wake of liberalization. The other strand of the literature predicts that firms themselves will become more productive as a result of liberalization. The productivity effect in these models works either via increased import competition or via additional revenues from exporting: Aghion, Burgess, Redding and Zilibotti's (2004) model, for example, predicts that firms' incentives to innovate are sharpened by increased import competition, whereby the effect will be stronger for firms which are closer to the technology frontier and might be negative for the least productive firms. Alternatively, Bustos (2011) builds on Melitz's (2003) selection model adding a mechanism by which increased export revenues prompt firms to increase technology investments in response to liberalization. Again, the effect is strongest for the most productive firms and potentially reversed for the least productive ones.

Many empirical papers have tried to establish the validity of these theories and a number of them find strong evidence in favour of selection. Some prominent examples are Pavcnik (2002), Bernard, Jensen and Schott (2006) and Fernandes (2007). Looking at Chile's unilateral liberalization experience in the late 1970s, Pavcnik (2002) finds both post-liberalization productivity increases at the firm level and changes in composition, which would point towards selection.⁶ Van Biesebroeck (2005) and de Loecker (2007) on the other hand present evidence suggesting that at least part of a post-liberalization productivity increase is due to improved efficiency at the firm level - for example via

⁶The seminal papers in this literature are Clerides, Lach and Tybout (1998), Bernard and Jensen (1999), and Aw, Chung and Roberts (2000). A survey of the empirical literature in this vein is provided by Tybout (2003). Earlier empirical micro studies on trade and productivity include Levinsohn (1993), Harrison (1994), Tybout and Westbrook (1995), Krishna and Mitra (1998), and Head and Ries (1999a, b).

economies of scale or learning by exporting. Bustos (2011) finds increased technology investment by the most productive firms in the wake of liberalization.

Trade in Differentiated Products Product differentiation and monopolistic competition found their way into the trade literature when the need arose to model intra-industry trade. A more recent empirical literature suggests an important role for quality in explaining trade in differentiated products.

Empirical evidence on the importance of quality in explaining trade stylized facts has accumulated fast (see Chapter 1). Antoniades' (2008) model is one of the first theoretical contributions combining monopolistic competition with quality. The paper generalizes Melitz and Ottaviano (2008) to account for quality choice by firms. In addition to generating the standard firm selection effects as in Melitz (2003), the model implies that prices can increase in productivity if the elasticity of markups with respect to quality choice is high. This is consistent with the evidence found by Baldwin and Harrigan (2011) and is something that cannot be explained using Melitz (2003) or Melitz and Ottaviano (2008). Below I extend Antoniades (2008) to containing an industry continuum where each industry is characterised by a different degree of product differentiation. To this end, I make use of a modeling device from Neary (2010).

The interaction between product differentiation and trade has also been cast in frameworks other than the monopolistic competition or oligopoly paradigms. In a seminal contribution, Rauch (1999) argues that it is more appropriate to model trade in differentiated products in a network/search framework rather than a market context, since "heterogeneity of manufactures along the dimensions of both characteristics and quality interferes with the ability of their prices to signal relative scarcity" (Rauch, 1999, p.7). Most of the subsequent literature in this vein has been empirical and focused on the implications of product differentiation on patterns in bilateral trade flows. Rauch (1999) divides goods into three categories: homogeneous, reference priced and differentiated. He shows that gravity coefficients (on colonial ties and common language) differ depending on the de-

gree of differentiation. Javorcik and Narciso (2008) summarize the subsequent literature: Rauch and Trinidad (2002) and Rauch and Casella (2003) follow up on Rauch (1999) by testing for breaks in the impact of ethnic networks and international ties between wholesalers on bilateral trade flows and find that the effect is more positive for differentiated products. Fink et al (2005) find similar breaks for the effect of communication costs on trade, as do Feenstra et al (2001) for the home market effect. There is further evidence that the border effect is less pronounced (Evans, 2003) and that trade relationships last longer for more differentiated products (Besedes and Prusa, 2006). Javorcik and Narciso (2008) find that tariff evasion is more pervasive the higher the degree of differentiation.

This chapter contributes to the existing trade literature by exploring the relationship between productivity gains and product differentiation in the context of trade liberalization. My theoretical results match Pavcnik's (2002) observation of widely varying industry responses to trade liberalization. Given that the recent literature strongly suggests an important role for quality competition in international trade, I further investigate the extent to which quality competition is important in driving theoretical results. I do so by comparing predictions arising in Antoniades' (2008) framework with those generated by Melitz and Ottaviano's (2008) framework. I investigate the role of quality in more depth by exploring how firm-level quality choice varies for industries with different degrees of product differentiation. In doing so, I show that one of the theoretical predictions matches Schott's (2004) stylized fact that the range of qualities offered increases in the degree of differentiation characterising an industry. To the best of my knowledge, this is the first theoretical study considering the relationship between product differentiation and trade-induced industry productivity gains in a heterogeneous firms framework.

2.2 Theory

2.2.1 Set-Up

In this section, I present the model that will serve as the basis for the subsequent analysis of the role of product differentiation in determining productivity and quality outcomes. In what follows, I retrace Antoniadou's (2008) derivation of the closed and open economy equilibrium expressions, adding heterogeneous industries.

2.2.1.1 Closed Economy

Consumers There are L consumers in the economy, who each supply one unit of labour. The economy consists of two sectors, one producing a homogeneous good, the other producing differentiated varieties. The latter in turn contains an industry continuum. The upper tier of the utility function is quasi-linear, ensuring that the marginal utility of income for the differentiated goods is one (i.e. the entire income effect falls on the numeraire good q_0). We have:

$$U = q_0^c + \int_0^1 u(k) dk \quad (2.1)$$

for varieties from industries $k \in [0, 1]$. The lower tier defines consumer preferences for goods from the differentiated sector as quadratic:

$$\begin{aligned} u(k) = & \alpha \int_{i \in \Omega} q_{ik}^c di + \alpha \int_{i \in \Omega} z_{ik} di - \frac{1}{2} \gamma_k \int_{i \in \Omega} (q_{ik}^c)^2 di - \frac{1}{2} \gamma_k \int_{i \in \Omega} (z_{ik})^2 di + \\ & \gamma_k \int_{i \in \Omega} (q_{ik}^c z_{ik}) di - \frac{1}{2} \eta \left\{ \int_{i \in \Omega} (q_{ik}^c - \frac{1}{2} z_{ik}) di \right\}^2. \end{aligned} \quad (2.2)$$

From the first two terms in equation 2.2, individuals care about both total quantity q_{ik} and quality z_{ik} consumed of variety i in industry k . The third, fourth and fifth term of the lower-tier introduce love of variety as a function of γ_k , where γ_k is the degree of product differentiation between varieties in industry k ($\gamma_k \in [0, \infty]$). The more differentiated

products are, i.e. the larger is γ_k , the more do consumers care about variety. As γ_k tends to zero in the limit, varieties in sector k become perfect substitutes, such that only the total quantity consumed matters; α and η are also demand parameters, representing the degree of substitutability between the differentiated goods and the numeraire good.

The specification of quadratic preferences in the lower tier yields a linear expression for demand for goods from the differentiated industries. Preferences are additively separable, so that we can write demand for variety i in industry k as:

$$p_{ik} = \alpha - \gamma_k q_{ik}^c + \gamma_k z_{ik} - \eta Q_k^c \quad \text{where } Q_k^c = \int_{i \in \Omega} (q_{ik}^c - \frac{1}{2} z_{ik}) di \quad (2.3)$$

$$q_{ik} = L q_{ik}^c = \frac{\alpha L}{\eta N + \gamma_k} - \frac{L}{\gamma_k} p_{ik} + L z_{ik} + \frac{\eta N L}{\gamma_k (\eta N + \gamma_k)} \bar{p}_k - \frac{1}{2} \frac{\eta N L}{\eta N + \gamma_k} \bar{z}_k \quad (2.4)$$

where N is the number of firms in the market, L is the number of consumers (market size), \bar{p}_k is the average price and \bar{z}_k is the average quality level in industry k . Since demand is linear, there is a maximum bound to the price firms can charge in any given sector. This price p_k^{\max} occurs where demand $q_{ik} = 0$. In order for demand to be non-negative, it must therefore be the case that

$$p_{ik} \leq \frac{\alpha \gamma_k}{\eta N_k + \gamma_k} + \gamma_k z_{ik} + \frac{\eta N_k}{\eta N_k + \gamma_k} \bar{p}_k - \frac{\gamma_k}{2} \frac{\eta N_k}{\eta N_k + \gamma_k} \bar{z}_k = p_k^{\max}. \quad (2.5)$$

It can be shown that this is equivalent to the cost cut-off, c_{Dk} , the maximum cost a firm can have and produce, just breaking even. Since the marginal firm with cost c_{Dk} would not be able to afford any quality investments ($z_{ik} = 0$), we can write

$$c_{Dk} = \frac{1}{\eta N_k + \gamma_k} (\alpha \gamma_k + \eta N_k \bar{p}_k - \frac{1}{2} \eta \gamma_k N_k \bar{z}_k). \quad (2.6)$$

Firms The model contains two sectors, one producing a homogeneous numeraire good under perfect competition and constant returns to scale and the other made up of a continuum of monopolistically competitive industries producing differentiated varieties. Labour is the only factor of production in the model and its supply is perfectly elastic.

The labour market is assumed to be perfectly competitive and wage is unity.

Firms in the model have rational expectations. In the monopolistically competitive sector, an ex ante identical continuum of firms initially faces uncertainty about their productivity (represented by the inverse of their unit cost c) as well as their industry capability k , with $k \in [0, 1]$ similar to Neary (2010): Neary (2010) extends Melitz (2003) to generate industry heterogeneity in terms of market structure. As in Melitz (2003), potential firms face uncertainty about their characteristics, which will only be revealed to them after they have paid a sunk cost f . In Melitz (2003), which looks at one sector, the only uncertainty is over a firm's productivity represented by its unit cost c . Neary (2010) breaks this sector down into an industry continuum and adds uncertainty about a firm's industry capability, k , such that each firm is assigned a $\{c, k\}$ pair by the draw. Both c and k follow known distributions $g(c)$ and $h(k)$ and the industry continuum is restricted by $k \in [0, 1]$. Importantly, each industry is associated with a particular fixed cost, such that a low k draw implies that the firm is suited for an industry with low fixed cost (described by the function $f(k)$).

In the present chapter, the sequencing differs compared to Neary (2010). In Neary (2010), paying a sunk cost f gives a firm the right to draw simultaneously its characteristic $\{c, k\}$ pair from two known distributions $g(c)$ and $h(k)$. Here on the other hand, the draw takes place in two stages: the first stage consists of firms costlessly drawing their industry capability k , whereby their draw of k will determine the industry-specific sunk entry cost f_k and degree of differentiation between varieties γ_k a firm will face when making its entry and production decisions. This set-up allows to avoid feedback effects between industries, thereby retaining the partial equilibrium nature of the original model. I assume $g(c)$ to be a Pareto distribution and $h(k)$ a uniform distribution with dispersion parameter n . The fixed cost of entry f_k is higher the more differentiated the industry. After firms have paid f_k , production is constant returns to scale and marginal costs are c . Firms whose profit maximising price is above p_k^{\max} exit immediately (i.e. their productivity draw was too low). The remaining firms start production in their assigned industry.

Firms also decide how much to invest in quality. The cost of quality is proportional to the chosen level of quality, such that more productive firms will be able to afford higher quality levels. Quality upgrades come at a cost which is variable with respect to the quality level but fixed with respect to the level of output. Unlike in Antoniadou (2008, Section 1.2), firms here do not face an additional fixed cost of quality. This simplifies the model to the extent that all firms which produce output also invest in quality. The total cost function of a firm conditional on entry is given by:

$$TC_{ik} = c_{ik}q_{ik} + \theta z_{ik}^2. \quad (2.7)$$

The sequencing of the model is as follows:

- Firms are assigned an industry ex ante by a random draw from a uniform distribution at zero cost; this industry assignment determines f_k and γ_k .
- Firms pay the sunk entry cost f_k which gives them the right to draw their unit cost c and which is higher for the more differentiated sector.
- Firms whose productivity draw is too low to cover costs withdraw.
- The remaining firms choose the optimal level of quality, maximising profits.
- Firms set price as mark-up over marginal cost for a given level of quality, N , \bar{p} and \bar{z} .

Since industries are independent of each other, I subsequently disregard the industry subscript k .

Solving backwards, we start out with the firm's pricing decision. A firm's profit maximising price must satisfy:

$$p = \frac{\gamma}{L}q + c. \quad (2.8)$$

Substituting in q and rearranging, price and all other variables of importance can be expressed as functions of the cut-off c_D and a firm's cost c , and quality z . The optimal

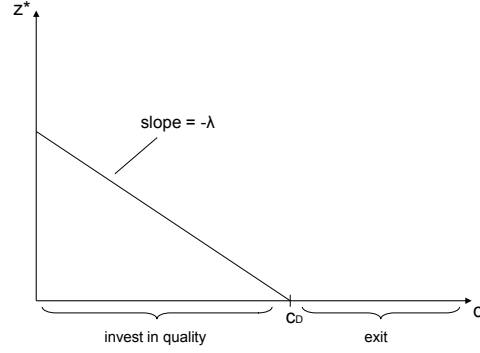


Figure 2.1: Optimal Quality vs Cost

level of quality upgrade z^* is found by maximizing π with respect to z :

$$z^* = \lambda (c_D - c) \quad (2.9)$$

where $\lambda = \frac{L}{4\theta - \gamma L}$. A sufficient condition for z^* to be profit-maximizing can be established by requiring the second derivative to be negative:

$$\frac{\partial^2 \pi}{\partial z^2} = \frac{L\gamma}{2} - 2\theta < 0 \quad \text{if } \gamma < \frac{4\theta}{L}. \quad (2.10)$$

I therefore restrict γ to $0 < \gamma < \frac{4\theta}{L}$. For values of $\gamma > \frac{4\theta}{L}$, the optimal value of z is unbounded (costs are falling as firms invest more in quality). Assuming the second order condition holds, equation (2.10) also implies that λ will always be positive, where $-\lambda$ is the slope of the quality-cost relationship for firms (Figure 2.1). This means that as long as equation (2.10) holds, the level of quality chosen is a decreasing function of a firm's unit cost, c , or equivalently an increasing function of its productivity $1/c$.

Substituting for z , profits can be written in terms of c_D and c only:

$$\pi(c_D, c) = \frac{L}{4\gamma} (1 + \gamma\lambda) (c_D - c)^2.$$

Free Entry Equilibrium By the free entry condition, expected profits have to be zero in equilibrium in all differentiated industries. This yields the free entry condition:

$$f = E\pi(c_D, c) = \int_0^{c_D} \frac{L}{4\gamma} (1 + \gamma\lambda) (c_D - c)^2 G(c) dc. \quad (2.11)$$

In order to obtain expressions for aggregate variables, the cost distribution is parametrized assuming cost draws come from a Pareto distribution. This assumption is common in the heterogeneous firms trade literature and is supported by the literature on firm size distributions. More specifically, firms in Antoniadou (2008) draw their costs from $G(c) = \left(\frac{c}{c_M}\right)^n$, $c \in [0, c_M]$ where n is the dispersion parameter. Parametrizing, integrating and solving equation (2.11) for c_D , gives an explicit equilibrium solution for the cost-cut off, i.e. the maximum cost a firm can have and just break even:

$$c_D = \left[\frac{\phi\gamma}{(1 + \gamma\lambda)L} \right]^{\frac{1}{(n+2)}} \quad (2.12)$$

where $\phi = 2(n+1)(n+2)(c_M)^n f$. The equilibrium in the closed economy is characterised by two types of firm: those that exit immediately and those that enter and invest in quality, whereby quality investments will be increasing in productivity. Importantly, average cost (or inversely, average productivity) in an industry will be:

$$\bar{c} = \frac{nc_D}{n+1}. \quad (2.13)$$

From this expression it is clear that average industry productivity will be higher, the lower is the cost cut-off, c_D . Finally, average quality in an industry can be expressed as

$$\bar{z} = \frac{\lambda c_D}{n+1}. \quad (2.14)$$

2.2.1.2 Open Economy

In the open economy setting there are two countries l , with $l = \{home, foreign\} = \{H, F\}$. The countries are assumed to be symmetric, with the exception of country size L^l . Most importantly, trade costs, τ , are symmetric and consumer preferences and ability to innovate, $1/\theta$, are identical in the two countries. It is further assumed that labour is immobile between the two countries and that the numeraire good is freely traded, thereby pinning down wages. Markets are segmented and firms set different prices and quality levels for the home and foreign market respectively. Trade costs take the iceberg form: $\tau > 1$. The parameter τ indicates the number of units that need to be shipped in order for one unit to arrive in the destination country. In the limit when $\tau = 1$, we have free trade. Consumer preferences in the two countries are symmetric and the same as in the closed economy setting (equation 2.4). The mechanisms by which firms decide to produce and invest in quality remain as in the closed economy setting. However, the most productive firms will now also be able to export. Following the same methodology as in the closed economy setting, Antoniadou (2008) shows that the open economy domestic cost cut-off associated with this model is:

$$c_D^l = \left[\frac{\gamma\phi}{L^l(1 + \gamma\lambda_D^l)(1 + \rho)} \right]^{\frac{1}{n+2}}, \quad (2.15)$$

where $\rho = \frac{1}{\tau^n}$. Importantly, this cut-off changes with trade liberalization, as reflected in changes in trade-freeness ρ and market size L . I subsequently focus on the implications of trade liberalization for this domestic cost cut-off.

2.3 Productivity, Quality and Product Differentiation

This section studies the relationship between the degree of product differentiation and two outcomes of interest: (i) the productivity impact of trade via the composition effect; and (ii) firm-level investment in quality. Subsection 2.3.1 presents the results in Melitz and

Ottaviano's (2008) framework and serves as the benchmark for the subsequent analysis. Trade here affects composition but there is no firm-level investment; I therefore only investigate point (i) above. Subsection 2.3.2 draws out the effect of quality in this setting by conducting the analysis in Antoniadou's (2008) framework.

More specifically, I focus on the implications of changes in product differentiation parameters on the domestic industry cost cut-off, c_D . The behaviour of c_D in turn determines average productivity outcomes by industry $1/\bar{c}$ and affects optimal quality investments by firms, z^* , as well as average industry quality \bar{z} . As can be seen from the expression for average cost (equation 2.13)

$$\bar{c} = \frac{n}{n+1}c_D$$

an increase in the cost cut-off translates directly into an increase in average cost or equivalently a decrease in average industry productivity.

Product differentiation in the present specification affects the relevant equilibrium expressions in two ways: firstly, explicitly in γ , the demand parameter representing the degree of product differentiation between varieties in a given industry. Secondly, I assume that the sunk cost of entry, f , into an industry is increasing in the degree of product differentiation. The two parameters γ and f affect the cut-off in different ways. So as to not confound effects, I first focus on comparative statics with respect to γ (assuming the same fixed cost f for all industries). I then consider effects with respect to f , and finally, I look at the interaction between the two.

In answering the question how product differentiation affects productivity gains from trade, I investigate three ways in which trade can have an impact on productivity: (i) an increase in market size, which can also be interpreted as a move from autarky to free trade; (ii) the move from a closed economy to an open economy setting with trade costs; and (iii) a reduction in trade costs.

2.3.1 No-Quality Benchmark

The equilibrium expressions presented above for the quality-augmentation reduce to those found in Melitz and Ottaviano (2008) as the cost of quality, θ , tends to infinity (and hence $\lambda \rightarrow 0$). The domestic productivity cut-off in Melitz and Ottaviano (2008) is given by

$$c_D = \left(\frac{\phi}{L} \gamma \right)^{\frac{1}{n+2}}. \quad (2.16)$$

where $\phi \equiv 2(n+1)(n+2)(c_M)^n f$ (Melitz and Ottaviano (2008), equation 15).

Before looking at the impact of γ on trade-induced productivity gains, I briefly set out the more basic relationship between γ and c_D . The domestic cut-off, c_D is a positive, concave function of the degree of product differentiation γ :

$$\frac{\partial c_D}{\partial \gamma} = \frac{1}{n+2} \frac{c_D}{\gamma} > 0 \quad (2.17)$$

$$\frac{\partial^2 c_D}{\partial \gamma^2} = -\frac{(n+1)}{(n+2)^2} \frac{c_D}{\gamma^2} < 0. \quad (2.18)$$

A higher γ , reflecting a higher degree of differentiation, has the effect of increasing c_D , reducing the residual demand price elasticity ε_i faced by firms and hence implying weaker competitive pressures in any given industry. The demand elasticity ε_i in Melitz and

Ottaviano (2008) is given by⁷:

$$\varepsilon_i \equiv \left| \frac{\partial q_i}{\partial p_i} \frac{p_i}{q_i} \right| = \frac{1}{(p^{\max}/p_i) - 1}. \quad (2.19)$$

Since c_D is increasing in γ (from equation (2.17)) and from equation (2.19), ε_i is decreasing in c_D ($= p^{\max}$ from equations (2.5) and (2.6)), ε_i is also decreasing in γ .

Hence, competition in an industry is weaker, the higher is the degree of product differentiation γ . This in turn feeds back into firm selection: a higher c_D allows less productive firms to stay in the market, taking market share away from the more productive firms. Average industry productivity is therefore lower. Further, mark-ups are higher as γ increases. The maximum cost a firm can have and remain profitable is therefore increasing in γ .

2.3.1.1 Closed Economy: Market Size Effect

The market size effect is defined as the impact of a change in market size on domestic industry cost cut-offs. An alternative interpretation in a two-country setting is that it represents the effect of a move from autarky to total trade integration.

The market size effect in Melitz and Ottaviano (2008) is unambiguously negative and

⁷The same result can also be seen from the non-parametrized expressions:

$$\varepsilon_i \equiv |(\partial q_i / \partial p_i) (p_i / q_i)| = [(p^{\max} / p_i) - 1]^{-1}$$

where

$$p^{\max} \equiv \frac{\alpha\gamma + \eta N \bar{p} - \frac{1}{2}\gamma\eta N \bar{z}}{\eta N + \gamma}$$

which was shown to be equivalent to c_D in equations (2.5) and (2.6). We can show that

$$\frac{\partial \varepsilon_i}{\partial \gamma} = \frac{\partial \varepsilon_i}{\partial p^{\max}} \frac{\partial p^{\max}}{\partial \gamma} < 0$$

since

$$\begin{aligned} \frac{\partial \varepsilon_i}{\partial p^{\max}} &= -[(p^{\max}/p_i) - 1]^{-2} (p_i)^{-1} < 0 \\ \frac{\partial p^{\max}}{\partial \gamma} &= \frac{\eta N (\alpha - \bar{p})}{(\eta N + \gamma)^2} > 0 \end{aligned}$$

where $\alpha > \bar{p}$ (from equation (2.3))

c_D is convex in L . Using equation (2.16), we get

$$\frac{\partial c_D}{\partial L} = -\frac{1}{n+2} \frac{c_D}{L} < 0 \quad (2.20)$$

$$\frac{\partial^2 c_D}{\partial L^2} = \frac{n+3}{(n+2)^2} \frac{c_D}{L^2} > 0. \quad (2.21)$$

The larger the market, the more attractive it is as a location for firms, the more elastic is demand and the tougher the resulting competitive environment. As market shares of low productivity firms are squeezed and mark-ups shrink, the least productive firms are forced to exit, while the most productive firms expand their market shares. Average industry productivity is therefore increasing in market size in this model.

Turning to the interaction between market size effect and the degree of product differentiation, we find the following relationship:

Proposition 1. *The productivity effect of an increase in market size is monotonically increasing in the degree of product differentiation.*

Proof.

$$\frac{\partial^2 c_D}{\partial \gamma \partial L} = -\frac{1}{(n+2)^2} \frac{c_D}{\gamma L} < 0 \quad (2.22)$$

□

This expression suggests that the market size effect is amplified (more negative) for industries where the degree of product differentiation is high: an increase in L will lead to a larger drop in c_D with increasing γ . While equation (2.17) above showed that being in an industry with a higher degree of product differentiation affords firms more protection (competitive pressures are decreasing in γ), this protection disappears as the market size gets large. Further, this drop in protection increases with γ . This is illustrated in Figure 2.2. In the limit, as the market size gets infinitely large, $\partial c_D / \partial \gamma \rightarrow 0$ (equation 2.17) and $c_D \rightarrow 0$ (equation 2.16) for all values of γ .

The market size effect works via an increase in the demand elasticity and downward pressure on mark-ups. Intuitively, this mark-up pressure will be most pronounced the

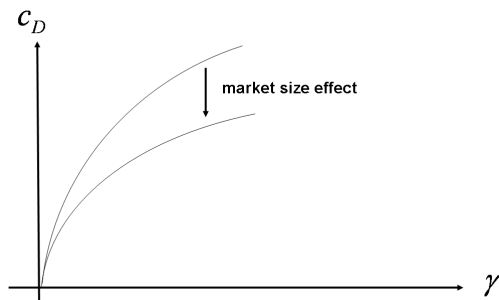


Figure 2.2: Market Size Effect without Quality

higher the degree of differentiation as mark-ups are highest in these industries. We would therefore expect the impact on the cost cut-off and hence the industry shake-out to increase with γ . This suggests that the greatest productivity gains from integration will be achieved in the most highly differentiated industries.

2.3.1.2 Open Economy: Trade and Bilateral Liberalization

The productivity effect from firm selection in the wake of changes in openness and trade liberalization is the main result in Melitz's (2003) seminal contribution. I now assess how this effect varies with the degree of product differentiation.

As noted by Melitz and Ottaviano (2008), the productivity effect in the model presented here echoes Melitz's (2003) selection effect, though it works through the product rather than the labour market. In Melitz (2003), new export opportunities lead the most productive firms to expand production and in the process bid up the real wage (there is no import competition channel, as residual demand price elasticities are exogenously fixed by the CES assumption). The least productive firms will become unprofitable in the face of the new higher real wage and are forced to exit, thereby increasing average industry productivity. By contrast, in Melitz and Ottaviano (2008) adjustment happens through the product market; factor market competition is unaffected due to the assumption of a perfectly elastic labour supply. Instead, import competition increases competition in the domestic product market and hence demand price elasticities faced by firms at any given

demand level. Again, only the more productive firms remain profitable.

Trade: Autarky to Open Economy The next result concerns the productivity benefits of moving from autarky to an open economy with positive trade costs. I compare the autarky cut-off with the open economy cut-off and interpret the difference as an indicator for the productivity gains from trade. The open economy cut-off is as in Melitz and Ottaviano (2008) equation (29):

$$c_D^l = \left[\frac{\gamma\phi}{L(1+\rho)} \right]^{\frac{1}{n+2}} \quad (2.23)$$

where $\rho = (\tau^l)^{-n}$. The expressions below show how this gain changes with the degree of product differentiation.

Proposition 2. *The move from autarky to a trading equilibrium with positive trade costs implies productivity gains for industries of all levels of product differentiation. The productivity gains from trade are monotonically increasing and concave in the degree of differentiation.*

Proof. Using equations (2.16) and (2.23), we have:

$$c_D - c_D^l = \left(\frac{\gamma\phi}{L} \right)^{\frac{1}{n+2}} \left(1 - \left(\frac{1}{1+\rho} \right)^{\frac{1}{n+2}} \right) > 0 \quad (2.24)$$

$$\frac{\partial(c_D - c_D^l)}{\partial\gamma} = \frac{1}{n+2} \frac{c_D}{\gamma} \left(1 - \left(\frac{1}{1+\rho} \right)^{\frac{1}{n+2}} \right) > 0 \quad (2.25)$$

$$\frac{\partial^2(c_D - c_D^l)}{\partial\gamma^2} = -\frac{(n+1)}{(n+2)^2} \frac{c_D}{\gamma^2} \left(1 - \left(\frac{1}{1+\rho} \right)^{\frac{1}{n+2}} \right) < 0. \quad (2.26)$$

From equation (2.24), we can see that the open economy cost cut-off is smaller than the autarky cut-off for all admissible values of γ (for all other parameter values). This implies the first part of the proposition. Average industry productivity is higher in the open economy, as the lower cut-off forces the least productive firms to exit. This effect is more pronounced, the higher the degree of product differentiation. \square

Open Economy: Bilateral Liberalization The expression for the domestic cut-off in the open economy is augmented to include iceberg trade costs, τ^l . I assume trade costs to be symmetric for the two countries. Comparative statics are with respect to the parameter ρ which is in turn a function of τ^l . Baldwin (e.g. in Baldwin and Harrigan, 2011) refers to ρ as the "freeness of trade", where $\rho \in [0, 1]$. Trade is completely free when $\rho = 1$ and a country is autarkic when $\rho = 0$. The domestic cut-off for country l is given in equation (2.23). I showed in equations 2.17 and 2.18, that the cut-off is monotonically increasing and concave in the degree of product differentiation for the closed economy model without quality. The same is true for the open economy version:

$$\frac{\partial c_D^l}{\partial \gamma} = \frac{1}{n+2} \frac{c_D^l}{\gamma} > 0 \quad (2.27)$$

$$\frac{\partial^2 c_D^l}{\partial \gamma^2} = -\frac{(n+1)}{(n+2)^2} \frac{c_D^l}{\gamma^2} < 0. \quad (2.28)$$

Bilateral liberalization for countries with symmetric import barriers (i.e. a drop in τ or equivalently an increase in ρ), leads to a drop in c_D and raises competition in both markets, whereby c_D is convex in ρ :

$$\frac{\partial c_D^l}{\partial \rho} = -\frac{1}{n+2} \frac{c_D^l}{(1+\rho)} < 0 \quad (2.29)$$

$$\frac{\partial^2 c_D^l}{\partial \rho^2} = \frac{n+3}{(n+2)^2} \frac{c_D^l}{(1+\rho)^2} > 0. \quad (2.30)$$

Proposition 3. *The productivity effect of bilateral liberalization is monotonically increasing in the degree of product differentiation.*

Proof.

$$\frac{\partial^2 c_D^l}{\partial \rho \partial \gamma} = -\frac{1}{(n+2)^2} \frac{c_D^l}{\gamma(1+\rho)} < 0 \quad (2.31)$$

□

As in the case of changes in market size, the productivity effect from trade liberalization is amplified here by the degree of product differentiation. As $\tau \rightarrow 1$ in the limit, i.e. as

we approach free trade, the relationship between the cut-off and the degree of product differentiation tends to

$$\frac{\partial c_D^l}{\partial \gamma} = \frac{1}{n+2} \left(\frac{\phi}{2L^l} \right)^{\frac{1}{n+2}} \gamma^{-\frac{(n+1)}{n+2}} \quad (2.32)$$

i.e. we are back to the case of total integration discussed above, with a doubling in country size. In effect, $(1 + \rho)$ as a multiplier of L acts to "increase" country size from 1 (autarky, $\rho = 0$) to 2 (free trade, $\rho = 1$) in the two-country model.

In summary, for the benchmark case without quality, (i) the domestic cost cut-off, (ii) the market size effect, (iii) the open economy effect and (iv) the partial liberalization effect increase monotonically with the degree of product differentiation. The more differentiated the industry, the lower is average industry productivity as mark-ups which are increasing in differentiation make it easier for less productive firms to enter. Furthermore, while the cost cut-off is monotonically increasing in γ , the market size and open economy/ liberalization effects (which create downward pressure on the domestic cut-off) are amplified by higher degrees of product differentiation. In terms of average industry productivity, this means, *ceteris paribus*, while average productivity in this model is lower the more differentiated the industry, increases in market size, the move from autarky to an open economy or symmetric falls in import barriers lead to larger productivity improvements for higher degrees of differentiation. Since competitive pressures are laxer in industries where varieties are less substitutable, an increase in market size will have a bigger effect in these industries than in industries where competition is already very tight (i.e. those where varieties are highly substitutable).

It might seem counter-intuitive that average industry productivity should be decreasing as the degree of differentiation among products and hence the sophistication of the industry increases. This issue is resolved once the quality dimension is accounted for in the theoretical framework. I now turn to the more complex scenario where firms can choose to invest in quality.

2.3.2 Introducing Quality

I now revert to the more general model by Antoniadou (2008). The analysis proceeds analogously to the benchmark case with respect to productivity effects, however, here I add comparative statics for firm-level quality investment across industries characterised by different degrees of differentiation.

Recalling the cut-off for Antoniadou (2008) from equation (2.12), we have:

$$c_D = \left[\frac{\phi\gamma}{(1 + \gamma\lambda)L} \right]^{\frac{1}{n+2}}$$

where again $\phi \equiv 2(n+1)(n+2)(c_M)^n f$ and $\lambda = L/(4\theta - \gamma L)$. Competition in the economy with quality upgrading is tougher, *ceteris paribus*: the cut-off in the economy with quality is always lower than the one in the benchmark case due to an extra term in the denominator ($\gamma\lambda L$). The difference will depend on the slope of the quality-cost relationship, $-\lambda$ and the degree of differentiation γ . The steeper the slope, the faster is the level of quality investment increasing in firms' productivities, and the tougher is competition. The slope $-\lambda$, is a function of two country- and one industry-specific parameter, country size L , ability to innovate $1/\theta$ and degree of product differentiation γ . It is increasing in all three.

The cut-off is zero at both extremes of the domain of γ : for $\gamma = 0$ and in the limit as $\gamma \rightarrow 4\theta/L$, the upper bound of γ ,

$$\lim_{\gamma \rightarrow \frac{4\theta}{L}^-} c_D = 0^+$$

since

$$\lim_{\gamma \rightarrow \frac{4\theta}{L}^-} \lambda = \infty.$$

I subsequently rule out the case of perfect competition ($\gamma = 0$) and the upper bound of the γ -domain ($\gamma = 4\theta/L$) and focus only on industries with intermediate degrees of differentiation.

2.3.2.1 Differentiation and Productivity

The relationship between γ and c_D is now more complex compared to the benchmark specification without quality: γ enters in the numerator of c_D and twice in the denominator. An increase in γ will increase the numerator, but at the same time increase the denominator directly and indirectly via its positive impact on the slope parameter λ . Formally, the following proposition holds with respect to the relationship between the domestic cut-off and the degree of differentiation:

Proposition 4. *In the model with quality, the domestic cost cut-off depends non-monotonically on the degree of product differentiation. The cut-off is strictly concave in γ and has a global maximum at $\gamma = \frac{2\theta}{L}$, the midpoint of the γ -domain.*

Proof. Using equation (2.12), we have

$$\frac{\partial c_D}{\partial \gamma} = \frac{1 - \gamma\lambda}{(n+2)\gamma} c_D \quad (2.33)$$

$$= 0 \text{ if } \gamma = \frac{2\theta}{L}$$

$$\frac{\partial^2 c_D}{\partial \gamma^2} = -\frac{[(n+1)(1 + \gamma^2\lambda^2) + 2\gamma\lambda]}{(n+2)^2\gamma^2} c_D < 0. \quad (2.34)$$

□

We can see from Figure 2.3 that the effect of increased product differentiation is initially similar to the effect in the benchmark case without quality: the cut-off rises in the degree of differentiation for small values of γ . For high values of γ , the effect is, however, reversed. As γ moves beyond $\gamma = 2\theta/L$, the toughness of the competitive environment starts increasing in γ .

As we will see more clearly in the firm-level quality investment effect discussed below, two competing forces are driving this non-monotonicity. While an increasing degree of product differentiation is on the one hand relaxing competitive pressures by making varieties less substitutable (call this the direct effect), it is also increasing the scope for quality

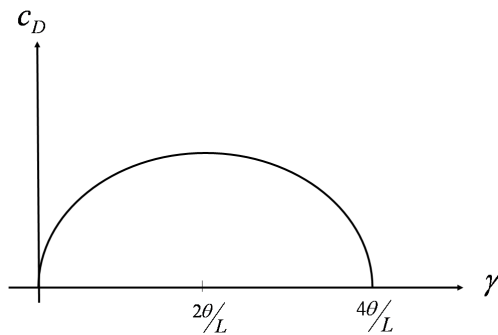


Figure 2.3: Cut-off and Product Differentiation with Quality

investment and, more importantly, the rate at which quality upgrading is increasing in firms' productivity (call this the quality effect). This in turn increases the toughness of competition in the market. As the scope for quality investment rises, pressure to invest in quality increases, making it more difficult for the less productive firms to remain profitable. The direct effect outweighs the quality effect for $\gamma < \frac{2\theta}{L}$, and vice versa for $\gamma > \frac{2\theta}{L}$.

2.3.2.2 Differentiation and Firm-Level Quality Upgrading

I next demonstrate that firms' incentives to invest in quality change as the competitive environment changes. In particular, I consider the effect of product differentiation on firm-level investment in quality upgrading. Importantly, the results below match Schott's (2004) stylized fact that the range of qualities offered is increasing in an industry's degree of product differentiation (see Proposition 8). Recalling the expression for the optimal level of quality z^* (equation 2.9), we have:

$$z^* = \lambda (c_D - c)$$

where $\lambda = \frac{L}{4\theta - \gamma L}$. The ambiguity of the effect of γ on c_D shown in equation (2.33) translates into an ambiguous effect of the degree of product differentiation on the optimal level of quality investment for a firm with unit cost c . The effect is further complicated by the fact that firms are heterogeneous in their cost. In general terms, we can write the effect

of differentiation on an individual firm's optimal level of quality as:

$$\frac{\partial z^*}{\partial \gamma} = \underbrace{\lambda}_{+} \underbrace{\frac{\partial c_D}{\partial \gamma}}_{+/-} + \underbrace{(c_D - c)}_{+/0} \underbrace{\frac{\partial \lambda}{\partial \gamma}}_{+} \geq 0 \quad (2.35)$$

where

$$\frac{\partial \lambda}{\partial \gamma} = \left(\frac{L}{4\theta - \gamma L} \right)^2 = \lambda^2 > 0.$$

The sign of the first product in equation (2.35) is ambiguous since the sign of $\frac{\partial c_D}{\partial \gamma}$ depends on the value of γ (equation (2.33)). The second product is everywhere non-negative: it is zero for the marginal firm, with $c = c_D$, and positive otherwise. I now investigate some special cases:

Proposition 5. *For values of $\gamma < \frac{2\theta}{L}$, the optimal level of quality is strictly increasing in the degree of product differentiation for firms of the same productivity level.*

Proof. For $\gamma < \frac{2\theta}{L}$ it is the case that $\frac{\partial c_D}{\partial \gamma} > 0$ (from equation (2.33)), such that all terms in (2.35) are positive; hence

$$\frac{\partial z^*}{\partial \gamma} = \lambda \frac{\partial c_D}{\partial \gamma} + (c_D - c) \frac{\partial \lambda}{\partial \gamma} > 0. \quad (2.36)$$

□

In other words, for $\gamma < \frac{2\theta}{L}$, firms with the same productivity level across industries will engage in more quality upgrading the higher the degree of differentiation characterizing their industry.

For values of $\gamma > \frac{2\theta}{L}$, the effect will depend on the productivity of the individual firm relative to the cut-off, as the first product in equation (2.35) is now negative. We can show that the overall effect is negative for the least productive firm and positive for the most productive firm, which implies Schott's (2004) stylized fact that the quality range is increasing in product differentiation.

Proposition 6. *For values of $\gamma > \frac{2\theta}{L}$ the optimal level of quality for the least productive firm in every industry (with $c = c_D$) is strictly decreasing in the degree of product differentiation.*

Proof. At $c = c_D$ and with $\gamma > \frac{2\theta}{L}$ it is the case that $\frac{\partial c_D}{\partial \gamma} < 0$ (from equation (2.33)), such that

$$\frac{\partial z^*}{\partial \gamma} = \lambda \frac{\partial c_D}{\partial \gamma} < 0. \quad (2.37)$$

□

It should be noted that the optimal quality level for the least productive firm (with $c = c_D$) in every industry is zero (from equation (2.9)), however, as we move beyond $\gamma = \frac{2\theta}{L}$, the least productive firm will have increasingly higher productivity, explaining the negative value in (2.37).

We can also show that the optimal quality level for the most productive firm in every industry is monotonically increasing in product differentiation for the entire domain of γ .

Proposition 7. *The optimal level of quality for the highest productivity firm in every industry (with $c = 0$) is strictly increasing in the degree of product differentiation for all admissible values of γ . [$0 < \gamma < \frac{4\theta}{L}$].*

Proof. At $c = 0$,

$$\frac{\partial z^*}{\partial \gamma} = \lambda \left(\frac{\partial c_D}{\partial \gamma} + \lambda c_D \right) \quad (2.38)$$

$$= \frac{\lambda c_D}{(n+2)} \left[\frac{1}{\gamma} + (n+1)\lambda \right] > 0 \quad (2.39)$$

□

This suggests that for every industry with $\gamma > \frac{2\theta}{L}$, a fraction of firms at the lower end of the productivity scale will have their optimal quality level decreasing in γ (for the *least* productive firm it is always zero), while a fraction of high productivity firms will choose

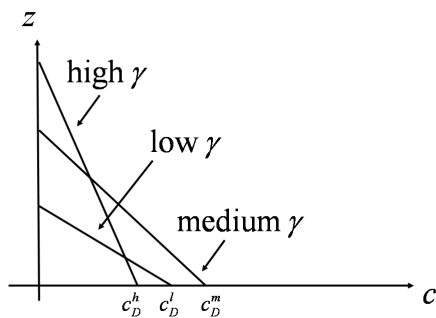


Figure 2.4: Optimal Quality vs Cost for Different Values of γ

a higher level of quality the more differentiated their industry. Further, it can be shown that:

Proposition 8. *The range of qualities produced is increasing in the degree of product differentiation.*

Proof. This follows from Propositions 5 and 7. □

Put differently, the highest level of quality upgrading chosen by the most productive firm in any industry is increasing in the industries' product differentiation, while the lowest level of upgrading will always be zero (chosen by the marginal firm).

Figure 2.4 illustrates the interaction between the productivity and quality upgrading effects: the three panels show the relationship between z^* and c for a low, medium and high value of γ . The slope of the quality-cost line is monotonically increasing in γ as is the range of quality levels available within one industry. Further, the domestic cost cut-off first increases and then decreases in the degree of differentiation. Both seem intuitive: we would expect (i) the range of qualities available to be increasing in the degree of product differentiation, and (ii) average industry productivity to be highest at the extremes of the γ range in the model with quality, as a high degree of substitutability (for low γ) and ever increasing quality investments by the highly productive firms (for high γ) respectively are driving competition.

While the effect on quality upgrading by individual firms was shown to be ambiguous

and dependent on individual firms' costs, we can say following about the average level of quality in an industry from equation (2.14):

$$\bar{z} = \frac{\lambda c_D}{n+1}.$$

Proposition 9. *Average quality is monotonically increasing in the degree of differentiation.*

Proof.

$$\frac{\partial \bar{z}}{\partial \gamma} = \frac{\lambda c_D}{n+1} \frac{1 + (n+1)\gamma\lambda}{(n+2)\gamma} > 0. \quad (2.40)$$

□

This is in line with an upper quality bound which is increasing in the degree of differentiation as argued in Proposition 7 and with the intuition that more differentiated industries would on average offer more sophisticated products.

With this in mind, I next consider the effect of market size and trade in the quality-augmented model.

2.3.2.3 Closed Economy: Market Size Effect

Effect on Average Productivity As in the model without quality (equation 2.20), the relationship between the domestic cut-off and market size is unambiguously negative: an increase in market size always toughens the competitive environment and hence leads to a drop in the maximum cost a firm can have and still be able to enter.

$$\frac{\partial c_D}{\partial L} = -\frac{(1+\gamma\lambda)}{(n+2)L} c_D < 0 \quad (2.41)$$

The basic mechanism is the same as in the model without quality: as the market size increases, the market becomes more attractive as a location for firms, encouraging entry. Competition toughens as a result, forcing the least productive firms to exit and thereby

raising average industry productivity. This competition effect is reinforced by quality upgrading by the higher productivity firms.

The behaviour of the market size effect for high values of γ is partly driven by the endogeneity of the upper bound to γ .

Proposition 10. *In the model with quality, the productivity effect of an increase in market size is monotonically increasing in the degree of product differentiation.*

Proof.

$$\frac{\partial^2 c_D}{\partial L \partial \gamma} = -\frac{(1 + \gamma\lambda)}{(n + 2)L} \left[\frac{1 + (n + 1)\gamma\lambda}{(n + 2)\gamma} \right] c_D < 0 \quad (2.42)$$

□

The relationship between the market size effect and the degree of product differentiation in the model with quality can best be understood by means of Figure 2.5. As can be seen from the graph, the market size effect is zero for $\gamma = 0$ and is amplified as γ increases. However, by contrast to the model without quality (cf figure 2.2), the market size effect is bounded. This is intuitive given the two competing effects on the cost cut-off in the presence of quality competition: I argued in Proposition 4 that quality competition has the effect of increasing competitive pressures as γ rises, such that competition is tough at the higher end of the γ -spectrum. An increase in market size will therefore have a weaker effect than in the model without quality where competition is increasingly lax for high values of γ .

2.3.2.4 Open Economy: Trade and Bilateral Liberalization

Trade: Autarky to Open Economy As in the benchmark case, the difference between the autarky and open economy cut-offs is interpreted as giving an indication of the productivity gain from trading.

Proposition 11. *In the model with quality, the move from autarky to a trading equilibrium with positive trade costs implies productivity gains for industries of all levels of product*

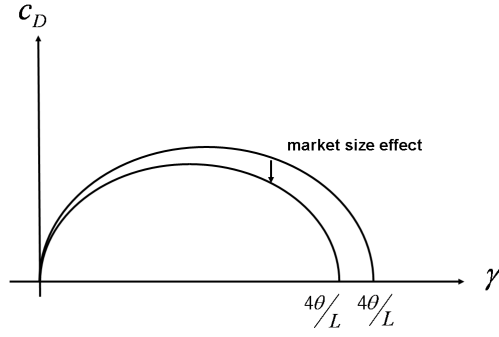


Figure 2.5: Market Size Effect with Quality

differentiation, whereby the productivity gains from trade are non-monotonic in γ . The gains are strictly concave in γ and have a global maximum at $\gamma = \frac{2\theta}{L}$, the midpoint of the γ -domain.

Proof. From equations (2.12) and (2.15) we have:

$$\begin{aligned}
 c_D - c_D^l &= \left(\frac{\phi\gamma}{(1+\gamma\lambda)L} \right)^{\frac{1}{n+2}} \left[1 - \left(\frac{1}{1+\rho} \right)^{\frac{1}{n+2}} \right] > 0 \\
 \frac{\partial(c_D - c_D^l)}{\partial\gamma} &= \frac{1-\gamma\lambda}{(n+2)\gamma} \left[1 - \left(\frac{1}{1+\rho} \right)^{\frac{1}{n+2}} \right] c_D \\
 &= 0 \text{ if } \gamma = \frac{2\theta}{L}
 \end{aligned} \tag{2.43}$$

$$\frac{\partial^2(c_D - c_D^l)}{\partial\gamma^2} = -\frac{[(n+1)(1+\gamma^2\lambda^2) + 2\gamma\lambda]}{(n+2)^2\gamma^2} \left[1 - \left(\frac{1}{1+\rho} \right)^{\frac{1}{n+2}} \right] c_D < 0. \tag{2.44}$$

□

This result is driven by the result obtained in equation (2.33) for the relationship between γ and c_D . Due to the off-setting nature of the direct and quality effects illustrated in figure 3.2 which in turn imply that the competitive environment is weakest at intermediate degrees of differentiation, a move from autarky to an open economy with trade costs will have the greatest impact for intermediate values of γ . These gains from triggering an industry shake-out in favour of the most productive firms disappear entirely for $\gamma = 0$ and as $\gamma \rightarrow \frac{4\theta}{L}$, since only the most productive firms are profitable to begin with.

Open Economy: Bilateral Liberalization Recalling the expressions for the open economy cut-off with quality from equation (2.15), we have:

$$c_D^l = \left[\frac{\gamma\phi}{L^l(1 + \gamma\lambda_D^l)(1 + \rho)} \right]^{\frac{1}{n+2}}$$

where $\rho = \tau^{-n}$. Similar to the closed economy case, the effect of increasing differentiation on the cost cut-off is

$$\frac{\partial c_D^l}{\partial \gamma} = \frac{1 - \gamma\lambda}{(n + 2)\gamma} c_D^l. \quad (2.45)$$

The expression is the same as in equation (2.33) with the exception that c_D^l contains an additional $(1 + \rho)$ term in the denominator (see equation (2.15)). The behaviour of this expression is as stated in Proposition 4 and illustrated in Figure 2.3 for the closed economy.

A symmetric lowering of tariff barriers by both countries (i.e. an increase in ρ , the freeness of trade) here has the effect of reducing the cost cut-off, which is in line with the benchmark result:

$$\frac{\partial c_D^l}{\partial \rho} = -\frac{c_D^l}{n + 2}(1 + \rho)^{-1} < 0. \quad (2.46)$$

The productivity effect of bilateral liberalization is qualitatively similar to the effect for the move from autarky to an open economy as stated in Proposition 11: the liberalization effect is initially reinforced by increasing degrees of product differentiation and is decreasing in γ for $\gamma > \frac{2\theta}{L}$.

Proposition 12. *In the model with quality, the liberalization effect is non-monotonic and convex in γ . The liberalization effect in absolute terms is largest for $\gamma = \frac{2\theta}{L}$.*

Proof.

$$\frac{\partial^2 c_D^l}{\partial \rho \partial \gamma} = -\frac{(1 - \gamma\lambda)}{(n + 2)^2 \gamma} \frac{c_D^l}{(1 + \rho)} \quad (2.47)$$

$$= 0 \text{ if } \gamma = \frac{2\theta}{L} \quad (2.48)$$

$$\frac{\partial^3 c_D^l}{\partial \rho \partial \gamma^2} = \frac{(n + 1)(1 + \gamma^2 \lambda^2) + 2\gamma\lambda}{(n + 2)^3 \gamma^2} \frac{c_D^l}{(1 + \rho)} > 0$$

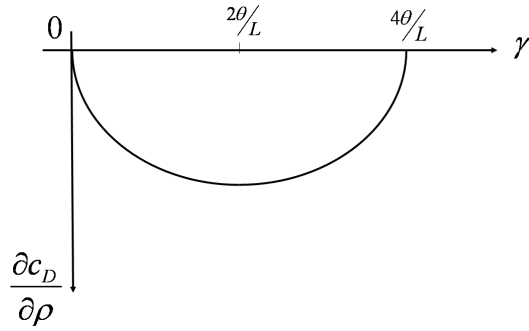


Figure 2.6: Partial Liberalization with Quality

□

This result is illustrated in Figure 2.6. This prediction links back to Pavcnik's (2002) empirical results of varying productivity effects from trade liberalization depending on the industry being liberalized. While Pavcnik (2002) attributes at least part of this variation to differing pre-liberalization tariff protection, this result provides an alternative explanation for her observations. It is worth noting that Pavcnik (2002) finds relatively small effects for high and low differentiated products and large effects for products of intermediate degrees of differentiation: 6-7% in manufacturing of machinery and equipment (high γ), and 18% in food, textiles and metals (low γ), and 33% in glass and 43% in chemicals (intermediate γ).

In summary, when I allow for the possibility of quality investments by firms, the interaction between the degree of differentiation and industry productivity becomes more complex. Firstly, the relationship between productivity and the degree of differentiation is now non-monotonic. Two effects are working in opposite directions: (i) competitive pressure and hence average productivity is falling as varieties are becoming less substitutable (the "direct effect", which is also present in the benchmark case without quality); (ii) the scope for quality upgrading and hence the range of qualities offered increases as the degree of differentiation rises, making competition tougher and increasing average productivity (the "quality effect"). The quality effect is reflected in a steeper negative slope of

the quality/cost relationship, which means firms' optimal quality upgrades are increasing more rapidly in their productivities the higher the degree of differentiation. Lower productivity firms are squeezed out as they cannot sufficiently keep up with industry pressures to upgrade quality. I was able to show that the toughness of competition is therefore most stringent for very low or very high values of γ and laxest for intermediate values of γ .

The non-monotonic relationship between the degree of differentiation and average productivity is also reflected in firms' quality upgrading decisions across industries. Firms with the same productivity level across industries will engage in more quality upgrading the higher the degree of differentiation in their industry for values of $\gamma < \frac{2\theta}{L}$. This relationship is, however, more complex and partly reversed for high values of γ . Here, only the most productive firms will increasingly upgrade as the industry becomes more sophisticated, while less productive firms will invest in less quality as the degree of differentiation rises. I have shown that at the extreme ends of the productivity spectrum in every industry the following result holds: while the least productive firms will optimally have zero quality investment in every industry, the quality investments of the highest productivity firms in every industry are increasing in the degree of product differentiation. In other words, the range of qualities offered increases with the degree of differentiation. This is Schott's (2004) stylized fact discussed in the introduction.

When it comes to the impact of trade on productivity, we can say the following: by strengthening competition, increases in market size have a positive effect on average productivity in all industries. Qualitatively, this is the same result as in the benchmark case: the market size effect is amplified by higher degrees of differentiation. However, by contrast to the benchmark case, the market size effect is bounded. This is due to the fact that the quality effect is driving competition, particularly for high values of γ , such that an additional toughening of competition through an increase in market size will have a smaller effect. Further, productivity is affected non-monotonically in γ if we consider partial liberalization (autarky to open economy with trade costs and bilateral liberalization). The partial liberalization effect is greatest at intermediate values of γ and

disappears for very high and very low values. This is intuitive, as competition is laxest for these values. It is also consistent with Pavcnik's (2002) findings that the productivity impact of trade liberalization varies by industry and hence offers an alternative explanation for this observation (note also that Pavcnik (2002) finds relatively small effects for high and low differentiated products and large effects for products of intermediate degrees of differentiation).

2.3.3 Product Differentiation and Fixed Costs

The degree of product differentiation, my main variable of interest, may also affect the sunk entry cost paid by firms. In this section, I therefore investigate the effects of sunk costs and to what extent they change previous predictions. I assume that these sunk costs are increasing in the degree of differentiation. Before I investigate the interaction between γ and f , I briefly consider the effect of f in isolation.

2.3.3.1 Closed Economy

Since f enters the expressions for the models with and without quality in the same way, the results are qualitatively the same for the two cases. In the closed economy, an increase in f both raises the domestic cost cut-off and amplifies the market size effect. The intuition is similar to the one laid out for the comparative statics on γ in the case without quality: as f increases, firms are effectively more protected; this means the cost cut-off will be higher and average productivity therefore lower. Changes in market size will therefore have a higher impact, the higher is f . For the case without quality, we have:

$$\frac{\partial c_D}{\partial f} = \frac{1}{n+2} \frac{c_D}{f} > 0 \quad (2.49)$$

$$\frac{\partial^2 c_D}{\partial f \partial L} = -\frac{1}{(n+2)^2} \frac{c_D}{Lf} < 0 \quad (2.50)$$

And in the model with quality:

$$\frac{\partial c_D}{\partial f} = \frac{1}{n+2} \frac{c_D}{f} > 0 \quad (2.51)$$

$$\frac{\partial^2 c_D}{\partial f \partial L} = -\frac{1}{(n+2)^2} \frac{c_D}{(1+\gamma\lambda)Lf} \left(1 + \gamma\lambda + \frac{4\theta}{(4\theta - L\gamma)^2}\right) < 0 \quad (2.52)$$

2.3.3.2 Open Economy

The results are similar for the open economy scenario. Again, a higher sunk entry cost implies both a laxer cut-off and a larger effect from bilateral liberalization. The expressions for the benchmark case and the model with quality are identical except that c_D is now augmented by trade costs:

$$\frac{\partial c_D^l}{\partial f} = \frac{1}{n+2} \frac{c_D^l}{f} > 0 \quad (2.53)$$

$$\frac{\partial^2 c_D^l}{\partial f \partial \rho} = -\frac{1}{(n+2)^2} \frac{c_D^l}{f(1+\rho)} < 0 \quad (2.54)$$

Overall, results are driven more by variation in the preference parameter γ than by the sunk entry cost f . However, the presence of sunk costs f is important in helping us match observed market structures: isolating the effect of γ , the model with quality suggests that selection is tough at high levels of differentiation, with the number of firms in the industry very high.⁸ However, we would expect a smaller number of firms in highly differentiated industries (Shaked and Sutton, 1983; Sutton, 1989, 1991). We can therefore boost intuition by assuming f - or barriers to entry - are increasing in the sophistication of the industry, counterbalancing the effect of γ . In predicting productivity gains for any given industry, we need to be careful to separate out the effect of product differentiation from the effect of barriers to entry that characterise differentiated industries to different extents.

⁸ $N = \frac{2(n+1)\gamma}{n} \frac{(a-c_D)}{c_D}$ which is increasing in γ .

2.3.4 Interaction Between Differentiation and Fixed Costs

It is easy to see that in the benchmark case without quality, the product differentiation parameter γ and the fixed entry costs f impact the cost cut-off in the same direction. The overall effect of an increase in product differentiation (via both γ and f) is therefore an unambiguous increase in c_D and hence a weakening of competition and decrease in average productivity. In the case with quality, γ and f reinforce each other in lessening competition for $\gamma < \frac{2\theta}{L}$. For higher values of γ , f will counterbalance the increase in toughness of competition brought about by a higher γ .

Recalling the benchmark expression for the domestic cut-off in the case without quality from equation (2.16)

$$c_D = \left[\frac{2(n+1)(n+2)(c_M)^n f \gamma}{L} \right]^{\frac{1}{n+2}}$$

and totally differentiating, we have

$$dc_D = \frac{1}{n+2} \frac{c_D}{\gamma} d\gamma + \frac{1}{n+2} \frac{c_D}{f} df \quad (2.55)$$

$$\left. \frac{d\gamma}{df} \right|_{dc_D=0} = -\frac{\gamma}{f}. \quad (2.56)$$

There is hence a one-to-one trade-off between the degree of differentiation and the sunk entry cost along the iso-cut-off line in the model without quality. For the set-up with quality, we have the following proposition:

Proposition 13. *In the model with quality, fixed entry costs act to reinforce the competition dampening effect of γ for $\gamma < \frac{2\theta}{L}$ and counteract the competition toughening effect of γ for $\gamma > \frac{2\theta}{L}$.*

Proof.

$$c_D = \left(\frac{2(n+1)(n+2)(c_M)^n f}{(1+\gamma\lambda)L} \gamma \right)^{\frac{1}{n+2}} \quad (2.57)$$

$$dc_D = \frac{c_D}{n+2} \frac{1-\gamma\lambda}{\gamma} d\gamma + \frac{c_D}{n+2} \frac{1}{f} df \quad (2.58)$$

$$\begin{aligned} \frac{d\gamma}{df} \Big|_{dc_D=0} &= -\frac{\gamma}{(1-\gamma\lambda)f} \\ &< 0 \text{ if } \gamma < \frac{2\theta}{L} \\ &> 0 \text{ if } \gamma > \frac{2\theta}{L} \end{aligned} \quad (2.59)$$

□

Here, the iso-cut-off line is initially negative for $\gamma < \frac{2\theta}{L}$ - i.e. an increase in γ has to be offset by a decrease in f in order for the cut-off to stay constant. For $\gamma > \frac{2\theta}{L}$, γ and f are off-setting each other, such that an increase in γ has to be offset by an increase in f along the iso-cost cut-off line.

By considering changes in the demand differentiation parameter separately from the effect of sunk entry costs, I can therefore clearly identify the role of quality in driving industry productivity results. The fixed entry cost helps boost intuition: with fixed costs, we match the observation that the most highly differentiated industries are not usually the ones with the most fragmented market structures.

2.4 Conclusion

This chapter has extended the heterogeneous firms trade model by Antoniades (2008) to contain a continuum of industries which vary in their degree of product differentiation. I have shown that this framework provides one potential explanation for the observed variation in industries' productivity responses to trade liberalization.

In line with recent evidence (Schott, 2004; Verhoogen, 2008; Baldwin and Harrigan, 2011; Iacovone and Javorcik, 2012), I have further argued that accounting for quality com-

petition is important. My analysis shows that the quality dimension has an impact on the predictions for average industry productivities and the heterogeneity in industries' productivity responses to liberalization. The quality dimension further allows me to explain observed differences in firm-level quality choice depending on the industry.

My results suggest that two effects play a role in the interaction between product differentiation and productivity in the model with quality: a higher degree of differentiation softens competition, and by allowing less productive firms to survive, reduces average productivity in the industry (the direct effect). The presence of quality competition, however, counteracts this effect by increasing pressure on firms to invest more in quality upgrades, the higher the degree of differentiation characterizing their industry. The more differentiated the industry, the faster are firms' optimal quality investments increasing in their productivity; firms with low productivity draws will find it harder to compete and are increasingly likely to exit. Average industry productivity therefore rises in the degree of differentiation (the quality effect). I have shown that the direct effect outweighs the indirect effect for low levels of differentiation and vice versa for high levels. The effects offset each other for intermediate degrees of differentiation. Investigating more closely quality upgrading decisions on a firm-level, I have also shown formally that my framework matches Schott's (2004) stylized fact that the range of qualities offered for a good is increasing in the degree of product differentiation of the industry which produces it.

The interplay of the two effects has repercussions for industries' productivity responses to trade liberalization. In this context, I have considered three scenarios: an increase in market size (or total integration), a move from autarky to an open economy with trade costs, and partial bilateral liberalization. I have shown that the productivity effect of liberalization in the framework without quality is monotonically increasing in the degree of differentiation for all liberalization scenarios considered; however, predictions change once quality is taken into account. While the effect of total integration is amplified by higher degrees of differentiation, the effect of moving from autarky to an open economy and of bilateral liberalization is non-monotonic. It is highest at intermediate levels of product

differentiation as this is where competitive pressures are most lax in the model with quality. In line with the empirical evidence, both the model with quality and the model without quality exhibit heterogeneity in industries' productivity responses to liberalization; the nature of the heterogeneity in the model with quality seems to match stylized facts more closely.

By considering changes in the demand parameter separately from the effect of fixed entry costs, I can identify the role of quality in driving industry productivity results. The inclusion of fixed entry costs helps in boosting intuition and matching the observation that the most highly differentiated industries are not generally the most fragmented.

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2.5 Appendix

2.5.1 Derivations and Proofs Relating to the Benchmark Model without Quality

2.5.1.1 Closed Economy

$$\begin{aligned}
 \frac{\partial c_D}{\partial \gamma} &= \frac{1}{n+2} \left(\frac{\phi}{L} \right)^{\frac{1}{n+2}} \gamma^{-\frac{(n+1)}{n+2}} \\
 &= \frac{1}{n+2} \frac{c_D}{\gamma} > 0 \\
 \frac{\partial^2 c_D}{\partial \gamma^2} &= -\frac{(n+1)}{(n+2)^2} \left(\frac{\phi}{L} \right)^{\frac{1}{n+2}} \gamma^{-\frac{(2n+3)}{n+2}} \\
 &= -\frac{(n+1)}{(n+2)^2} \frac{c_D}{\gamma^2} < 0
 \end{aligned}$$

$$\begin{aligned}
 \frac{\partial c_D}{\partial L} &= -\frac{1}{n+2} (\phi\gamma)^{\frac{1}{n+2}} L^{-\frac{(n+3)}{n+2}} \\
 &= -\frac{1}{n+2} \frac{c_D}{L} < 0 \\
 \frac{\partial^2 c_D}{\partial L^2} &= \frac{n+3}{(n+2)^2} (\phi\gamma)^{\frac{1}{n+2}} L^{-\frac{(2n+5)}{n+2}} \\
 &= \frac{n+3}{(n+2)^2} \frac{c_D}{L^2} > 0
 \end{aligned}$$

Proof of Proposition 1:

$$\begin{aligned}
 \frac{\partial^2 c_D}{\partial \gamma \partial L} &= -\frac{1}{(n+2)^2} \phi^{\frac{1}{n+2}} L^{-\frac{(n+3)}{n+2}} \gamma^{-\frac{(n+1)}{n+2}} \\
 &= -\frac{1}{(n+2)^2} \frac{c_D}{\gamma L} < 0
 \end{aligned}$$

2.5.1.2 Open Economy

Proof of Proposition 2:

$$\begin{aligned}
c_D - c_D^l &= \left(\frac{\gamma\phi}{L}\right)^{\frac{1}{n+2}} - \left(\frac{\gamma\phi}{L(1+\rho)}\right)^{\frac{1}{n+2}} \\
&= \left(\frac{\gamma\phi}{L}\right)^{\frac{1}{n+2}} \left(1 - \left(\frac{1}{1+\rho}\right)^{\frac{1}{n+2}}\right) > 0 \\
\frac{\partial(c_D - c_D^l)}{\partial\gamma} &= \frac{1}{n+2} \gamma^{-\frac{(n+1)}{n+2}} \left(\frac{\phi}{L}\right)^{\frac{1}{n+2}} \left(1 - \left(\frac{1}{1+\rho}\right)^{\frac{1}{n+2}}\right) \\
&= \frac{1}{n+2} \frac{c_D}{\gamma} \left(1 - \left(\frac{1}{1+\rho}\right)^{\frac{1}{n+2}}\right) > 0 \\
\frac{\partial^2(c_D - c_D^l)}{\partial\gamma^2} &= -\frac{(n+1)}{(n+2)^2} \gamma^{-\frac{(2n+3)}{n+2}} \left(\frac{\phi}{L}\right)^{\frac{1}{n+2}} \left(1 - \left(\frac{1}{1+\rho}\right)^{\frac{1}{n+2}}\right) \\
&= -\frac{(n+1)}{(n+2)^2} \frac{c_D}{\gamma^2} \left(1 - \left(\frac{1}{1+\rho}\right)^{\frac{1}{n+2}}\right) < 0
\end{aligned}$$

Derivation of cut-off - differentiation relationship:

$$\begin{aligned}
\frac{\partial c_D^l}{\partial\gamma} &= \frac{1}{n+2} \left(\frac{\phi}{L^l(1+\rho)}\right)^{\frac{1}{n+2}} \gamma^{-\frac{(n+1)}{n+2}} \\
&= \frac{1}{n+2} \frac{c_D^l}{\gamma} > 0 \\
\frac{\partial^2 c_D^l}{\partial\gamma^2} &= -\frac{(n+1)}{(n+2)^2} \left(\frac{\phi}{L^l(1+\rho)}\right)^{\frac{1}{n+2}} \gamma^{-\frac{(2n+3)}{n+2}} \\
&= -\frac{(n+1)}{(n+2)^2} \frac{c_D^l}{\gamma^2} < 0
\end{aligned}$$

Derivation of cut-off - trade-cost relationship:

$$\begin{aligned}
\frac{\partial c_D^l}{\partial\rho} &= -\frac{1}{n+2} \left(\frac{\gamma\phi}{L^l}\right)^{\frac{1}{n+2}} (1+\rho)^{-\frac{(n+3)}{n+2}} \\
&= -\frac{1}{n+2} \frac{c_D^l}{(1+\rho)} < 0 \\
\frac{\partial^2 c_D^l}{\partial\rho^2} &= \frac{n+3}{(n+2)^2} \left(\frac{\gamma\phi}{L^l}\right)^{\frac{1}{n+2}} (1+\rho)^{-\frac{(2n+5)}{n+2}} \\
&= \frac{n+3}{(n+2)^2} \frac{c_D^l}{(1+\rho)^2} > 0
\end{aligned}$$

Proof of Proposition 3:

$$\begin{aligned}\frac{\partial^2 c_D^l}{\partial \rho \partial \gamma} &= -\frac{1}{(n+2)^2} \gamma^{-\frac{(n+1)}{n+2}} \left(\frac{\phi}{L^l}\right)^{\frac{1}{n+2}} (1+\rho)^{-\frac{(n+3)}{n+2}} \\ &= -\frac{1}{(n+2)^2} \frac{c_D^l}{\gamma(1+\rho)} < 0\end{aligned}$$

2.5.2 Derivations and Proofs Relating to the Model with Quality

2.5.2.1 Closed Economy

Proof of Proposition 4:

$$\begin{aligned}c_D &= \left(\frac{2(n+1)(n+2)(c_M)^n f}{(1+\gamma\lambda)L} \gamma\right)^{\frac{1}{n+2}} = \left(\frac{\phi\gamma}{(1+\gamma\lambda)L}\right)^{\frac{1}{n+2}} \\ \frac{\partial c_D}{\partial \gamma} &= \frac{1}{n+2} \left(\frac{\phi}{L}\right)^{\frac{1}{n+2}} \left(\frac{\gamma}{1+\gamma\lambda}\right)^{-\frac{(n+1)}{n+2}} \frac{\partial}{\partial \gamma} \left(\frac{\gamma}{1+\gamma\lambda}\right) \\ \frac{\partial}{\partial \gamma} \left(\frac{\gamma}{1+\gamma\lambda}\right) &= \frac{(1+\gamma\lambda) - \gamma \frac{\partial}{\partial \gamma} (1+\gamma\lambda)}{(1+\gamma\lambda)^2} \\ \frac{\partial}{\partial \gamma} \left(1 + \gamma \left(\frac{L}{4\theta - \gamma L}\right)\right) &= \gamma \left(\frac{L}{4\theta - \gamma L}\right)^2 + \lambda = \gamma\lambda^2 + \lambda \\ \frac{\partial}{\partial \gamma} \left(\frac{\gamma}{1+\gamma\lambda}\right) &= \frac{(1+\gamma\lambda) - \gamma^2\lambda^2 - \gamma\lambda}{(1+\gamma\lambda)^2} = \frac{1 - \gamma^2\lambda^2}{(1+\gamma\lambda)^2} = \frac{1 - \gamma\lambda}{1 + \gamma\lambda} \\ \therefore \frac{\partial c_D}{\partial \gamma} &= \frac{1}{n+2} \left(\frac{\phi}{L}\right)^{\frac{1}{n+2}} \left(\frac{\gamma}{1+\gamma\lambda}\right)^{-\frac{(n+1)}{n+2}} \frac{1 - \gamma\lambda}{1 + \gamma\lambda} \\ &= \frac{1}{n+2} c_D \left(\frac{\gamma}{1+\gamma\lambda}\right)^{-1} \frac{1 - \gamma\lambda}{1 + \gamma\lambda} \\ &= \frac{1 - \gamma\lambda}{(n+2)\gamma} c_D\end{aligned}$$

Proof of Proposition 4 continued:

$$\begin{aligned}
\frac{\partial^2 c_D}{\partial \gamma^2} &= \frac{1 - \gamma\lambda}{(n+2)\gamma} \frac{\partial c_D}{\partial \gamma} + \frac{\partial}{\partial \gamma} \left(\frac{1 - \gamma\lambda}{(n+2)\gamma} \right) c_D \\
&= \left(\frac{1 - \gamma\lambda}{(n+2)\gamma} \right)^2 c_D + \frac{\partial}{\partial \gamma} \left(\frac{1 - \gamma\lambda}{(n+2)\gamma} \right) c_D \\
\frac{\partial}{\partial \gamma} \left(\frac{1 - \gamma\lambda}{(n+2)\gamma} \right) &= \frac{(n+2)\gamma(-\gamma\lambda^2 - \lambda) - (n+2)(1 - \gamma\lambda)}{(n+2)^2 \gamma^2} \\
&= \frac{(n+2)(-\gamma^2\lambda^2 - 1)}{(n+2)^2 \gamma^2} \\
\frac{\partial^2 c_D}{\partial \gamma^2} &= \left(\frac{1 - \gamma\lambda}{(n+2)\gamma} \right)^2 c_D + \frac{(n+2)(-\gamma^2\lambda^2 - 1)}{(n+2)^2 \gamma^2} c_D \\
&= \frac{1 - 2\gamma\lambda + \gamma^2\lambda^2 - n\gamma^2\lambda^2 - n - 2\gamma^2\lambda^2 - 2}{(n+2)^2 \gamma^2} c_D \\
&= -\frac{(n+1)(1 + \gamma^2\lambda^2) + 2\gamma\lambda}{(n+2)^2 \gamma^2} c_D < 0
\end{aligned}$$

Proof of Propositions 5 and 6: no additional derivations

Proof of Proposition 7

$$\begin{aligned}
\frac{\partial z^*}{\partial \gamma} &= \lambda \left(\frac{\partial c_D}{\partial \gamma} + \lambda c_D \right) \\
&= \lambda \left[\frac{1 - \gamma\lambda}{(n+2)\gamma} c_D + \lambda c_D \right] \\
&= \lambda c_D \left[\frac{1 - \gamma\lambda + n\lambda\gamma + 2\lambda\gamma}{(n+2)\gamma} \right] \\
&= \frac{\lambda c_D}{(n+2)} \left[\frac{1}{\gamma} + (n+1)\lambda \right] > 0
\end{aligned}$$

Proof of Proposition 8: no additional derivations

Proof of Proposition 9:

$$\begin{aligned}
\bar{z} &= \frac{\lambda c_D}{n+1} \\
\frac{\partial \bar{z}}{\partial \gamma} &= \frac{\lambda}{n+1} \frac{\partial c_D}{\partial \gamma} + \frac{c_D}{n+1} \frac{\partial \lambda}{\partial \gamma} \\
&= \frac{\lambda}{n+1} \frac{1 - \gamma\lambda}{(n+2)\gamma} c_D + \frac{c_D}{n+1} \lambda^2 \\
&= \frac{\lambda c_D}{n+1} \frac{1 + (n+1)\gamma\lambda}{(n+2)\gamma} > 0
\end{aligned}$$

Derivation of market size effect:

Note that $\lambda = \frac{L}{4\theta - \gamma L}$ and $\frac{4\theta}{4\theta - \gamma L} = 1 + \gamma\lambda$

$$\begin{aligned}
c_D &= \left[\frac{\phi\gamma}{(1 + \gamma\lambda)L} \right]^{\frac{1}{n+2}} \\
\frac{\partial c_D}{\partial L} &= -\frac{1}{n+2} (\phi\gamma)^{\frac{1}{n+2}} [(1 + \gamma\lambda)L]^{-\frac{(n+3)}{n+2}} (1 + \gamma\lambda + \gamma L \frac{\partial \lambda}{\partial L}) < 0 \\
\frac{\partial \lambda}{\partial L} &= \frac{4\theta}{(4\theta - \gamma L)^2} > 0 \\
\therefore \frac{\partial c_D}{\partial L} &= -\frac{1}{n+2} (\phi\gamma)^{\frac{1}{n+2}} [(1 + \gamma\lambda)L]^{-\frac{(n+3)}{n+2}} (1 + \gamma\lambda + \frac{4\theta\gamma L}{(4\theta - \gamma L)^2}) \\
&= -\frac{1}{n+2} \frac{c_D}{(1 + \gamma\lambda)L} (1 + \gamma\lambda + \gamma\lambda(1 + \gamma\lambda)) \\
&= -\frac{1}{n+2} \frac{c_D}{(1 + \gamma\lambda)L} (1 + \gamma\lambda)^2 \\
&= -\frac{(1 + \gamma\lambda)}{(n+2)L} c_D < 0
\end{aligned}$$

Proof of Proposition 10:

$$\begin{aligned}
\frac{\partial c_D}{\partial L} &= -\frac{(1 + \gamma\lambda)}{(n+2)L} c_D \\
\frac{\partial^2 c_D}{\partial L \partial \gamma} &= -\frac{(1 + \gamma\lambda)}{(n+2)L} \frac{\partial c_D}{\partial \gamma} + c_D \frac{\partial}{\partial \gamma} \left[-\frac{(1 + \gamma\lambda)}{(n+2)L} \right] \\
&= -\frac{(1 + \gamma\lambda)}{(n+2)L} \frac{1 - \gamma\lambda}{(n+2)\gamma} c_D - \frac{1}{(n+2)L} c_D \frac{\partial}{\partial \gamma} [(1 + \gamma\lambda)] \\
&= -\frac{(1 + \gamma\lambda)}{(n+2)L} \frac{1 - \gamma\lambda}{(n+2)\gamma} c_D - \frac{\lambda(1 + \gamma\lambda)}{(n+2)L} c_D \\
&= -\frac{(1 + \gamma\lambda)}{(n+2)L} \left[\frac{1 - \gamma\lambda}{(n+2)\gamma} + \frac{(n+2)\gamma\lambda}{(n+2)\gamma} \right] c_D \\
&= -\frac{(1 + \gamma\lambda)}{(n+2)L} \left[\frac{1 + (n+1)\gamma\lambda}{(n+2)\gamma} \right] c_D < 0
\end{aligned}$$

2.5.2.2 Open Economy

Proof of Proposition 11:

$$\begin{aligned}
c_D - c_D^l &= \left(\frac{\phi\gamma}{(1+\gamma\lambda)L} \right)^{\frac{1}{n+2}} - \left(\frac{\phi\gamma}{(1+\gamma\lambda)L(1+\rho)} \right)^{\frac{1}{n+2}} = \left(\frac{\phi\gamma}{(1+\gamma\lambda)L} \right)^{\frac{1}{n+2}} \left[1 - \left(\frac{1}{1+\rho} \right)^{\frac{1}{n+2}} \right] \geq 0 \\
\frac{\partial(c_D - c_D^l)}{\partial\gamma} &= \frac{1-\gamma\lambda}{(n+2)\gamma} \left[1 - \left(\frac{1}{1+\rho} \right)^{\frac{1}{n+2}} \right] c_D \\
\frac{\partial^2(c_D - c_D^l)}{\partial\gamma^2} &= -\frac{[(n+1)(1+\gamma^2\lambda^2) + 2\gamma\lambda]}{(n+2)^2\gamma^2} \left[1 - \left(\frac{1}{1+\rho} \right)^{\frac{1}{n+2}} \right] c_D < 0
\end{aligned}$$

Derivation of cut-off - trade-cost relationship:

$$\begin{aligned}
c_D^l &= \left(\frac{\gamma\phi}{L^l(1+\gamma\lambda_D^l)(1+\rho)} \right)^{\frac{1}{n+2}} \\
\frac{\partial c_D^l}{\partial\rho} &= -\frac{1}{n+2} \left(\frac{\gamma\phi}{L^l(1+\gamma\lambda_D^l)} \right)^{\frac{1}{n+2}} (1+\rho)^{-\frac{(n+3)}{n+2}} \\
&= -\frac{c_D^l}{n+2} (1+\rho)^{-1} < 0
\end{aligned}$$

Proof of Proposition 12:

$$\begin{aligned}
\frac{\partial^2 c_D^l}{\partial\rho\partial\gamma} &= -\frac{1}{n+2} (1+\rho)^{-1} \frac{\partial c_D^l}{\partial\gamma} \\
&= -\frac{1}{n+2} (1+\rho)^{-1} \frac{(1-\gamma\lambda)}{(n+2)\gamma} c_D^l \\
&= -\frac{(1-\gamma\lambda)}{(n+2)^2\gamma} (1+\rho)^{-1} c_D^l
\end{aligned}$$

Derivation of domestic quality - differentiation relationship:

$$\begin{aligned}
\frac{\partial z_D^*}{\partial\gamma} &= \lambda_D \frac{\partial c_D^l}{\partial\gamma} + (c_D^l - c) \frac{\partial\lambda_D}{\partial\gamma} \\
\frac{\partial z_X^*}{\partial\gamma} &= \lambda_X \frac{\partial c_X^l}{\partial\gamma} + (c_X^l - c) \frac{\partial\lambda_X}{\partial\gamma} \\
\text{where } \frac{\partial\lambda_D}{\partial\gamma} &= \frac{(L^l)^2}{(4\theta - \gamma_k L^l)^2} > 0 \\
\text{and } \frac{\partial\lambda_X}{\partial\gamma} &= \frac{\tau (L^h)^2}{(4\theta - \gamma L^h)^2} > 0
\end{aligned}$$

2.5.3 Derivations and Proofs Relating to Fixed Costs

2.5.3.1 Closed Economy

Benchmark without quality:

Derivation of cut-off fixed cost relationship:

$$\begin{aligned}
 \frac{\partial c_D}{\partial f} &= \frac{1}{n+2} \left(\frac{2(n+1)(n+2)(c_M)^n \gamma}{L} \right)^{\frac{1}{n+2}} f^{-\frac{(n+1)}{n+2}} > 0 \\
 &= \frac{1}{n+2} \frac{c_D}{f} > 0 \\
 \frac{\partial^2 c_D}{\partial f \partial L} &= -\frac{1}{(n+2)^2} [2(n+1)(n+2)(c_M)^n \gamma]^{\frac{1}{n+2}} L^{-\frac{(n+3)}{n+2}} f^{-\frac{(n+1)}{n+2}} \\
 &= -\frac{1}{(n+2)^2} \frac{c_D}{Lf} < 0
 \end{aligned}$$

With quality:

Derivation of cut-off - fixed cost relationship:

$$\begin{aligned}
 \frac{\partial c_D}{\partial f} &= \frac{1}{n+2} \left(\frac{2(n+1)(n+2)(c_M)^n \gamma}{(1+\gamma\lambda)L} \right)^{\frac{1}{n+2}} f^{-\frac{(n+1)}{n+2}} \\
 &= \frac{1}{n+2} \frac{c_D}{f} > 0 \\
 \frac{\partial^2 c_D}{\partial f \partial L} &= -\frac{1}{(n+2)^2} [2(n+1)(n+2)(c_M)^n \gamma]^{\frac{1}{n+2}} [(1+\gamma\lambda)L]^{-\frac{(n+3)}{n+2}} \left(1 + \gamma\lambda + \frac{4\theta}{(4\theta - L\gamma)^2}\right) f^{-\frac{(n+1)}{n+2}} \\
 &= -\frac{1}{(n+2)^2} \frac{c_D}{(1+\gamma\lambda)Lf} \left(1 + \gamma\lambda + \frac{4\theta}{(4\theta - L\gamma)^2}\right) < 0
 \end{aligned}$$

2.5.3.2 Open Economy

Benchmark without quality:

Derivation of cut-off - fixed cost relationship:

$$\begin{aligned}
 \frac{\partial c_D^l}{\partial f} &= \frac{1}{n+2} \left(\frac{2(n+1)(n+2)(c_M)^n \gamma}{L(1+\rho)} \right)^{\frac{1}{n+2}} f^{-\frac{(n+1)}{n+2}} \\
 &= \frac{1}{n+2} \frac{c_D^l}{f} > 0 \\
 \frac{\partial^2 c_D^l}{\partial f \partial \rho} &= -\frac{1}{(n+2)^2} \left[\frac{2(n+1)(n+2)(c_M)^n \gamma}{L^l} \right]^{\frac{1}{n+2}} (1+\rho)^{-\frac{(n+3)}{n+2}} f^{-\frac{(n+1)}{n+2}} \\
 &= -\frac{1}{(n+2)^2} \frac{c_D^l}{f(1+\rho)} < 0
 \end{aligned}$$

With quality:

Derivation of cut-off - fixed cost relationship:

$$\begin{aligned}
\frac{\partial c_D^l}{\partial f} &= \frac{1}{n+2} \left(\frac{2(n+1)(n+2)(c_M)^n \gamma}{(1+\gamma\lambda)L(1+\rho)} \right)^{\frac{1}{n+2}} f^{-\frac{(n+1)}{n+2}} \\
&= \frac{1}{n+2} \frac{c_D^l}{f} > 0 \\
\frac{\partial^2 c_D^l}{\partial f \partial \rho} &= -\frac{1}{(n+2)^2} \left[\frac{2(n+1)(n+2)(c_M)^n \gamma}{L^l(1+\gamma\lambda_D^l)} \right]^{\frac{1}{n+2}} [1+\rho]^{-\frac{(n+3)}{n+2}} f^{-\frac{(n+1)}{n+2}} \\
&= -\frac{1}{(n+2)^2} \frac{c_D^l}{f(1+\rho)} < 0
\end{aligned}$$

2.5.4 Derivations and Proofs Relating to FC- γ Interaction

Benchmark without quality: Derivation of fixed cost - γ interaction:

$$\begin{aligned}
c_D &= \left(\frac{2(n+1)(n+2)(c_M)^n f \gamma}{L} \right)^{\frac{1}{n+2}} \\
dc_D &= \frac{1}{n+2} \left(\frac{\phi}{L} \right)^{\frac{1}{n+2}} \gamma^{-\frac{(n+1)}{n+2}} d\gamma + \frac{1}{n+2} \left(\frac{2(n+1)(n+2)(c_M)^n \gamma}{L} \right)^{\frac{1}{n+2}} f^{-\frac{(n+1)}{n+2}} df \\
&= \frac{1}{n+2} \frac{c_D^l}{\gamma} d\gamma + \frac{1}{n+2} \frac{c_D^l}{f} df \\
\frac{d\gamma}{df} \Big|_{dc_D=0} &= -\frac{\gamma}{f}
\end{aligned}$$

With quality:

Proof of Proposition 13:

$$\begin{aligned}
c_D &= \left(\frac{2(n+1)(n+2)(c_M)^n f}{(1+\gamma\lambda)L} \gamma \right)^{\frac{1}{n+2}} \\
dc_D &= \frac{1}{n+2} \left(\frac{\phi}{L} \right)^{\frac{1}{n+2}} \left(\frac{\gamma}{1+\gamma\lambda} \right)^{-\frac{(n+1)}{n+2}} \frac{1-\gamma\lambda}{1+\gamma\lambda} d\gamma + \frac{1}{(n+2)} \left(\frac{2(n+1)(n+2)(c_M)^n \gamma}{(1+\gamma\lambda)L} \right)^{\frac{1}{n+2}} f^{-\frac{(n+1)}{n+2}} df \\
&= \frac{c_D}{n+2} \frac{1-\gamma\lambda}{\gamma} d\gamma + \frac{c_D}{n+2} \frac{1}{f} df \\
\frac{d\gamma}{df} \Big|_{dc_D=0} &= -\frac{\gamma}{(1-\gamma\lambda)f} \\
&< 0 \text{ if } \gamma < \frac{2\theta}{L} \\
&> 0 \text{ if } \gamma > \frac{2\theta}{L}.
\end{aligned}$$

Chapter 3

Does Product Quality Matter for Gains from Trade?

3.1 Introduction¹

Product quality is an important dimension of international competition. The recent trade literature has provided strong empirical evidence² of this and several theoretical papers have formalized the mechanisms.³ This chapter adds to the literature by analysing the implications of quality for gains from trade. To guide the welfare analysis, I build a quality-augmented heterogeneous firms model with variable elasticity of demand (VED) preferences and hence market size effects. The model combines several mechanisms for gains from trade: quality-adjusted prices and the mass of varieties are affected by changes

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²Schott, 2004; Hummels and Klenow, 2005; Hallak, 2006; Verhoogen, 2008; Khandelwal, 2010; Eckel, Iacovone, Javorcik and Neary, 2011; Baldwin and Harrigan, 2011; Iacovone and Javorcik, 2012; Kugler and Verhoogen, 2012; Crozet, Head and Mayer, 2012.

³Antoniades, 2008; Eckel, Iacovone, Javorcik and Neary, 2011; Baldwin and Harrigan, 2011; Johnson, 2012; Demir, 2011; Fajgelbaum, Grossman and Helpman, 2011; Fieler, 2011.

on the extensive and intensive margin as well as by firms' responses in terms of quality choice.

In the traditional heterogeneous firms models, welfare is directly related to the level of competitive toughness in a market, which can in turn be summarized by the cost cut-off (the level of marginal cost that implies break-even in equilibrium). This chapter adds to the literature by showing that in the quality-augmented model, these relationships no longer hold due to an additional quality channel. An alternative welfare analysis is required. The indirect utility function is hence derived to provide a complete picture of welfare. Guided by the structure of the indirect utility function, I analyse each welfare channel in turn and show that an increase in market size can have conflicting effects on the individual channels: while quality-adjusted price is always falling, a larger market may also be associated with less variety. Overall gains from trade are nevertheless positive.

When it comes to market size effects, I argue that it is necessary to distinguish between two quality cost structures: when quality is achieved via fixed cost investment only, the optimal level of quality chosen by high quality firms is increasing in market size, leading to a polarization of the quality distribution. In addition, average quality increases due to tougher selection and a larger expansion of sales for the high quality firms. At the same time, product variety may fall as the market trades off higher quality for less variety. When quality production incurs only variable cost, on the other hand, a larger market has no effect on firm quality choice, such that the quality upgrading channel is shut down: trade integration leads to a rise in average quality as long as selection gets tougher. These theoretical predictions add granularity to Shaked and Sutton's (1983) and Sutton's (1989, 1991) well-known result that increases in market size do not necessarily lead to market fragmentation if endogenous product quality is important.

Several theories have been proposed to formalize the observed relationship between product quality and trade patterns. Antoniadou (2008) augments Melitz and Ottaviano (2008) by an endogenous quality dimension. Eckel, Iacovone, Javorcik and Neary (2011) consider optimal quality investment by multi-product firms. Both of these contributions

have demand sides which are characterised by VED preferences and are thus the most relevant in the current context. Other heterogeneous-firms trade models with quality are presented in Baldwin and Harrigan (2011), Demir (2011), Johnson (2012) and Crozet, Head and Mayer (2012) (all with CES preferences).

The theoretical framework in the present chapter draws elements from the two quality-augmented models with VED preferences mentioned above. The baseline model for the fixed cost case builds directly on Antoniadis (2008). The preference structure I use is adapted from Eckel, Iacovone, Javorcik and Neary (2011). Their formulation with only one quality-related parameter allows for a convenient isolation of the quality dimension, as opposed to a direct quality-augmentation of Melitz-Ottaviano (2008) preferences as in Antoniadis (2008). Product quality in the present model takes the following form: quality investment by firms raises consumers' willingness to pay and incurs either a fixed or a variable cost. I consider the equilibria obtained under the two cost structures in turn. In the fixed quality cost case the cost of quality depends on the level of quality chosen, but not on output. The incentive to invest in quality is increasing in firm scale, as fixed costs can be spread over more units. In the variable cost case, marginal cost is convex in the level of product quality chosen. Under both scenarios is it the case that all firms that produce strictly positive output in equilibrium also invest in quality, with the level of optimal quality increasing in a firm's productivity. This chapter goes beyond the existing literature by considering the implications of product quality for gains from trade, checking for robustness of results across fixed and variable quality cost structures and linking the analysis to the recent debate on the macro-economic gains from trade.⁴ To the best of my knowledge, this is the first paper to consider the welfare impact of product quality in a heterogeneous firms context.⁵

Importantly, the VED demand specification allows me to capture the effect of market

⁴Arkolakis, Costinot and Rodriguez-Clare, 2012; Arkolakis, Costinot, Donaldson and Rodriguez-Clare, 2012; Simonovska and Waugh, 2013; Dhingra and Morrow, 2012; Mrazova and Neary, 2013; Nocco, Ottaviano and Salto, 2013; Melitz and Redding, 2013.

⁵An earlier conference version of this chapter (May 2012) predates an updated version of Antoniadis (2008) from November 2012 which adds a welfare analysis.

size on firm behaviour. Since changes in market size affect the elasticity of demand and hence mark-ups, a larger market entails a pro-competitive effect. Other recent quality-augmented theories rely on Melitz (2003) who assumes CES preferences, and therefore do not address market size effects (Baldwin and Harrigan, 2011; Johnson, 2012; Crozet, Head and Mayer, 2012). Several recent contributions show that the assumption of endogenous mark-ups is empirically highly relevant. This includes Chapter 3 of this thesis. Furthermore, findings of Syverson (2004) and Campbell and Hopenhayn (2005), based on data on US states, are consistent with theoretical predictions regarding the effect of market size on firm selection. Mayer, Melitz and Ottaviano (2014) find that the size of the destination market is an important determinant of the export behaviour of multi-product firms in terms of product range and product mix; in particular, they find strong evidence that in markets with tougher competition, multi-product firms skew their exports towards their best performing products. Berry and Waldfogel (2004) consider the relationship between market size and quality. They confirm Shaked and Sutton's (1983) and Sutton's (1989, 1991) result on endogenous quality and non-fragmentation in a direct empirical test using data on local US restaurant and newspaper markets which are characterised by variable and fixed quality cost respectively. As market size increases, they observe a proliferation of variety and a filling in of the quality distribution for the restaurant market and non-fragmentation and increases in quality at the top end of the distribution for the newspaper market. As opposed to the model presented in this chapter, their underlying model is one of symmetric firms and heterogeneous consumers.

The findings presented in this chapter can also be related to the current debate around the macroeconomic gains from trade sparked by Arkolakis, Costinot and Rodriguez-Clare (2012, ACR hereafter). The authors show that in a large class of trade models ranging from Krugman (1980) to Melitz (2003), welfare can be summarized by the share of expenditure on domestic goods and a gravity-estimator for the elasticity of imports with respect to variable trade costs. Arkolakis, Costinot, Donaldson and Rodriguez-Clare (2012, ACDR hereafter) show that a variation of this result also applies to a class of VED models which

includes Melitz and Ottaviano (2008). Here, I derive the gravity equation implied by my model, which takes the same form as in ACDR (2012) as long as quality preferences and technologies in the trade partners are symmetric. I also show that the baseline model in the present chapter matches the other four key assumptions in ACDR, thus making the models studied by ACDR and the quality-augmented model presented here comparable. The quality dimension is nevertheless expected to manifest itself in the trade elasticities.

The remainder of the chapter is organized as follows: section 3.2 presents the theoretical framework underlying the welfare analysis. Section 3.3 considers the impact of product quality on product market competition. Section 3.4 studies the effect of product quality on individual mechanisms for gains from trade. Section 3.5 derives the variable cost case. Section 3.6 derives the gravity equation and takes first steps in drawing a comparison to the current literature on the macroeconomic gains from trade. Section 3.7 concludes.

3.2 Set-Up

3.2.1 Consumers

There are L consumers in the economy, who each supply one unit of labour, and consume varieties i from a set $\tilde{\Omega}$ of a differentiated product; Ω will denote the endogenous subset which is actually consumed. Consumers in this model have identical tastes. Adapting the specification in Eckel, Iacovone, Javorcik and Neary (2011), I assume quasi-linear preferences (q_0 being the numeraire good), which are quadratic in the differentiated varieties, and exhibit love of variety and a preference for quality of the following form:

$$U = q_0 + u_1 + \beta u_2, \tag{3.1}$$

where

$$u_1 = \alpha Q - \frac{1}{2}b \left[(1-e) \int_{i \in \tilde{\Omega}} q_i^2 di + eQ^2 \right] \quad (3.2)$$

$$u_2 = b(1-e) \int_{i \in \tilde{\Omega}} q_i z_i di. \quad (3.3)$$

Here, q_i is the quantity consumed of variety i , and $Q \equiv \int_{i \in \tilde{\Omega}} q_i di$. The level of product quality embedded in variety i is z_i . The parameter e , where $0 < e < 1$, reflects the degree of product differentiation between varieties; as $e \rightarrow 1$ varieties become perfect substitutes.⁶ Importantly, β , is a product-specific weight on quality and can be interpreted as consumers' preference for quality. The introduction of an explicit parameter associated with the quality dimension is a departure from Antoniadou (2008) that makes the model more tractable and makes it possible to isolate the role of quality in driving results. Setting $\beta = 0$ switches off the quality channel and reduces results to those presented by Melitz and Ottaviano (2008). Furthermore, quality here enters linearly, as opposed to Antoniadou's (2008) specification which implies increasing marginal utility from product quality. As I show below, this difference in the way in which quality enters the utility function has implications for the equilibrium mass of varieties and hence the extensive margin for gains from trade.

Consumers maximise utility subject to the budget constraint $q_0 + \int_{i \in \tilde{\Omega}} p_i q_i di = I$. Individual inverse linear demand functions can then be aggregated over all consumers to give inverse market demand faced by firms for each variety. Given market clearing, $x_i = Lq_i$, we have:

$$p_i = a_i - \tilde{b} [(1-e)x_i + eX], \quad (3.4)$$

where $\tilde{b} \equiv \frac{b}{L}$ and $X \equiv \int_{i \in \tilde{\Omega}} x_i di$. The intercept is $a_i = \alpha + \beta b(1-e)z_i$, with product quality entering as a demand shifter. The specification of quadratic preferences yields a

⁶In the appendix (Section 3.8.2), I derive the equilibrium with preferences which distinguish between horizontal and vertical differentiation. Equilibrium expressions under this new preference structure are very clean and intuitive and allow for more nuance in the interpretation of results. I plan to explore this specification in more detail in future work.

linear expression for demand for goods from the differentiated sector. From equation (3.4), we can write direct demand for variety i as:

$$x_i = \frac{\alpha}{\tilde{\epsilon}b} - \frac{1}{\tilde{b}(1-e)}p_i + \frac{eN}{\tilde{\epsilon}b(1-e)}\bar{p} + \beta Lz_i - \frac{\beta beN}{\tilde{\epsilon}b}\bar{z}, \quad (3.5)$$

where $\epsilon = 1 - e + eN$ and where N is the mass of firms in the market (equivalently, the measure of varieties), \bar{p} is the average price and \bar{z} is the average industry quality level. Since demand is linear, there is a maximum bound to the price p_i that firms can charge and face positive demand. This choke price p^{\max} occurs where demand $x_i = 0$. From equation (3.5), firms face positive demand as long as

$$p_i < p^{\max} \equiv \frac{\alpha(1-e)}{\epsilon} + \frac{eN}{\epsilon}\bar{p} + \beta b(1-e)z_i - \frac{\beta b(1-e)eN}{\epsilon}\bar{z}. \quad (3.6)$$

I show below (equation 3.9) that $z_i = 0$ if $x_i = 0$, and so the choke price p_i^{\max} is the same for all varieties.

3.2.2 Firms

The model economy consists of two sectors, one producing a homogeneous numeraire good under perfect competition and constant returns to scale and the other made up of a continuum of monopolistically competitive firms producing differentiated varieties indexed by i . Labour is the only factor of production in the model and its supply is perfectly elastic. The labour market is assumed to be perfectly competitive and wage is unity.

Firms in the model have rational expectations. In the monopolistically competitive sector, a continuum of ex ante identical firms initially faces Melitz-type uncertainty about their productivity; the latter is represented by the inverse of their unit cost c . Paying a sunk cost f allows firms to draw their productivity level from a known distribution. Only those firms whose productivity draw is favourable enough to at least break even will stay in the market and produce. All other firms exit immediately. All firms that stay in the

market in equilibrium also invest in quality.

For now, I think of "quality production" as a one-off investment that allows a firm to reach a certain level of quality. Cost is increasing in the level of quality chosen and there are diminishing returns to quality investment. No statement is made here about quality issues related to the production process (e.g. the fault rate in the production of a high tech product once it has been developed) or the quality of inputs. The latter quality dimension would be best captured by a variable quality cost (e.g. Mandel, 2010; Baldwin and Harrigan 2011). I examine the variable cost case in Section 3.5. For now, the level of quality upgrading does not affect a firm's marginal cost of output.

The total cost function of a firm consists of two components: a firm-specific variable cost and an endogenous fixed cost component associated with quality investment, as in Antoniadou (2008):

$$TC_i = c_i x_i + \frac{1}{2} \theta z_i^2. \quad (3.7)$$

The marginal cost of quality also depends on a parameter θ , which is country specific. Inversely, $\frac{1}{\theta}$ is the marginal return to quality investment (Leahy and Neary, 2010) and can be interpreted as representing a country's technological capabilities.

The sequencing of the model is as follows: firms pay the sunk entry cost f which gives them the right to draw their unit cost c_i . Firms whose productivity draw is too low to cover fixed costs withdraw. The remaining firms simultaneously choose the optimal level of quality and output, z_i and x_i . A firm's profit maximising price and output must satisfy:

$$p_i = \tilde{b}(1 - e) x_i + c_i, \quad (3.8)$$

and, its profit maximising level of quality is given by the first-order condition:

$$z_i = \frac{\beta b(1 - e) x_i}{\theta}. \quad (3.9)$$

From equation (3.9), there will be no quality investment by any firm if the cost of quality

upgrading is prohibitive ($\theta \rightarrow \infty$), or if consumers do not value quality ($\beta = 0$). It is also apparent from equation (3.9) that the optimal level of quality investment is increasing in firm scale x_i . In order to obtain an interior solution, I restrict $\frac{\beta^2 b(1-e)L}{2\theta} < 1$.

Using equation (3.6) and defining as c_D the cost of the marginal firm which has $c_i = p^{\max}$ and therefore produces zero output and does not invest in quality ($z_i = 0$ for $x_i = 0$ from equation (3.9)), we can write:

$$c_D = \frac{1}{\epsilon} [\alpha(1-e) + eN\bar{p} - \beta b(1-e)eN\bar{z}]. \quad (3.10)$$

Following Melitz and Ottaviano (2008) and Antoniadis (2008), it is possible to express all variables of interest as functions of the cut-off c_D , a firm's cost c_i and quality z_i . Maximising profits with respect to z_i , the optimal level of quality z_i^* then is:

$$z_i^* = \lambda(c_D - c_i) \quad (3.11)$$

where $\lambda = \frac{\beta L}{2\theta - \beta^2 b(1-e)L}$. Note that λ is positive by second-order conditions, and the slope of the quality-cost relationship ($-\lambda$) hence always negative. In other words, the optimal level of quality is a decreasing function of a firm's unit cost c . λ itself is increasing in market size, a country's technological capabilities, and preference for quality and decreasing in the degree of product differentiation. It can be interpreted as a market-level indicator of the degree of quality competition - the greater is λ , the faster is optimal quality increasing in firm productivity.

At this stage, we can drop the i subscripts since a cost draw c uniquely identifies a product/firm.

Free Entry Equilibrium By the free entry condition, expected profits have to be zero in equilibrium in the differentiated sector. This yields the expression:

$$f = E\pi = \int_0^{c_D} \frac{L}{4b(1-e)} [1 + \beta\lambda b(1-e)] (c_D - c)^2 dG(c). \quad (3.12)$$

In order to obtain an explicit solution for the cost cut-off, I parametrize the cost distribution, assuming cost draws come from a Pareto distribution as in Melitz and Ottaviano (2008) and Antoniadis (2008). More specifically, firms draw their costs from

$$G(c) = \left(\frac{c}{c_M}\right)^n, \quad c \in [0, c_M],$$

where n is the dispersion parameter of the distribution, and a higher n implies a more unequal distribution of resources among firms (many small firms, very few very large firms). Parametrizing, integrating and solving equation (3.12) for c_D gives an explicit solution for the equilibrium cost-cut off, i.e. the maximum cost a firm can have and just break even:

$$c_D = \left[\frac{\phi b(1-e)}{(1+\lambda B)L} \right]^{\frac{1}{n+2}}, \quad (3.13)$$

where I define $\phi \equiv 2(n+1)(n+2)(c_M)^n f$ and $B \equiv \beta b(1-e)$. B can be interpreted as a demand side summary statistic which is increasing in the scope for quality differentiation. The cut-off is an indicator of the strength of selection, and affects all firm level and aggregate indicators of interest — in particular mark-ups, quality levels and the mass of firms. However, unlike in the classic heterogeneous-firms models, it does not fully determine them if quality investment is possible.

The equilibrium is characterised by two types of firm: those that exit immediately and those that produce and invest in quality. Quality investments will be increasing in firm productivity. The mass of active firms in the differentiated sector is given by:

$$N = \frac{2(n+1)(1-e)(\alpha - c_D)}{e(1+\lambda B)c_D}. \quad (3.14)$$

A tougher cut-off, *ceteris paribus*, is associated with a higher mass of firms. The presence of product quality adds two effects: (i) from equation (3.13), we know that quality competition toughens selection, implying a lower c_D and therefore a higher mass of firms. There is, however, also (ii) a direct effect of quality which works in the opposite direction, implying a lower mass of firms for higher levels of quality competition. The overall effect of quality on the mass of firms depends on parameter values.

An intermediate case is Antoniadou (2008), which does not have the above direct effect of quality on the mass of firms: the fact that the utility function in Antoniadou (2008) is quadratic in quality means firms get an additional kick in willingness to pay from any given quality investment such that the market can always support more firms in equilibrium; tougher quality competition in Antoniadou (2008) means an unambiguous increase in the mass of firms.

This resonates with Zhelobodko, Kokovin, Parenti and Thisse's (2011, p.3) observation that "what looks like an anti-competitive outcome" [here a lower mass of firms in equilibrium for the linear case] "need not be driven by defence or collusive strategies: it may result from the nature of preferences with well-behaved utility functions". In the Appendix (Section 3.8.3), I present preferences that nest both the specification in the present chapter and Antoniadou (2008) and derive the associated generalized demand and equilibrium mass of varieties. I consider the behaviour of the mass of varieties in more detail below.

The above expressions can be simplified by defining:

$$\varepsilon_\lambda \equiv \frac{\partial \lambda}{\partial L} \frac{L}{\lambda} = \frac{2\theta}{2\theta - \beta BL} = 1 + \lambda B. \quad (3.15)$$

ε_λ can be interpreted as an indicator for a market's scope for quality differentiation, showing how quickly quality competition toughens as market size increases. Using this definition, all variables of interest can be written in terms of ε_λ and $(c_D - c)$, a firm's

relative efficiency:

$$p(c_D, c) = \mu(c_D, c) + c = \frac{\varepsilon_\lambda}{2} (c_D - c) + c, \quad (3.16)$$

$$x(c_D, c) = \frac{\varepsilon_\lambda L}{2b(1-e)} (c_D - c), \quad (3.17)$$

$$z(c_D, c) = \lambda (c_D - c) \quad (3.18)$$

$$\pi(c_D, c) = \frac{\varepsilon_\lambda L}{4b(1-e)} (c_D - c)^2, \quad (3.19)$$

$$N(c_D, c) = \frac{1}{\varepsilon_\lambda} \frac{2(n+1)(1-e)}{e} \frac{(\alpha - c_D)}{c_D}. \quad (3.20)$$

Note that where quality does not play a role, $\varepsilon_\lambda = 1$ and all expressions reduce to those found in Melitz and Ottaviano (2008).

3.3 Quality and Product Market Competition

This section assesses how quality investment affects the competitive environment in a market and ultimately consumer welfare. In Melitz (2003) as well as Melitz and Ottaviano (2008), the productivity- or cost cut-off can be used as short-hand for the level of competition in a market and is therefore informative for welfare: a lower cut-off implies more stringent selection, greater product variety and lower prices on average due to higher average productivity of firms and lower mark-ups; in other words, competition becomes unambiguously tougher, and tougher competition is associated with higher welfare. Here, I demonstrate that “competitive toughness” is an ambiguous concept in the quality-augmented model. Using two standard indicators for the level of competition - the cost cut-off (c_D , selection) and average mark-ups ($\bar{\mu}$, market power) - I show divergence between the two as the scope for quality differentiation increases. I illustrate this point by considering divergence of the two indicators across degrees of product differentiation; the same type of divergence can also be shown across markets of different size. I hence derive the indirect utility function to give a more complete picture of welfare and use its structure to guide the analysis of gains from trade in Section 3.4.

3.3.1 Divergence of Competition Measures

In this model, the scope for quality upgrading is increasing in the degree of horizontal differentiation, $(1 - e)$. The theoretical link between horizontal and vertical differentiation is consistent with empirical evidence which suggests that quality investment plays a larger role in more differentiated sectors (for example Eckel, Iacovone, Javorcik and Neary, 2011; Mandel, 2010; Kugler and Verhoogen, 2012). In particular, we can show that the average level of quality in an industry is increasing monotonically with the degree of product differentiation (see Appendix, Section 3.8.4). The more differentiated are varieties, the higher are incentives for quality investment for the most productive firms.

3.3.1.1 Selection

In Lemma 14, I restate a result that was derived in Chapter 2, but will serve a different argument in the current context. The level of quality competition in a market has an impact on the stringency of firm selection, as represented by the value of the cost cut-off, c_D . Recalling from equation (3.13) the expression for the cut-off,

$$c_D = \left[\frac{\phi b (1 - e)}{\varepsilon_\lambda L} \right]^{\frac{1}{(n+2)}}$$

the following result obtains:

Lemma 14. *The relationship between the cost cut-off and the degree of product differentiation has an inverted U-shape. Selection is most stringent at the extremes of the differentiation spectrum, namely where varieties are closely substitutable and where demands are highly independent.*

Proof. See Appendix 3.8.4. □

The result is illustrated in Figure 3.1, with the monotonic relationship in Melitz and Ottaviano (2008) given as a benchmark case (light line). Some intuition for the inverted

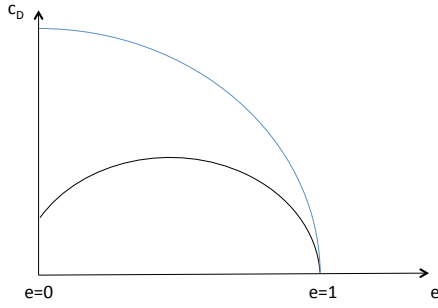


Figure 3.1: Cost Cut-off for Different Degrees of Product Differentiation

U-shape of the quality-augmented relationship can be gleaned from considering the benchmark case without the possibility of quality investments. In Melitz and Ottaviano (2008), the cost cut-off is monotonically increasing in the degree of product differentiation (decreasing in substitutability); in other words, selection becomes increasingly laxer as products become more differentiated. Selection is toughest when products are almost perfect substitutes and c_D tends to zero. I call this the direct effect of product differentiation on the cost cut-off.

The possibility to innovate introduces a countervailing effect: as product differentiation increases, incentives of highly productive firms to invest in quality increase. This is reflected in a cost cut-off that is falling in product differentiation towards the high differentiation end of the spectrum. Low productivity firms find it harder to compete, the higher the degree of differentiation. For values of e which are associated with a high degree of substitutability (i.e. as $e \rightarrow 1$), the competition effect outweighs the quality effect, and the relationship hence resembles the no quality-benchmark. Note that the location of the turning point in the $c_D \leftrightarrow e$ relationship depends on θ , the cost of quality innovation, β , consumers' preference for quality and market size L . The lower the cost of innovation, the higher consumers' preference for quality, and the larger the market, the stronger will be the quality effect.

3.3.1.2 Market Power

Mark-ups are another important indicator of the level of competition in a market. Indeed, the Lerner Index, which is a widely used measure of competition in the industrial organization literature, uses firms' mark-ups to capture their market power. The model predicts the following for the average absolute mark-up across different degrees of product differentiation:

Lemma 15. *Average mark-ups are monotonically increasing in the degree of product differentiation. Hence, for a high degree of product differentiation, while firms need a higher productivity to produce [Lemma 14], competition conditional on successful entry is lax.*

Proof. See Appendix Section 3.8.4. □

In the case of mark-ups, the competition and quality effects are reinforcing each other: as varieties become more highly differentiated and firms are more protected from their competition, mark-ups are rising. At the same time, the highest productivity firms are investing in more quality, which increases consumers' willingness to pay and hence allows those firms to charge a higher mark-up.

3.3.1.3 Competitive Toughness

In Melitz and Ottaviano (2008), c_D and $\bar{\mu}$ move in the same direction, such that a market which has tough selection also has low mark-ups; "competitive toughness" is high. In the quality-augmented model, the idea of "competitive toughness" becomes ambiguous. Figure 3.2 illustrates the case of two markets, "A" and "B", at opposite ends of the differentiation spectrum which are characterised by the same cut-off; however, average mark-ups in the more differentiated market (A) are higher than in the less differentiated market (B).

Proposition 16. *From Lemmas 14 and 15, the domestic cost cut-off does not fully characterise the competitive environment. Markets with equally tough selection can have different levels of average mark-ups.*

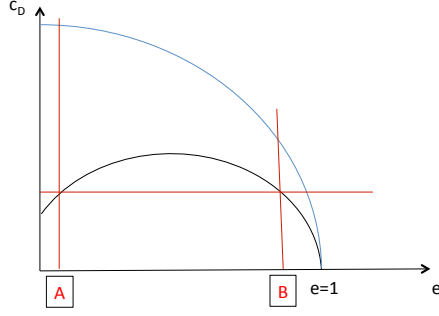


Figure 3.2: Selection and Competitive Toughness

Analogous results hold for average quality and conversely, for the mass of firms (the highly differentiated market has a relatively high quality and low mass of firms). In a model where quality investments are important, it is hence necessary to distinguish between two types of “competitive toughness”: (i) how difficult it is to enter the market as summarized by the cost cut-off c_D ; and (ii) the degree of market power of the average firm, which is reflected in the average mark-up, $\bar{\mu}$.

More importantly, given the question of trade integration, it can be shown that a similar ambiguity exists with respect to changes in market size, where a larger market is associated with a larger scope for quality upgrading. An increase in market size always leads to more stringent selection (see Appendix Section 3.8.4):

$$\frac{\partial c_D}{\partial L} = -\frac{\varepsilon_\lambda c_D}{(n+2)L} < 0, \quad (3.21)$$

but can imply higher average mark-ups for large enough values of β :

$$\begin{aligned} \frac{\partial \bar{\mu}}{\partial L} &= \frac{\varepsilon_\lambda c_D}{2(n+1)} \left[\frac{\lambda B(n+1) - 1}{(n+2)L} \right] \\ &> 0 \text{ for } \left[\frac{1}{n+2} \frac{2\theta}{Lb(1-e)} \right]^{\frac{1}{2}} < \beta < \left[\frac{2\theta}{Lb(1-e)} \right]^{\frac{1}{2}}. \end{aligned} \quad (3.22)$$

For the cut-off, the quality and competition channel are working in the same direction. A larger market increases competition by attracting more entrants and at the same time

gives firms an incentive to invest in more quality. Both effects make selection tougher. For mark-ups they work in opposite directions: while the competition channel exercises downward pressure on mark-ups, the quality channel works in the opposite direction by shifting consumers' willingness to pay. If consumers' quality preference is strong, the quality channel takes over the competition channel and average mark-ups rise.

3.4 Welfare and Gains from Trade

In order to avoid the ambiguity associated with the idea of competitive toughness in this model, I derive the indirect utility function as an indicator for welfare (see Appendix Section 3.8.5 for derivation). The latter takes the following form:

$$U = I^c + \frac{N}{2\epsilon b} (\alpha - \bar{p} + B\bar{z})^2 + \frac{N}{2b(1-e)} [\sigma_p^2 + B^2\sigma_z^2]. \quad (3.23)$$

Here, I^c is the consumer's income, σ_p^2 the variance of prices, and σ_z^2 is the variance of quality levels. I assume $I^c > \int_{i \in \tilde{\Omega}} p_i q_i di = \bar{p}Q - \frac{N}{b(1-e)}\sigma_p^2$, such that the consumption of the numeraire good is strictly positive.

Proposition 17. *Welfare increases in product variety N , the average level of quality \bar{z} , and is higher the greater the variance of both prices and quality levels. It is decreasing in average price \bar{p} .*

When considering the gains from trade in this model, I focus entirely on the market size effects arising from trade integration. In doing so, I follow the thought experiment in Krugman (1979) for the case of frictionless trade. Melitz and Ottaviano (2008) are the first to capture the market size effect in a heterogeneous-firms setting by moving away from the standard CES preference specification and introducing quadratic preferences following Ottaviano, Tabuchi and Thisse (2002). These preferences give rise to linear demand, a non-constant demand elasticity and hence endogenous mark-ups which react to changes in market size, along with all other firm-level performance indicators, such as price, quality

and firm scale.

The relevant expressions for the respective gains from trade mechanisms are given by:

$$N = \frac{1}{\varepsilon_\lambda} \frac{2(n+1)(1-e)(\alpha - c_D)}{e c_D} \quad (3.24)$$

$$\bar{p} = \frac{2n + \varepsilon_\lambda}{2(n+1)} c_D \quad (3.25)$$

$$\bar{z} = \frac{\lambda}{n+1} c_D \quad (3.26)$$

$$\sigma_p^2 = \frac{1}{4} \frac{n(\varepsilon_\lambda - 2)^2}{(n+2)(n+1)^2} c_D^2 \quad (3.27)$$

$$\sigma_z^2 = \frac{n\lambda^2}{(n+2)(n+1)^2} c_D^2. \quad (3.28)$$

Note that where consumers do not value quality, ($\beta = 0$), or where quality investment is infinitely expensive ($\theta \rightarrow \infty$), the above expressions reduce to the expressions in Melitz and Ottaviano (2008).

3.4.1 Quality

I first consider the implications of trade integration for product quality. Importantly, in the fixed quality cost case, changes in market size have an effect on quality at the firm level in addition to the industry composition effect that is characteristic of heterogeneous firms trade models. Industry composition in turn changes due to responses on the intensive margin and on the extensive margin through selection. I examine all three effects in turn.

The Intensive Margin and Quality Upgrading The assumption of VED preferences implies that changes in market size have an effect on firm size (as opposed to CES preferences, where firm size is fixed and adjustment happens only via the extensive margin). Combined with the assumption of heterogeneous firms and an optimised profit function which is submodular in market size and firms' cost draws, an increase in market size has asymmetric effects across the distribution of firms. We observe what Mrazova and Neary (2011) call the "Matthew Effect": trade integration magnifies competitive advantages. In

the present case, it means that an increase in market size will disproportionately benefit the highest quality firms.

The redistribution of sales to the high quality firms is one mechanism which contributes to an increase in average quality and hence to an increase in welfare. We can show the result formally (see Appendix Section 3.8.6 for derivation):

$$\begin{aligned} \frac{\partial r^2}{\partial c \partial L} &= -\frac{\varepsilon_\lambda^2}{2b(1-e)} \left[\frac{B\lambda}{L} \left(\frac{n+1}{n+2} c_D - c \right) + B\lambda(c_D - c) + c \right] \\ \frac{\partial r^2}{\partial c \partial L} &< 0 \text{ for } c < \frac{n+1}{n+2} c_D. \end{aligned} \quad (3.29)$$

Firm-level sales are falling in a firm's marginal cost draw, and these gaps become even larger as the market gets bigger. Since the low cost firms in this model are also the high quality firms, the improvement in average productivity through this composition effect translates to an increase in average quality. I explore this channel of adjustment empirically in Chapter 4.

Proposition 18. *The optimized revenue function is submodular in c and L with a sufficient condition of $c < \frac{n+1}{n+2} c_D$: an increase in market size implies a disproportionate expansion in sales for high quality firms. This effect is greater, the greater the scope for quality differentiation as reflected in ε_λ .*

Under the assumption of fixed quality costs, this asymmetric effect of market size on sales is amplified by additional quality investments by firms. We can see formally from equation (3.29), that a higher scope for quality differentiation, ε_λ , increases the skewness of the effect. Here is why: the revenue result in Proposition 18 is driven by disproportionate expansions in output for the higher productivity firms.⁷ This in turn has repercussions on firms' optimal quality choice. Recall that the endogenous fixed cost incurred by quality implies scale effects for quality investment, i.e. optimal quality is a positive function of firms' output. The polarization in outputs that we observe as market size increases,

⁷It can be shown that $\frac{\partial x^2}{\partial c \partial L} = -\frac{\varepsilon_\lambda^2}{2b(1-e)} < 0$.

thus carries over to the level of quality differentiation. The gap in quality investment between highly productive firms and lower productivity firms increases as a consequence of integration:

$$\frac{\partial z^2}{\partial c \partial L} = -\frac{\partial \lambda}{\partial L} < 0. \quad (3.30)$$

Proposition 19. *An increase in market size induces quality polarization through the intensive margin effect and quality upgrading.*

Summarizing, the intensive margin contribution to changes in average quality in this model is ultimately driven by productivity via the Matthew Effect, which will be reinforced in the presence of quality investment.

The Extensive Margin On the extensive margin, selection is unambiguously getting tougher in market size, as the effects of the competition channel are reinforced by the quality channel as shown in equation (3.21). As market size gets bigger, only the relatively high quality firms survive. The contribution of the extensive margin therefore goes in the same direction as the intensive margin in terms of increasing average quality.

Overall, the positive demand (and hence sales) effect from having access to a larger market is partially offset by tougher selection due to entry and tougher quality competition arising from large quality investments by the most productive firms. Intuitively, varieties produced by the most productive firms become even more attractive for consumers due to a relatively larger drop in quality-adjusted prices. This in turn makes it increasingly difficult for the least productive firms to survive. As a consequence of integration, low productivity firms will thus either be forced out of the market or see their sales and quality-level shrink.

Note, however, that the theoretical welfare impact of the extensive margin depends on assumptions about fixed costs of production and exporting: while the marginal firm has a strictly positive mass and therefore a positive welfare weight in Melitz (2003)-type models (entrants have to cover fixed costs of entry, requiring a strictly positive level of output), entrants in models with a choke price and no fixed costs - as in the present chapter - are of

zero mass (Mayer, Melitz, Ottaviano, 2014). I therefore do not emphasize welfare effects with respect to the extensive margin.

3.4.2 Quality-Adjusted Prices

What matters in terms of welfare (Equation 3.23), are average price and quality levels - or ultimately, average “true” (in the sense of welfare weighted) quality-adjusted prices. For quality, the decomposition into intensive and extensive margin and firm quality choice effects above shows that all effects are contributing to an increase in average quality. Prices are affected along the same three margins. Due to conflicting competition and quality effects, however, average prices can be increasing or decreasing in market size. If β is high, for example, the quality effect can outweigh the competition effect, such that average prices increase (see Appendix equation 3.75). We can show formally, however, that the combined welfare effect is positive.

Proposition 20. *Trade integration induces an increase in average quality and can also lead to an increase in the average price if consumers’ preference for quality is strong. However, the combined effect on welfare is unambiguously positive.*

Proof. From equation 3.23, the welfare contribution from quality-adjusted prices is positive if $\frac{\partial \bar{p}}{\partial L} - B \frac{\partial \bar{z}}{\partial L} < 0$. Indeed we find that:

$$\frac{\partial \bar{p}}{\partial L} - B \frac{\partial \bar{z}}{\partial L} = -\frac{\varepsilon_\lambda c_D}{2(n+2)L} \left[\varepsilon_\lambda + \frac{n}{n+1} \right] < 0.$$

□

3.4.3 Mass of Varieties

Krugman (1979) first captured the idea of gains from trade through more available product variety. This result also characterises Melitz and Ottaviano (2008) and Antoniadis (2008).

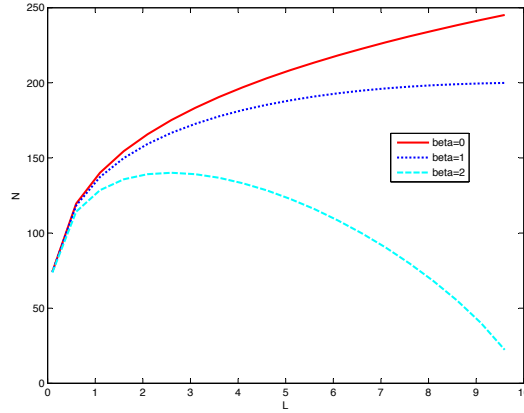


Figure 3.3: Variety and Market Size

However, in the model presented here, for high values of β , the market is trading off variety in favour of higher quality, such that variety can also be falling in market size.

Proposition 21. *In the presence of quality investment, the effect of integration on product variety is ambiguous; it is negative for large enough values of β .*

Proof.

$$\frac{\partial N}{\partial L} = \frac{c_D^{n+1}}{eb(n+2)fc_m} \left[\frac{a}{n+2} + \left(c_D - \frac{n+1}{n+2}a \right) B\lambda \right] \leq 0.$$

The relationship is drawn in Figure 3.3 for the range of admissible values of β . □

Where quality differentiation does not play a role ($\beta = 0$), the impact of trade integration on the mass of varieties available is unambiguously positive: a larger market implies a bigger mass of firms as aggregate demand increases and more firms can be accommodated. However, the possibility of quality differentiation here dampens this effect, and can reverse it for large enough β . Where consumers have a strong preference for quality, the mass of firms is lower in a larger market as the most productive firms expand market share and push out disproportionately many small, low-quality firms. That is, the polarization effect described in Section 3.4.1 is strong. The result is reminiscent of and adds granularity to Shaked and Sutton's (1983) insight that industries in which quality is important, do not see complete fragmentation as market size gets large.

3.4.4 Price and Quality Variance

In Melitz and Ottaviano (2008), the price variance is decreasing in market size, as the most productive firms with the lowest prices expand market share and in addition experience downward pressure on mark-ups due to increased competition. Price increases due to quality upgrading may however offset these effects, such that the price variance will increase in market size in cases where the scope for quality upgrading is high enough. For values of $0 \leq B\lambda < 1$, i.e. where consumer preferences for quality are weak, products are highly substitutable or quality upgrading is expensive, the variance of prices is falling in market size; this implies a negative effect on the welfare function. If $B\lambda > 1$, it is rising:

$$\begin{aligned} \frac{\partial \sigma_p^2}{\partial L} &= \frac{1}{2} \frac{n(B\lambda - 1)(nB\lambda + \varepsilon_\lambda)\varepsilon_\lambda}{(n+2)^2(n+1)^2 L} c_D^2 \\ &> 0 \text{ if } B\lambda > 1 \\ &< 0 \text{ if } 0 \leq B\lambda < 1 \end{aligned}$$

The quality variance on the other hand is unambiguously increasing in market size:

$$\frac{\partial \sigma_z^2}{\partial L} = \frac{2n\varepsilon_\lambda\lambda^2}{(n+2)^2(n+1)L} c_D^2 > 0.$$

3.4.5 Summary

Table 3.1 summarizes the effects of trade integration on the different elements of the welfare function for environments with high and low scope of quality differentiation.

From this, the overall impact of symmetric trade integration on welfare seems ambiguous. Two predictions stand out: (i) in this model, consumers will benefit from trade liberalization via higher quality products, with quality-adjusted prices now lower; however (ii) the higher the scope for quality upgrading, the lower are the gains from variety; industry concentration may even *increase* post trade-liberalization, as the market trades off variety in favour of higher quality.

Effect of $\uparrow L$ on	for low β	for high β
Mass of firms	\uparrow	\downarrow
Quality-adjusted price	\downarrow	\downarrow
σ_p^2	\downarrow	\uparrow
σ_z^2	\uparrow	\uparrow

Table 3.1: Channels for Gains from Trade

3.4.6 Overall Welfare Impact

Having disentangled the individual channels for gains from trade, I next consider the overall welfare prediction from this model. By substituting the expressions from equations (3.24)-(3.28), we can write welfare in terms of the endogenous cost-cut off (see Appendix 3.8.6):

$$U = 1 + \frac{1}{2eb} (\alpha - c_D) \left\{ \alpha - \frac{n+1}{n+2} c_D + \frac{\varepsilon_\lambda - 1}{n+2} \left[1 + \frac{2n}{n+1} \left(1 - \frac{2}{\varepsilon_\lambda} \right) \right] c_D \right\}. \quad (3.31)$$

Since ε_λ and the cost cut-off c_D are affected in opposite directions by an increase in market size, the implications of trade integration for overall welfare are not immediately obvious.

In the benchmark case without quality upgrading, symmetric trade integration unambiguously implies welfare gains:

$$\frac{\partial U}{\partial L} = -\frac{1}{2eb} \left(\frac{2n+3}{n+2} \alpha - \frac{2n+2}{n+2} c_D \right) \frac{\partial c_D}{\partial L} > 0,$$

since $a > c_D$ and $\frac{\partial c_D}{\partial L} < 0$. This result carries over directly from Melitz and Ottaviano (2008).

For $\varepsilon_\lambda > 1$, I show in Appendix 3.8.6 that the additional terms in equation (3.31) are increasing in L , such that the above welfare result of positive gains from trade remains.

Proposition 22. *Symmetric trade integration has a strictly positive effect on welfare.*

3.5 Variable Quality Cost

So far, I have assumed that firms can achieve a higher level of quality only by incurring a higher fixed cost. Product quality can, however, also be achieved via higher quality inputs or more stringent monitoring of the production process, which is reflected in higher variable cost (cf. e.g. Demir, 2011; Baldwin and Harrigan, 2011; Kugler and Verhoogen, 2012). In what follows, I derive the equilibrium for the case where quality is achieved solely via higher variable cost outlays and compare results to the fixed cost case (detailed derivations are given in Appendix 3.8.7). The variable quality cost assumption is consistent with the patterns Kugler and Verhoogen (2012) find in the data: using Colombian firm-level data, they show that larger firms pay more for inputs and charge more for output.

Set-up The consumption side is as above. Firm i 's cost c_i is determined as before via a random draw from a known distribution. I now assume that total cost can be expressed as:

$$TC_i = \frac{1}{\varphi} x_i c_i z_i^\varphi, \quad (3.32)$$

where x_i is again firm i 's output and z_i their level of quality; φ gives an indication of the curvature of quality costs, i.e. it tells us how expensive is quality. In order to ensure an interior solution, I restrict $\varphi > 1$, that is total cost is convex in quality (see Appendix 3.8.7 for second order conditions). The size of φ has important implications for the nature of quality competition and I explore this further below. Firms optimally choose output and quality according to the following first-order conditions:

$$p_i = \tilde{b}(1 - e) x_i + \frac{1}{\varphi} c_i z_i^\varphi \quad (3.33)$$

and

$$z_i = \left(\frac{B}{c_i} \right)^{\frac{1}{\varphi-1}}. \quad (3.34)$$

As is evident from equation (3.34), the restriction that $\varphi > 1$ implies that firms with a lower cost draw will always choose a higher level of quality. Quality is thus monotonically increasing in productivity. Note also that in the variable cost case, the optimal level of quality is independent of firm scale and therefore also independent of the cost cut-off. It is determined solely by a firm's cost draw, demand side parameters and the curvature of the MC function. In particular, it is decreasing in the convexity of the cost function, which is intuitive: if marginal cost is rising fast in quality, the optimal firm quality choice will be lower.

Free Entry Equilibrium I again drop the i subscripts. The free entry condition is now:

$$f = E\pi = \int_0^{c_D} \frac{L}{4b(1-e)} \left[c_D + \frac{\varphi-1}{\varphi} \left(\frac{B^\varphi}{c} \right)^{\frac{1}{\varphi-1}} \right]^2 dG(c). \quad (3.35)$$

In order to obtain a solution for the cost cut-off, I parametrize the cost distribution, assuming cost draws come from a Pareto distribution as before. This gives an implicit solution for the cut-off c_D :

$$\frac{4b(1-e)f c_M^n}{L} = c_D^{n+2} \left\{ 1 + 2 \left[\frac{\varphi-1}{\varphi} \left(\frac{B}{c_D} \right)^{\frac{\varphi}{\varphi-1}} \right] \frac{n}{n - \frac{1}{\varphi-1}} + \left[\frac{\varphi-1}{\varphi} \left(\frac{B}{c_D} \right)^{\frac{\varphi}{\varphi-1}} \right]^2 \frac{n}{n - \frac{2}{\varphi-1}} \right\}. \quad (3.36)$$

Finally, the mass of firms, N , can be expressed as:

$$N = \frac{2(1-e)(\alpha - c_D)}{e c_D + \Gamma}, \quad (3.37)$$

where $\Gamma = \frac{\varphi-1}{\varphi} \left[\frac{(n+1)B^\varphi}{n c_D} \right]^{\frac{1}{\varphi-1}}$ which is decreasing in c_D and increasing in β , consumers' preference for quality. As in the fixed quality cost case, quality therefore has a dampening effect on the mass of varieties.

To summarize, the equilibrium expressions for all variables of interest are given by:

$$p(c_D, c) = \frac{1}{2} \left[c_D + \frac{1 + \varphi}{\varphi} \left(\frac{B^\varphi}{c} \right)^{\frac{1}{\varphi-1}} \right], \quad (3.38)$$

$$x(c_D, c) = \frac{L}{2b(1-e)} \left[c_D + \frac{\varphi - 1}{\varphi} \left(\frac{B^\varphi}{c} \right)^{\frac{1}{\varphi-1}} \right], \quad (3.39)$$

$$z(c) = \left(\frac{B}{c} \right)^{\frac{1}{\varphi-1}}, \quad (3.40)$$

$$\pi(c_D, c) = \frac{L}{4b(1-e)} \left[c_D + \frac{\varphi - 1}{\varphi} \left(\frac{B^\varphi}{c} \right)^{\frac{1}{\varphi-1}} \right]^2, \quad (3.41)$$

$$N(c_D) = \frac{2(1-e)(a-c_D)}{e(c_D + \Gamma)}. \quad (3.42)$$

As in the fixed cost case examined in the previous section, most firm performance indicators are a function of a firm's cost relative to the cut-off. The important exception here is the optimal level of quality chosen by a firm, which only depends on a firm's cost as well as demand side parameters including consumers' valuation of quality. From equation (3.40) it is clear that for any given productivity draw, the optimal level of quality is decreasing in the convexity of the quality cost function and increasing in consumers' valuation of quality.

3.5.1 Gains from Trade

From the welfare expression in Section 3.4, equation (3.23), we know that the most important factors which are driving welfare are the mass of varieties, N , average prices, \bar{p} , and average quality, \bar{z} . The key welfare indicators for the variable quality cost case are

given by:

$$N = \frac{2(1-e)(\alpha - c_D)}{e(c_D + \Gamma)}, \quad (3.43)$$

$$\bar{p} = \frac{1}{2} \left[c_D + \left(\frac{1+\varphi}{\varphi} \right) \left(\frac{(n+1)B^\varphi}{nc_D} \right)^{\frac{1}{\varphi-1}} \right] \quad (3.44)$$

$$\bar{z} = \left[\frac{(n+1)B}{nc_D} \right]^{\frac{1}{\varphi-1}}. \quad (3.45)$$

Note that unlike in the fixed quality cost case, market size affects these aggregates only through the cut-off, i.e. only via selection effects. This is due to the fact that there is no market-size-induced quality upgrading in the variable cost case, as shown in the previous section. However, the presence of product quality means that the relevant expressions also contain the inverse of the cut-off, thereby leading to conflicting effects.

Selection Differentiating the implicit solution for the variable cost cut-off in (3.36), we can show that a sufficient condition for selection to get tougher with integration is $n > \frac{2\varphi}{\varphi-1}$ (see Appendix 3.8.7.1). For the cut-off to be decreasing in market size, quality cost hence has to be sufficiently convex or the firm size distribution sufficiently skewed. For the subsequent analysis, I will assume that this is the case. There are no analytical solutions for the comparative statics of the welfare indicators with respect to market size; however, it is still possible to comment on the direction of the different effects if not always the sign of their combined effect.

Quality and Prices Since firm quality choice is not at all affected by scale, there is no quality upgrading in a larger market. It follows directly from equation (3.45) that average quality in the market will increase purely due to the change in industry composition in favour of the higher quality firms: (i) there will be a positive contribution from the extensive margin as long as selection gets tougher. However, the same caveat as in the fixed cost case applies since selection still happens through a choke price and entry and exit therefore have a negligible welfare weight. (ii) On the intensive margin, we again

have the Matthew Effect discussed above, which means that the highest productivity firms (which also in the variable cost case are the highest quality firms by second order conditions) expand their sales disproportionately in a larger market (see Appendix 3.8.7.1). Considering both the results from the fixed and variable quality cost case, we can therefore conclude that the most robust of the three aggregate quality adjustment mechanisms is the intensive margin effect.

From equation (3.44), average prices are affected by two conflicting forces: (i) a firm-level competition effect, which exerts downward pressure on prices of all firms and (ii) the quality composition effect above, whereby the compositional shift in favour of the higher quality firms drives up the average industry price. The latter effect will be more important, the more slowly cost is rising in quality (i.e. the less convex the quality cost function) and the greater is consumers' valuation of quality.

Mass of Varieties As in the fixed cost case, product quality introduces a dampening effect on the mass of firms; the difference here is that this effect arises from an additional cut-off term. From equation (3.43), the cost cut-off affects N negatively like in the fixed cost case (the tougher is selection, the higher the mass of firms), but now also positively via Γ : the tougher the cut-off, the larger is Γ , which reduces the equilibrium mass of varieties. A change in market size which reduces the cut-off will therefore imply more variety if the former effect is stronger than the quality effect (see Appendix 3.8.7.1). Note that the dampening effect of c_D on N is decreasing in the convexity of the quality cost φ (as $\varphi \rightarrow \infty$, $\Gamma \rightarrow B$ and the conflicting effect of c_D disappears). This is intuitive: if high quality output incurs a high variable cost, low quality producers are protected from high quality competition and the market can therefore support more variety.

Discussion The predictions of the fixed and variable cost versions of the model are interesting in light of earlier findings by Berry and Waldfogel (2004). The authors consider the relationship between quality, market size and market structure in two case studies of

a fixed and variable quality cost industry respectively. They study local markets for US newspapers (fixed cost) and restaurants (variable cost) and find that as market size increases, the quality of newspapers at the upper end of the distribution is higher, while the number of newspapers increases only moderately. For restaurants on the other hand, there is a proliferation of variety and a “filling in” of the quality distribution, i.e. entry at every level of quality. Within the above model, such an outcome would be generated by a relatively strong convexity of the cost function in quality. This is intuitive for the restaurant industry: the cost of ingredients is increasing quite rapidly in their quality. Low quality restaurants are therefore protected to a certain extent by the relatively high prices good restaurants have to charge in order to cover cost. On the other hand, if high quality firms can take advantage of scale effects allowing them to compete at relatively low quality-adjusted prices, as in the case of the newspaper industry, life for low quality firms becomes tougher and the industry therefore remains relatively concentrated.

3.6 Quality and the Macroeconomic Gains from Trade

The chapter so far has focused on the microeconomic mechanisms for gains from trade implied by the model, which are markedly different from the no-quality benchmark. A recent contribution by Arkolakis, Costinot and Rodriguez-Clare (2012, ACR hereafter) has sparked a lively debate by arguing that despite different microeconomic mechanisms implied by a series of important recent trade models, the macroeconomic welfare gains are the same in theory. The authors consider gains from trade arising from partial trade liberalization, i.e. reductions in variable trade cost. They take the compensating variation associated with a change in variable trade cost as a measure of welfare and show that this expression is identical for a large class of models from Krugman (1980) to Melitz (2003). It depends only on two widely available/easily estimable measures: the elasticity of imports with respect to variable trade costs (the trade elasticity) and the import share. This section takes some first steps in linking the question of gains from trade in the presence

of product quality to the recent debate on the macro gains from trade.

A follow-up paper by Arkolakis, Costinot, Donaldson and Rodriguez-Clare (2012, ACDR hereafter) modifies ACR's result for a related class of models which are characterised by variable elasticity of demand preferences and Pareto distributed productivity as the model presented here. In what follows I show that the model in the present chapter fulfills ACDR's basic assumptions and is thus comparable to their class of models; nevertheless, quality is expected to manifest itself in different trade elasticities depending on the scope for quality upgrading in an industry, such that the size of welfare gains will be affected by the quality dimension.⁸

ACDR's class of models is characterised by four assumptions and a CES import demand restriction. One of the cases considered by ACDR corresponds to the baseline model in the present chapter: the authors assume (i) a preference structure which contains as a special case quadratic preferences with an outside good; the demand function (ii) has a choke price; and (iii) is log-concave, implying that mark-ups are rising in productivity; and (iv) productivity is distributed according to a Pareto distribution.

In order to show that ACDR's CES import demand restriction holds, I derive the gravity equation associated with the model. The open economy equilibrium for the model presented in this chapter is given in Appendix 3.8.8. From the equilibrium expression for export revenues, I can thus derive the gravity equation (the derivation is also given in the appendix). Aggregate bilateral export sales by firms based in l to country h in this set-up are given by:

$$X^{lh} = N_E^l \int_0^{c_X^l} r_X^{lh}(c) dG^l(c) \quad (3.46)$$

$$= \frac{\varepsilon_\lambda^{lh} (n + \varepsilon_\lambda^{lh})}{n + 1} \frac{1}{2b(1 - e)(n + 2)} N_E^l c_M^{-n} L^h (c_D^h)^{n+2} (\tau^{lh})^{-n}. \quad (3.47)$$

Equation (3.47) shows that the value of bilateral exports depends on the market size

⁸See Simonovska and Waugh (2013) on the role of trade elasticities in determining macroeconomic gains from trade.

of the trading partner, bilateral trade barriers and comparative advantage (Melitz and Ottaviano, 2008; Eaton and Kortum, 2002; and Helpman, Melitz and Rubinstein, 2008) - as well as the scope for quality upgrading as reflected in ε_λ^{lh} . A higher ε_λ^{lh} will have an ambiguous effect; on the one hand, it will lower the value of aggregate exports: export market access becomes tougher (lower c_D^h) as quality competition increases; on the other hand, it will increase the value of exports since exporters will export higher quality goods.

Assuming that countries have the same technology, θ , and the same preference for quality, β , we can write the import share of country h from firms in country l as:

$$\lambda_{lh} = \frac{X^{lh}}{\sum_k X^{kh}} = \frac{N_E^l (c_M^l)^{-n} (\tau^{lh})^{-n}}{\sum_k N_E^k (c_M^k)^{-n} (\tau^{kh})^{-n}}. \quad (3.48)$$

The expression in equation (3.48) is what Arkolakis, Costinot and Rodriguez-Clare (2012) call a strong CES import demand system. The fact that this macro-level restriction is fulfilled by the quality-augmented model in addition to the other four assumptions means that the model is comparable to ACDR (2012).

An interesting avenue for future research will be to derive the exact welfare expression for the quality-augmented model and compute the effect of quality on overall welfare gains. The latter can be done by first estimating the trade elasticity using a gravity equation and combining this with the calculated import share (Head and Mayer, 2014). One way in which the quality dimension is expected to manifest itself is in differing trade elasticities which depend on the scope for quality upgrading in an industry.

3.7 Conclusion

The recent literature has presented rich evidence on the importance of product quality in international trade. This chapter provides novel insights on the relationship between product quality, market size and welfare. The analysis is conducted using the structure of a heterogeneous firms trade model with competition effects. I show theoretically that

product quality has important repercussions on traditional mechanisms for gains from trade. In the quality-augmented model, the idea of the level of “competitive toughness” in a market is ambiguous, and the cost cut-off is hence no longer an informative summary statistic for industry aggregates.

As an alternative indicator for welfare, I derive the indirect utility function and use its structure to guide the analysis of market size effects. I show that an increase in market size can have conflicting effects on the two principal welfare channels in the model: while the quality-adjusted price index falls, variety may also be reduced if consumers place a high weight on product quality. Nevertheless, overall gains from trade are positive in all cases. Changes in industry aggregates can come about through changes on the intensive and extensive margin, as well as a quality-upgrading mechanism by which the most productive firms invest in more quality as market size increases.

I compare the case of fixed quality costs with that of variable quality costs and show that the quality upgrading channel no longer operates when quality only incurs variable costs. I argue that the intensive margin adjustment is the most robust welfare mechanism in the model. I provide empirical evidence on its importance in Chapter 4 of this thesis. The underlying mechanism to this result is a complementarity which allows higher quality firms to benefit disproportionately more from increases in market size.

Finally, I take first steps in linking the analysis of gains from trade in a quality context to the current debate regarding the macroeconomic gains from trade. I derive the gravity equation associated with the model and use it to show that the model is comparable to a class of models for which Arkolakis, Costinot, Donaldson and Rodriguez-Clare (2012) derive a general welfare expression; the two key ingredients in this expression are the consumption share of domestically produced goods and the trade elasticity. An interesting avenue for future research will be to check that ACDR’s (2012) welfare expression holds for the quality-augmented model and to estimate trade elasticities for industries characterised by different scopes for quality upgrading. These could then be used to estimate the effect of quality on the macroeconomic gains from trade liberalization (cf Head and Mayer, 2014).

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3.8 Appendix

3.8.1 Fixed Cost of Quality: Closed Economy

Deriving Inverse Demand:

$$\begin{aligned}
 \max_{q_i} U &= q_0 + \alpha Q - \frac{1}{2}b \left[(1-e) \int_{i \in \tilde{\Omega}} q_i^2 di + eQ^2 \right] + \beta b (1-e) \int_{i \in \tilde{\Omega}} q_i z_i di \\
 \text{s.t. } I &= q_0 + \int_{i \in \tilde{\Omega}} p_i q_i di \quad \text{where } Q \equiv \int_{i \in \Omega} q_i di \\
 \frac{dU}{dq_i} &= -p_i + \alpha - b [(1-e) q_i + eQ] + \beta b (1-e) z_i = 0
 \end{aligned}$$

Given market clearing $x_i = Lq_i$, we can write:

$$p_i = \alpha + \beta b (1-e) z_i - \tilde{b} [(1-e) x_i + eX]$$

where $X \equiv \int_{i \in \Omega} x_i di$ and $\tilde{b} = \frac{b}{L}$.

Demand: Solving inverse demand for x_i :

$$\begin{aligned}
p_i &= \alpha + \beta b(1-e)z_i - \tilde{b}[(1-e)x_i + eX] \\
&= \alpha + \beta b(1-e)z_i - \tilde{b}[(1-e) + eN]x_i \\
x_i &= \frac{\alpha}{\tilde{\epsilon b}} + \frac{\beta b(1-e)}{\tilde{\epsilon b}}z_i - \frac{p_i}{\tilde{\epsilon b}} \quad \text{where } \epsilon = 1 - e + eN \\
&= \frac{\alpha}{\tilde{\epsilon b}} + \frac{\beta b(1-e)}{\epsilon b}Lz_i - \frac{p_i}{\tilde{\epsilon b}} \\
&= \frac{\alpha}{\tilde{\epsilon b}} - \frac{p_i}{\tilde{b}(1-e)} \frac{\tilde{b}(1-e)}{\tilde{\epsilon b}} + \left[1 - \left(\frac{beN}{\epsilon b}\right)\right] \beta Lz_i \\
&= \frac{\alpha}{\tilde{\epsilon b}} - \frac{p_i}{\tilde{b}(1-e)} \left[1 - \frac{\tilde{b}eN}{\tilde{\epsilon b}}\right] + \beta Lz_i - \left(\frac{beN}{\tilde{\epsilon b}}\right) \frac{\beta}{N} \int z_i di \\
&= \frac{\alpha}{\tilde{\epsilon b}} - \frac{p_i}{\tilde{b}(1-e)} + \frac{beN}{\tilde{\epsilon b b}(1-e)} \frac{1}{N} \int p_i di + \beta Lz_i - \left(\frac{beN}{\tilde{\epsilon b}}\right) \beta \bar{z} \\
x_i &= \frac{\alpha}{\tilde{\epsilon b}} - \frac{1}{\tilde{b}(1-e)} p_i + \frac{eN}{\tilde{\epsilon b}(1-e)} \bar{p} + \beta Lz_i - \frac{\beta beN}{\tilde{b}\epsilon} \bar{z} \tag{3.49}
\end{aligned}$$

Choke Price p^{\max} : The choke price p^{\max} happens occurs where $x_i = 0$. From equation (3.49) we therefore have:

$$\begin{aligned}
p_i &\leq \tilde{b}(1-e) \left[\frac{\alpha}{\tilde{\epsilon b}} + \frac{eN}{\tilde{\epsilon b}(1-e)} \bar{p} + \beta Lz_i - \frac{\beta beN}{\tilde{\epsilon b}} \bar{z} \right] \\
&= \frac{\alpha \tilde{b}(1-e)}{\tilde{\epsilon b}} + \frac{\tilde{b}(1-e)eN}{\tilde{\epsilon b}(1-e)} \bar{p} + \beta \tilde{b}(1-e) Lz_i - \tilde{b}(1-e) \frac{\beta beN}{\tilde{\epsilon b}} \bar{z} \\
&= \frac{\alpha(1-e)}{\epsilon} + \frac{eN}{\epsilon} \bar{p} + \beta b(1-e)z_i - \frac{\beta b(1-e)eN}{\epsilon} \bar{z} \\
&\equiv p^{\max}.
\end{aligned}$$

Output FOC: Profits are given by

$$\begin{aligned}
\pi_i &= (p_i - c_i)x_i - \frac{1}{2}\theta z_i^2 \\
&= \left(\alpha + \beta b(1-e)z_i - \tilde{b}[(1-e)x_i + eX] - c_i \right) x_i - \frac{1}{2}\theta z_i^2.
\end{aligned}$$

Maximising profits with respect to output:

$$\begin{aligned}\frac{\partial \pi_i}{\partial x_i} &= (p_i - c_i) + x_i \left(-\tilde{b}(1-e) \right) = 0 \\ p_i &= \tilde{b}(1-e)x_i + c_i.\end{aligned}\tag{3.50}$$

Quality FOC: Similarly for FOC with respect to quality:

$$\begin{aligned}\pi_i &= \left(\alpha + \beta b(1-e)z_i - \tilde{b}[(1-e)x_i + eX] - c_i \right) x_i - \frac{1}{2}\theta z_i^2 \\ \frac{\partial \pi_i}{\partial z_i} &= \beta b(1-e)x_i - \theta z_i = 0 \\ z_i &= \frac{\beta b(1-e)x_i}{\theta}.\end{aligned}$$

Second Order Conditions:

$$H = \begin{vmatrix} -2\tilde{b}(1-e) & \beta b(1-e) \\ \beta b(1-e) & -\theta \end{vmatrix}.$$

The Matrix $H = \begin{vmatrix} a & b \\ c & d \end{vmatrix}$ is negative definite and the solution is a local maximum iff $a < 0$ and $\det|H| > 0$. Here, $-2\tilde{b}(1-e) < 0$; and $\det|H| > 0$ if $2\theta > \beta^2 b(1-e)L$.

Optimal Price in terms of the Cut-off and Quality: Substituting demand x_i from (3.49) into (3.50):

$$\begin{aligned}p_i &= \tilde{b}(1-e) \left[\frac{\alpha}{\epsilon \tilde{b}} - \frac{1}{\tilde{b}(1-e)} p_i + \frac{eN}{\epsilon \tilde{b}(1-e)} \bar{p} + \beta L z_i - \frac{\beta b e N}{\tilde{b} \epsilon} \bar{z} \right] + c_i \\ &= \frac{\alpha(1-e)}{\epsilon} - p_i + \frac{eN}{\epsilon} \bar{p} + \beta b(1-e) z_i - \frac{\beta b(1-e)eN}{\epsilon \tilde{b}} \bar{z} + c_i \\ 2p_i &= c_D + c_i + \beta b(1-e) z_i \\ p_i(c_D, c_i, z_i) &= \frac{1}{2}(c_D + c_i) + \frac{\beta b(1-e)}{2} z_i\end{aligned}$$

From the last equation and the FOC for output, we can write:

$$\begin{aligned}
x_i(c_D, c_i, z_i) &= \frac{L}{2b(1-e)}(c_D - c_i) + \frac{\beta L}{2}z_i \\
\mu_i(c_D, c_i, z_i) &= p_i - c = \frac{1}{2}(c_D - c_i) + \frac{\beta b(1-e)}{2}z_i \\
r_i(c_D, c_i, z_i) &= \frac{L}{4b(1-e)}(c_D^2 - c_i^2) + \frac{\beta L}{2}z_i c_D + \frac{\beta^2 b(1-e)L}{4}z_i^2 \\
\pi_i(c_D, c_i, z_i) &= r_i - x_i c_i - \frac{1}{2}\theta z_i^2 \\
&= \frac{L}{4b(1-e)}(c_D - c_i)^2 + \frac{\beta L}{2}(c_D - c_i)z_i + \frac{\beta^2 b(1-e)L - 2\theta}{4}z_i^2
\end{aligned}$$

Maximising profits with respect to z_i gives $z_i^* = \lambda(c_D - c_i)$ where $\lambda = \frac{\beta L}{2\theta - \beta^2 b(1-e)L}$.

Profits in terms of the Cut-off only: Using

$$\pi_i(c_D, c_i, z_i) = \frac{L}{4b(1-e)}(c_D - c_i)^2 + \frac{\beta L}{2}(c_D - c_i)z_i + \frac{\beta^2 b(1-e)L - 2\theta}{4}z_i^2$$

and substituting $z^* = \lambda(c_D - c)$, we get:

$$\begin{aligned}
\pi(c_D, c) &= \frac{L}{4b(1-e)}(c_D - c)^2 + \frac{2\lambda\beta b(1-e)L}{4b(1-e)}(c_D - c)^2 + \frac{\lambda^2\beta^2 b^2(1-e)^2 L}{4b(1-e)}(c_D - c)^2 \\
&\quad - \frac{2\theta\lambda^2 b(1-e)}{4b(1-e)}(c_D - c)^2 \\
&= \frac{L}{4b(1-e)}(c_D - c)^2 \left[1 + 2\lambda\beta b(1-e) + \lambda^2\beta^2 b^2(1-e)^2 - \frac{2\theta\lambda^2 b(1-e)}{L} \right] \\
&= \frac{L}{4b(1-e)} [1 + \lambda\beta b(1-e)] (c_D - c)^2
\end{aligned}$$

Deriving the Cost Cut-off c_D : The free entry condition is:

$$f = E\pi = \int_0^{c_D} \frac{L}{4b(1-e)} (1 + \lambda\beta b(1-e)) (c_D - c)^2 dG(c)$$

Firms draw their cost from a Pareto distribution:

$$\begin{aligned}
G(c) &= \left(\frac{c}{c_M}\right)^n, \quad c \in [0, c_M] \\
\frac{dG(c)}{dc} &= G'(c) \\
dG(c) &= G'(c)dc = n\frac{1}{c_M} \left(\frac{c}{c_M}\right)^{n-1} dc.
\end{aligned}$$

Substituting, integrating and solving for c_D gives:

$$\begin{aligned}
f &= \frac{L}{4b(1-e)}(1 + \lambda\beta b(1-e)) \int_0^{c_D} (c_D - c)^2 n \frac{1}{c_M} \left(\frac{c}{c_M}\right)^{n-1} dc \\
&= \frac{Lnc_M^{-n}}{4b(1-e)}(1 + \lambda\beta b(1-e)) \int_0^{c_D} (c_D - c)^2 c^{n-1} dc \\
&= \frac{Lnc_M^{-n}}{4b(1-e)}(1 + \lambda\beta b(1-e)) \left[c_D^2 \int_0^{c_D} \left(c^{n-1} dc - 2c_D \int_0^{c_D} c^n dc + \int_0^{c_D} c^{n+1} dc \right) \right] \\
&= \frac{Lc_M^{-n}}{4b(1-e)}(1 + \lambda\beta b(1-e)) c_D^{n+2} \left[\left(\frac{(n+1)(n+2)}{(n+1)(n+2)} - \frac{2n(n+2)}{(n+1)(n+2)} + \frac{n(n+1)}{(n+1)(n+2)} \right) \right] \\
f &= \frac{L(1 + \lambda\beta b(1-e))}{2b(1-e)} \frac{1}{(n+1)(n+2)c_M^n} c_D^{n+2} \\
c_D^{n+2} &= \frac{b(1-e)}{L(1 + \lambda\beta b(1-e))} 2(n+1)(n+2) f c_M^n \\
c_D &= \left[\frac{\phi b(1-e)}{(1 + \lambda B)L} \right]^{\frac{1}{n+2}},
\end{aligned}$$

where $\phi = 2(n+1)(n+2) f c_M^n$ and $B = \beta b(1-e)$.

Mass of Firms N : The equilibrium mass of firms can be derived from the expression for the cost cut-off:

$$c_D = \frac{1}{\epsilon} [\alpha(1-e) + eN\bar{p} - BeN\bar{z}]$$

Average price is given by:

$$\bar{p} = \frac{1 + \lambda B}{2} (c_D - \bar{c}) + \bar{c}.$$

Given that $\bar{c} = \frac{nc_D}{n+1}$, we can write:

$$\bar{p} = \frac{2n+1+\lambda B}{2(n+1)}c_D.$$

Analogously for average quality:

$$\begin{aligned}\bar{z} &= \lambda(c_D - \bar{c}) \\ &= \frac{\lambda c_D}{n+1}.\end{aligned}$$

Rewriting c_D and substituting for \bar{p} , \bar{z} and ϵ , we can derive the mass of firms N :

$$\begin{aligned}c_D &= \frac{1}{1-e+eN} \left\{ \alpha(1-e) + eN \frac{2n+1+\lambda B}{2(n+1)}c_D - BeN \frac{\lambda c_D}{n+1} \right\} \\ (1-e)c_D + eNc_D &= \alpha(1-e) + \frac{2n+1+\lambda B}{2(n+1)}eNc_D - \frac{\lambda B}{n+1}eNc_D \\ eNc_D - \frac{2n+1+\lambda B}{2(n+1)}eNc_D + \frac{\lambda B}{n+1}eNc_D &= \alpha(1-e) - (1-e)c_D \\ \left[\frac{1+\lambda B}{2(n+1)}eNc_D \right] N &= (1-e)(\alpha - c_D) \\ N &= \frac{2(n+1)(1-e)(\alpha - c_D)}{e(1+\lambda B)c_D}.\end{aligned}$$

3.8.2 Introducing Vertical Differentiation

Here I introduce a preference specification which distinguishes between vertical and horizontal differentiation (cf also Gabszewicz and Thisse, 1979; di Comite, Thisse and Vandebussche, 2011). Vertical differentiation implies a common ranking of varieties by consumers, as reflected in their willingness to pay. The overall structure of the utility function is the same as in equation (3.1), however, here I introduce a new parameter v in u_2 which represents the degree of vertical differentiation. Like e , $0 < v < 1$ with vertical differentiation disappearing as $v \rightarrow 1$.

The utility function is now given by:

$$U = q_0 + u_1 + \beta u_2, \tag{3.51}$$

where

$$u_1 = \alpha Q - \frac{1}{2}b \left[(1-e) \int_{i \in \tilde{\Omega}} q_i^2 di + eQ^2 \right] \quad (3.52)$$

$$u_2 = b(1-v) \int_{i \in \tilde{\Omega}} q_i z_i di. \quad (3.53)$$

All variables and parameters are defined as before. I think of β (the strength of consumers' preference for quality) as country-specific and v as industry-specific. Demand is still:

$$p_i = a_i - \tilde{b}[(1-e)x_i + eX], \quad (3.54)$$

but the intercept is now given by $a_i = \alpha + \beta b(1-v)z_i$. The size of the demand shift induced by a change in quality is amplified by higher consumer quality preference, β , and the degree of vertical differentiation, $(1-v)$. From equation (3.54), we can write direct demand for variety i as:

$$x_i = \frac{\alpha}{\tilde{e}b} - \frac{1}{\tilde{b}(1-e)}p_i + \frac{eN}{\tilde{e}b(1-e)}\bar{p} + \frac{(1-v)}{(1-e)}\beta L z_i - \frac{(1-v)}{(1-e)}\frac{\beta b e N}{\tilde{e}b}\bar{z}. \quad (3.55)$$

From equation (3.55), firms face positive demand as long as

$$p_i < p^{\max} \equiv \frac{\alpha(1-e)}{\epsilon} + \frac{eN}{\epsilon}\bar{p} + \beta b(1-v)z_i - \frac{\beta b(1-v)eN}{\epsilon}\bar{z}. \quad (3.56)$$

The total cost function remains $TC_i = c_i x_i + \frac{1}{2}\theta z_i^2$. A firm's profit maximising price and output must satisfy:

$$p_i = \tilde{b}(1-e)x_i + c_i, \quad (3.57)$$

and, its profit maximising level of quality is given by the first-order condition:

$$z_i = \frac{\beta b(1-v)x_i}{\theta}. \quad (3.58)$$

Here, I restrict $\frac{\beta^2 b(1-v)L}{2\theta(\frac{1-e}{1-v})} < 1$ in order to ensure an interior solution. The cut-off is now given by:

$$c_D = \frac{1}{\epsilon} [\alpha(1-e) + eN\bar{p} - \beta b(1-v)eN\bar{z}]. \quad (3.59)$$

Maximising profits with respect to z_i , the optimal level of quality z_i^* is:

$$z_i^* = \lambda (c_D - c_i) \quad (3.60)$$

where $\lambda = \frac{\beta L}{2\theta(\frac{1-e}{1-v}) - \beta^2 b(1-v)L}$. Note the difference in the expression for λ : the slope is now affected in opposite directions by the degree of vertical and horizontal differentiation. It steepens as vertical differentiation becomes more important and flattens out as varieties become more horizontally differentiated. This is intuitive: with a high degree of vertical differentiation, the return to quality investment in terms of increasing consumers' willingness to pay is high. Firms invest heavily in quality and quality competition therefore toughens. With a high degree of horizontal differentiation, on the other hand, firms are more protected from their competitors and therefore have less incentive to invest in quality. λ can still be interpreted as a market-level indicator of the degree of quality competition. The other variables of interest - output, absolute mark-ups and profits - are now given by:

$$x(c_D, c) = \frac{[1 + \lambda\beta b(1-v)]L}{2b(1-e)} (c_D - c) \quad (3.61)$$

$$\mu(c_D, c) = p - c = \frac{1 + \lambda\beta b(1-v)}{2} (c_D - c) \quad (3.62)$$

$$\pi(c_D, c) = \frac{L}{4b(1-e)} [1 + \lambda\beta b(1-v)] (c_D - c)^2 \quad (3.63)$$

Parametrizing, integrating and solving the free-entry condition for c_D gives:

$$c_D = \left[\frac{\phi b(1-e)}{(1 + \lambda V)L} \right]^{\frac{1}{n+2}}, \quad (3.64)$$

where $V \equiv \beta b(1-v)$. Note that the distinction between vertical and horizontal differentiation is useful also for interpreting the effect of quality on the cut-off: while selection gets laxer as varieties become more horizontally differentiated, the degree of vertical differentiation has the opposite effect by encouraging more quality investment. This higher level of quality investment by the more productive firms makes it difficult for low productivity firms to survive, which is reflected in a tougher cut-off.

The mass of active firms in the differentiated sector is given by:

$$N = \frac{2(n+1)(1-e)(\alpha - c_D)}{e(1+\lambda V) c_D}. \quad (3.65)$$

Again, it is the degree of vertical differentiation which exercises a direct dampening effect on the mass of varieties, thereby giving the model a flavour of Shaked and Sutton's (1983) non-fragmentation result (while vertical differentiation has a positive effect on variety via a tougher cut-off). The elasticity of λ with respect to market size is now given by:

$$\varepsilon_\lambda \equiv \frac{\partial \lambda}{\partial L} \frac{L}{\lambda} = \frac{2\theta \left(\frac{1-e}{1-v} \right)}{2\theta \left(\frac{1-e}{1-v} \right) - \beta VL} = 1 + \lambda V. \quad (3.66)$$

Using this definition, all variables of interest can again be written in terms of ε_λ and $(c_D - c)$, a firm's relative efficiency:

$$p(c_D, c) = \mu(c_D, c) + c = \frac{\varepsilon_\lambda}{2} (c_D - c) + c, \quad (3.67)$$

$$x(c_D, c) = \frac{\varepsilon_\lambda L}{2b(1-e)} (c_D - c), \quad (3.68)$$

$$z(c_D, c) = \lambda (c_D - c) \quad (3.69)$$

$$\pi(c_D, c) = \frac{\varepsilon_\lambda L}{4b(1-e)} (c_D - c)^2, \quad (3.70)$$

$$N(c_D, c) = \frac{1}{\varepsilon_\lambda} \frac{2(n+1)(1-e)(\alpha - c_D)}{e c_D}. \quad (3.71)$$

These results look identical to the results obtained under the assumption of only one differentiation parameter. However, note that the expressions for ε_λ and c_D are now different.

3.8.3 Preferences Nesting both Antoniadis (2008) and this Chapter

A general preference specification which nests both Antoniadis (2008) and the model presented in this chapter is the following:

$$U = q_0 + \alpha Q + \alpha \xi Z - \frac{1}{2}b(1-e) \int q_i^2 di - \frac{1}{2}\xi b(1-e) \int z_i^2 di - \frac{1}{2}be \left\{ \int \left(q_i - \frac{1}{2}\xi z_i \right) di \right\}^2 + \beta b(1-e) \int q_i z_i di.$$

Letting

$$\begin{aligned} \xi &= 1; \\ \beta &= 1; \\ b(1-e) &\hat{=} \gamma; \text{ and} \\ be &\hat{=} \eta, \end{aligned}$$

the preference specification reduces to Antoniadis (2008):

$$\begin{aligned} U &= q_0 + \alpha \int q_i di + \alpha \int z_i di - \frac{1}{2}\gamma \int q_i^2 di - \frac{1}{2}\gamma \int z_i^2 di + \gamma \int q_i z_i di - \frac{1}{2}\eta \left\{ \int \left(q_i - \frac{1}{2}z_i \right) di \right\}^2 \\ &= q_0 + \alpha Q + \alpha Z - \frac{1}{2}\gamma \int q_i^2 di - \frac{1}{2}\gamma \int z_i^2 di + \gamma \int q_i z_i di - \frac{1}{2}\eta \left\{ Q^2 - QZ + \frac{1}{4}Z^2 \right\}^2 \end{aligned}$$

Letting

$$\begin{aligned} \xi &= 0; \text{ and} \\ 0 &< \beta < \left(\frac{2\theta}{Lb(1-e)} \right)^{\frac{1}{2}} \end{aligned}$$

we revert to the utility function assumed in equation (3.1) of this chapter:

$$U = q_0 + \alpha Q - \frac{1}{2}b(1-e) \int q_i^2 di - \frac{1}{2}beQ^2 + \beta b(1-e) \int q_i z_i di$$

Similarly, the general demand specification is:

$$p_i = \alpha + \beta b(1 - e) z_i - b(1 - e) q_i - be \int \left(q_i - \frac{1}{2} \xi z_i \right) di.$$

For the special cases we have, for Antoniadis (2008):

$$p_i = \alpha + b(1 - e) z_i - b(1 - e) q_i - be \int \left(q_i - \frac{1}{2} z_i \right) di$$

and for this chapter:

$$p_i = \alpha + \beta b(1 - e) z_i - b(1 - e) q_i - be \int q_i di.$$

The expression for direct demand derived from the general indirect demand expression above is:

$$x_i = \frac{\alpha}{\tilde{b}\epsilon} - \frac{1}{\tilde{b}(1 - e)} p_i + \frac{eN}{\tilde{b}(1 - e)} \bar{p} + \beta L z_i - (2\beta - \xi) \frac{beN}{2\tilde{b}\epsilon} \bar{z}.$$

Derivation of a general expression for N:

$$c_D = \frac{1}{1 - e + eN} \left[\alpha(1 - e) + eN \frac{2n + 1 + \lambda B}{2(n + 1)} c_D - (2\beta - \xi) b(1 - e) eN \frac{\lambda}{2(n + 1)} c_D \right]$$

$$N = \frac{2(n + 1)(1 - e)(\alpha - c_D)}{(1 - \lambda B + (2\beta - \xi) \lambda b(1 - e)) e c_D}.$$

This reduces to

$$N = \frac{2(n + 1)(1 - e)(\alpha - c_D)}{e c_D}$$

in Antoniadis (2008); and to

$$N = \frac{2(n + 1)(1 - e)(\alpha - c_D)}{\epsilon \lambda e c_D}$$

in this chapter.

3.8.4 Divergence of Competition Measures

Average Quality and Product Differentiation:

$$\begin{aligned}
 \bar{z} &= \frac{\lambda c_D}{n+1} \\
 \frac{\partial \bar{z}}{\partial e} &= \frac{1}{n+1} \left(\lambda \frac{\partial c_D}{\partial e} + c_D \frac{\partial \lambda}{\partial e} \right) \\
 &= \frac{1}{n+1} \left[\lambda \frac{\beta b (1-e) \lambda - 1}{(n+2)(1-e)} c_D - c_D \beta b \lambda^2 \right] \\
 &= \frac{\lambda c_D}{n+1} \left[\frac{\beta b (1-e) \lambda - 1}{(n+2)(1-e)} - \beta b \lambda \right] \\
 &= -\frac{\lambda c_D}{n+1} \left[\frac{1 + B\lambda(n+1)}{(n+2)(1-e)} \right] \\
 &< 0
 \end{aligned}$$

Lemma 14:

$$\begin{aligned}
 \lambda &= \frac{\beta L}{2\theta - \beta^2 b (1-e) L} = \beta L (2\theta - \beta^2 b (1-e) L)^{-1} \\
 \frac{\partial \lambda}{\partial e} &= -\beta L (2\theta - \beta^2 b (1-e) L)^{-2} (\beta^2 b L) \\
 &= -\beta b \left(\frac{\beta L}{2\theta - \beta^2 b (1-e) L} \right)^2 \\
 &= -\beta b \lambda^2
 \end{aligned}$$

Hence,

$$\begin{aligned}
 c_D &= \left[\frac{\phi b (1-e) 1}{L \varepsilon_\lambda} \right]^{\frac{1}{n+2}} \\
 \frac{\partial c_D}{\partial e} &= \frac{1}{n+2} \left[\frac{\phi b (1-e)}{(1+B\lambda)L} \right]^{\frac{1}{n+2}-1} \left[\frac{-(1+B\lambda)L\phi b - \phi b (1-e)L [-\beta b \lambda - \lambda^2 \beta b B]}{((1+B\lambda)L)^2} \right] \\
 &= \frac{c_D}{n+2} \left[\frac{\lambda^2 B^2 - 1}{(1-e)(1+B\lambda)} \right] \\
 &= \frac{B\lambda - 1}{(n+2)(1-e)} c_D \\
 &= 0 \text{ if } e = 1 - \frac{\theta}{\beta^2 b L} \\
 &> 0 \text{ if } e < 1 - \frac{\theta}{\beta^2 b L}
 \end{aligned}$$

Lemma 15:

$$\begin{aligned}
\mu &= \frac{1 + \lambda B}{2} (c_D - c) \\
\bar{\mu} &= \frac{1 + \lambda B}{2} (c_D - \bar{c}) \\
&= \frac{1 + \lambda B}{2} \left(\frac{(n+1)c_D}{n+1} - \frac{nc_D}{n+1} \right) \\
&= \frac{\varepsilon_\lambda}{2(n+1)} c_D
\end{aligned}$$

$$\begin{aligned}
\frac{\partial \bar{\mu}}{\partial e} &= \frac{\varepsilon_\lambda}{2(n+1)} \frac{\partial c_D}{\partial e} + \frac{1}{2(n+1)} c_D \frac{\partial \varepsilon_\lambda}{\partial e} \\
&= \frac{\varepsilon_\lambda}{2(n+1)} \frac{B\lambda - 1}{(n+2)(1-e)} c_D + \frac{1}{2(n+1)} c_D (-\beta b \lambda - B\lambda^2 \beta b) \\
&= \frac{1}{2(n+1)} c_D \left[\frac{B\lambda + B^2\lambda^2 - 1 - B\lambda + (-B\lambda - B^2\lambda^2)(n+2)}{(n+2)(1-e)} \right] \\
&= -\frac{\varepsilon_\lambda}{2(n+1)} c_D \left[\frac{B\lambda n + 1 + B\lambda}{(n+2)(1-e)} \right] \\
&= -\frac{\varepsilon_\lambda [1 + B\lambda(n+1)]}{2(n+1)(n+2)(1-e)} c_D \\
&< 0
\end{aligned}$$

Cut-off and Market Size:

$$\begin{aligned}
c_D &= \left[\frac{\phi b(1-e)}{L} \frac{1}{\varepsilon_\lambda} \right]^{\frac{1}{n+2}} \\
\frac{\partial c_D}{\partial L} &= \frac{1}{n+2} \left[\frac{\phi b(1-e)}{\varepsilon_\lambda L} \right]^{\frac{1}{n+2}-1} \frac{\varepsilon_\lambda L * 0 - \phi b(1-e) \left[\varepsilon_\lambda + L \frac{\partial \varepsilon_\lambda}{\partial L} \right]}{\varepsilon_\lambda^2 L^2} \\
&= -\frac{c_D}{n+2} \frac{\varepsilon_\lambda + L \frac{\partial \varepsilon_\lambda}{\partial L}}{\varepsilon_\lambda L} \\
\frac{\partial \varepsilon_\lambda}{\partial L} &= B \frac{\partial \lambda}{\partial L} \\
\frac{\partial \lambda}{\partial L} &= \frac{(2\theta - \beta^2 b(1-e)L) \beta + \beta L \beta^2 b(1-e)}{(2\theta - \beta^2 b(1-e)L)^2} \\
&= \frac{2\theta\beta}{(2\theta - \beta BL)^2} \\
\therefore \frac{\partial \varepsilon_\lambda}{\partial L} &= \frac{2\theta\beta B}{(2\theta - \beta BL)^2} \\
\therefore \frac{\partial c_D}{\partial L} &= -\frac{c_D}{n+2} \frac{\varepsilon_\lambda + \frac{2\theta\beta BL}{(2\theta - \beta BL)^2}}{\varepsilon_\lambda L} \\
&= -\frac{\varepsilon_\lambda c_D}{(n+2)L} \\
&< 0.
\end{aligned}$$

Mark-ups and Market Size:

$$\begin{aligned}
\bar{\mu} &= \frac{\varepsilon_\lambda}{2(n+1)} c_D \\
\frac{\partial \bar{\mu}}{\partial L} &= \frac{1}{2(n+1)} \left[\varepsilon_\lambda \frac{\partial c_D}{\partial L} + c_D \frac{\partial \varepsilon_\lambda}{\partial L} \right] \\
&= \frac{\varepsilon_\lambda c_D}{2(n+1)} \left[-\frac{\varepsilon_\lambda}{(n+2)L} + \frac{\beta B}{2\theta - \beta BL} \right] \\
&= \frac{\varepsilon_\lambda c_D}{2(n+1)} \left[\frac{\lambda B(n+1) - 1}{(n+2)L} \right] \\
&> 0 \text{ if } \lambda B(n+1) > 1 \text{ or} \\
\beta &> \left[\frac{1}{n+2} \frac{2\theta}{Lb(1-e)} \right]^{\frac{1}{2}}
\end{aligned}$$

3.8.5 Welfare Derivation

Utility in the model is given by

$$U = q_0 + u_1 + \beta u_2,$$

where

$$\begin{aligned} u_1 &= \alpha Q - \frac{1}{2}b \left[(1-e) \int_{i \in \tilde{\Omega}} q_i^2 di + eQ^2 \right] \\ u_2 &= b(1-e) \int_{i \in \tilde{\Omega}} q_i z_i di \end{aligned}$$

Using

$$Q \equiv \int_{i \in \tilde{\Omega}} q_i di$$

we can write

$$U = q_0 + \alpha \int q_i di - \frac{1}{2}b \left[(1-e) \int q_i^2 di + e \left(\int q_i di \right)^2 \right] + \beta b(1-e) \int q_i z_i di. \quad (3.72)$$

Demand is given by:

$$\begin{aligned} q_i &= \frac{x_i}{L} \text{ where} \\ x_i &= \frac{\alpha L}{\epsilon b} - \frac{L}{b(1-e)} p_i + \frac{eNL}{\epsilon b(1-e)} \bar{p} + \beta L z_i - \frac{\beta b e N L}{\epsilon b} \bar{z} \\ \therefore q_i &= \frac{\alpha}{\epsilon b} - \frac{1}{b(1-e)} p_i + \frac{eN}{\epsilon b(1-e)} \bar{p} + \beta z_i - \frac{\beta b e N}{\epsilon b} \bar{z} \end{aligned} \quad (3.73)$$

I use (3.72) and (3.73) to derive the indirect utility function element by element:

$$U = q_0 + \alpha \int q_i di - \frac{1}{2}b \left[(1-e) \int q_i^2 di + e \left(\int q_i di \right)^2 \right] + \beta b (1-e) \int q_i z_i di$$

$$\begin{aligned} \alpha \int q_i di &= \alpha \int \left(\frac{\alpha}{\epsilon b} - \frac{1}{b(1-e)} p_i + \frac{eN}{\epsilon b(1-e)} \bar{p} + \beta z_i - \frac{beN}{\epsilon b} \beta \bar{z} \right) di \\ &= \frac{\alpha^2 N}{\epsilon b} - \frac{\alpha N}{b(1-e)} \bar{p} + \frac{\alpha e N^2}{\epsilon b(1-e)} \bar{p} + \alpha \beta N \bar{z} - \frac{\alpha be N^2}{\epsilon b} \beta \bar{z} \\ &= \frac{\alpha^2 N}{\epsilon b} + \frac{(eN - \epsilon) \alpha N}{\epsilon b(1-e)} \bar{p} + \frac{\alpha b(1-e) N}{\epsilon b} \beta \bar{z} \\ &= \frac{\alpha^2 N}{\epsilon b} - \frac{\alpha N}{\epsilon b} \bar{p} + \frac{\alpha b(1-e) N}{\epsilon b} \beta \bar{z} \end{aligned}$$

$$\begin{aligned}
\frac{1}{2}b(1-e) \int q_i^2 di &= \frac{1}{2}b(1-e) \int \left(\frac{\alpha}{eb} - \frac{1}{b(1-e)}p_i + \frac{eN}{eb(1-e)}\bar{p} + \beta z_i - \frac{beN}{eb}\beta\bar{z} \right)^2 di \\
&= \frac{1}{2}b(1-e) \int \left(\frac{\alpha^2}{\epsilon^2 b^2} + \frac{1}{b^2(1-e)^2}p_i^2 + \frac{e^2 N^2}{\epsilon^2 b^2(1-e)^2}\bar{p}^2 + \beta^2 z_i^2 + \frac{(beN)^2}{\epsilon^2 b^2}\beta^2\bar{z}^2 - \frac{2\alpha}{eb^2(1-e)}p_i + \frac{2\alpha eN}{\epsilon^2 b^2(1-e)}\bar{p} + \frac{2\alpha}{eb}\beta z_i - \frac{2\alpha beN}{\epsilon^2 b^2}\beta\bar{z} - \frac{2eN}{eb^2(1-e)^2}p_i\bar{p} \right. \\
&\quad \left. - \frac{2\beta}{b(1-e)}p_i z_i + \frac{2\beta beN}{eb^2(1-e)}p_i\bar{z} + \frac{2\beta eN}{eb(1-e)}\bar{p}z_i - \frac{2\beta be^2 N^2}{\epsilon^2 b^2(1-e)}\bar{p}\bar{z} - \frac{2\beta^2 beN}{eb}\bar{z}z_i \right) di \\
&= \frac{1}{2}b(1-e) \left(\frac{\alpha^2 N}{\epsilon^2 b^2} + \frac{1}{b^2(1-e)^2} \int \left(p_i^2 + \frac{e^2 N^2}{\epsilon^2}\bar{p}^2 - \frac{2eN}{\epsilon}\bar{p}^2 \right) di + \beta^2 \int z_i^2 di + \frac{(beN)^2 N}{\epsilon^2 b^2}\beta^2\bar{z}^2 - \frac{2\alpha N}{eb^2(1-e)}\bar{p} + \frac{2\alpha eN^2}{\epsilon^2 b^2(1-e)}\bar{p} + \frac{2\alpha eN}{\epsilon^2 b}\beta\bar{z} - \frac{2\alpha eN^2}{\epsilon^2 b}\beta\bar{z} \right. \\
&\quad \left. - \frac{2\beta}{b(1-e)} \int p_i z_i di + \frac{2\beta beN^2}{eb^2(1-e)}\bar{p}\bar{z} + \frac{2\beta eN^2}{eb(1-e)}\bar{p}\bar{z} - \frac{2\beta be^2 N^3}{\epsilon^2 b^2(1-e)}\bar{p}\bar{z} - \frac{2beN^2}{eb}\beta^2\bar{z}^2 \right) \\
&= \frac{\alpha^2 N(1-e)}{2\epsilon^2 b} + \frac{1}{2b(1-e)} \int \left(p_i^2 + \frac{e^2 N^2}{\epsilon^2}\bar{p}^2 - \frac{2eN}{\epsilon}\bar{p}^2 \right) di + \frac{1}{2}\beta^2 b(1-e) \int z_i^2 di + \frac{b(1-e)(beN)^2 N}{2\epsilon^2 b^2}\beta^2\bar{z}^2 - \frac{b^2(1-e)eN^2}{\epsilon b}\beta^2\bar{z}^2 \\
&\quad - \frac{\alpha N}{\epsilon b}\bar{p} + \frac{\alpha eN^2}{\epsilon^2 b}\bar{p} + \frac{\alpha b(1-e)^2 N}{\epsilon^2 b}\beta\bar{z} - \beta \int p_i z_i di + \frac{\beta beN^2}{\epsilon b}\bar{p}\bar{z} + \frac{\beta eN^2}{\epsilon}\bar{p}\bar{z} - \frac{\beta be^2 N^3}{\epsilon^2 b}\bar{p}\bar{z} \\
&= \frac{\alpha^2 N(1-e)}{2\epsilon^2 b} + \frac{1}{2b(1-e)} \int \left(p_i^2 + \frac{e^2 N^2}{\epsilon^2}\bar{p}^2 - \frac{2\epsilon eN}{\epsilon^2}\bar{p}^2 \right) di + \frac{1}{2}\beta^2 b(1-e) \int z_i^2 di + \frac{(1-e)(beN)^2 N}{2\epsilon^2 b}\beta^2\bar{z}^2 - \frac{2\epsilon b^2(1-e)eN^2}{2\epsilon^2 b}\beta^2\bar{z}^2 \\
&\quad + \frac{\alpha eN^2 - \alpha\epsilon N}{\epsilon^2 b}\bar{p} + \frac{\alpha b(1-e)^2 N}{\epsilon^2 b}\beta\bar{z} - \beta \int p_i z_i di + \frac{\beta\epsilon beN^2 + \beta\epsilon beN^2 - \beta be^2 N^3}{\epsilon^2 b}\bar{p}\bar{z} \\
&= \frac{\alpha^2 N(1-e)}{2\epsilon^2 b} + \frac{1}{2b(1-e)} \int \left(p_i^2 - \bar{p}^2 + \frac{1+e^2-2e}{\epsilon^2}\bar{p}^2 \right) di + \frac{1}{2}\beta^2 b(1-e) \int z_i^2 di + \frac{(1-e)(beN)^2 N - 2\epsilon b^2(1-e)eN^2}{2\epsilon^2 b}\beta^2\bar{z}^2 \\
&\quad - \frac{(1-e)\alpha N}{\epsilon^2 b}\bar{p} + \frac{\alpha b(1-e)^2 N}{\epsilon^2 b}\beta\bar{z} - \beta \int p_i z_i di + \frac{\beta beN^2(2-2e+eN)}{\epsilon^2 b}\bar{p}\bar{z} \\
&= \frac{\alpha^2 N(1-e)}{2\epsilon^2 b} + \frac{1}{2b(1-e)} \int (p_i^2 - \bar{p}^2) di + \frac{(1+e^2-2e)N}{2\epsilon^2 b(1-e)}\bar{p}^2 + \frac{1}{2}\beta^2 b(1-e) \int z_i^2 di + \frac{1}{2}\beta^2 b(1-e) \frac{b(eN)^2 N - 2\epsilon beN^2}{\epsilon^2 b}\bar{z}^2 \\
&\quad - \frac{(1-e)\alpha N}{\epsilon^2 b}\bar{p} + \frac{\alpha b(1-e)^2 N}{\epsilon^2 b}\beta\bar{z} - \beta \int p_i z_i di + \frac{\beta beN(2-2e+eN)}{\epsilon^2 b}N\bar{p}\bar{z} \\
&= \frac{\alpha^2 N(1-e)}{2\epsilon^2 b} + \frac{N}{2b(1-e)} \frac{1}{N} \int (p_i^2 - \bar{p}^2) di + \frac{(1+e^2-2e)N}{2\epsilon^2 b(1-e)}\bar{p}^2 + \frac{1}{2}\beta^2 b(1-e) \int z_i^2 di + \frac{1}{2}\beta^2 b(1-e) \frac{-2beN + 2be^2 N - be^2 N^2}{\epsilon^2 b}N\bar{z}^2 \\
&\quad - \frac{(1-e)\alpha N}{\epsilon^2 b}\bar{p} + \frac{\alpha b(1-e)^2 N}{\epsilon^2 b}\beta\bar{z} - \beta \int p_i z_i di + \frac{\beta b(2eN - 2e^2 N + e^2 N^2)}{\epsilon^2 b}N\bar{p}\bar{z}
\end{aligned}$$

$$\begin{aligned}
&= \frac{\alpha^2 N(1-e)}{2\epsilon^2 b} + \frac{N}{2b(1-e)} \sigma_p^2 + \frac{(1+e^2-2e)N}{2\epsilon^2 b(1-e)} \bar{p}^2 + \frac{1}{2} \beta^2 b(1-e) \int z_i^2 di + \frac{1}{2} \beta^2 b(1-e) \frac{-2beN + 2be^2N - be^2N^2 - b + b + 2be - 2be - e^2 + e^2}{\epsilon^2 b} N \bar{z}^2 \\
&\quad - \frac{(1-e)\alpha N}{\epsilon^2 b} \bar{p} + \frac{\alpha b(1-e)^2 N}{\epsilon^2 b} \beta \bar{z} - \beta \int p_i z_i di + \frac{\beta b(2eN - 2e^2N + e^2N^2 + 1 - 1 - 2e + 2e + e^2 - e^2)}{\epsilon^2 b} N \bar{p} \bar{z} \\
&= \frac{\alpha^2 N(1-e)}{2\epsilon^2 b} + \frac{N}{2b(1-e)} \sigma_p^2 + \frac{(1+e^2-2e)N}{2\epsilon^2 b(1-e)} \bar{p}^2 + \frac{1}{2} \beta^2 b(1-e) \int z_i^2 di + \frac{1}{2} \beta^2 b(1-e) \frac{-\epsilon^2 b + b - 2be + be^2}{\epsilon^2 b} N \bar{z}^2 \\
&\quad - \frac{(1-e)\alpha N}{\epsilon^2 b} \bar{p} + \frac{\alpha b(1-e)^2 N}{\epsilon^2 b} \beta \bar{z} - \beta \int p_i z_i di + \frac{\beta b(\epsilon - 1 + 2e - e^2)}{\epsilon^2 b} N \bar{p} \bar{z} \\
&= \frac{\alpha^2 N(1-e)}{2\epsilon^2 b} + \frac{N}{2b(1-e)} \sigma_p^2 + \frac{(1+e^2-2e)N}{2\epsilon^2 b(1-e)} \bar{p}^2 + \frac{1}{2} \beta^2 b(1-e) N \frac{1}{N} \int (z_i^2 - \bar{z}^2) di + \frac{1}{2} \beta^2 b(1-e) \frac{b - 2be + be^2}{\epsilon^2 b} N \bar{z}^2 \\
&\quad - \frac{(1-e)\alpha N}{\epsilon^2 b} \bar{p} + \frac{\alpha b(1-e)^2 N}{\epsilon^2 b} \beta \bar{z} - \beta N \frac{1}{N} \int (p_i z_i - \bar{p} \bar{z}) di - \frac{\beta b(1 - 2e + e^2)}{\epsilon^2 b} N \bar{p} \bar{z} \\
&= \frac{\alpha^2 N(1-e)}{2\epsilon^2 b} + \frac{N}{2b(1-e)} \sigma_p^2 + \frac{(1+e^2-2e)N}{2\epsilon^2 b(1-e)} \bar{p}^2 + \frac{\beta^2 b(1-e)N}{2} \sigma_z^2 + \beta^2 b(1-e) \frac{b - 2be + be^2}{2\epsilon^2 b} N \bar{z}^2 \\
&\quad - \frac{(1-e)\alpha N}{\epsilon^2 b} \bar{p} + \frac{\alpha b(1-e)^2 N}{\epsilon^2 b} \beta \bar{z} - \beta N \sigma_{pz} - \frac{\beta b(1 - 2e + e^2)}{\epsilon^2 b} N \bar{p} \bar{z}
\end{aligned}$$

$$\begin{aligned}
\frac{1}{2}be \left(\int q_i di \right)^2 &= \frac{1}{2}be \left(\int \left(\frac{\alpha}{\epsilon b} - \frac{1}{b(1-e)} p_i + \frac{eN}{\epsilon b(1-e)} \bar{p} + \beta z_i - \frac{beN}{\epsilon b} \beta \bar{z} \right) di \right)^2 \\
&= \frac{1}{2}be \left(\frac{\alpha N}{\epsilon b} - \frac{N}{b(1-e)} \bar{p} + \frac{eN^2}{\epsilon b(1-e)} \bar{p} + N\beta \bar{z} - \frac{beN^2}{\epsilon b} \beta \bar{z} \right)^2 \\
&= \frac{1}{2}be \left(\frac{\alpha N}{\epsilon b} + \frac{eN^2 - \epsilon N}{\epsilon b(1-e)} \bar{p} + \frac{\epsilon b N}{\epsilon b} \bar{z} - \frac{beN^2}{\epsilon b} \beta \bar{z} \right)^2 \\
&= \frac{1}{2}be \left(\frac{\alpha N}{\epsilon b} + \frac{eN^2 - N(1-e + eN)}{\epsilon b(1-e)} \bar{p} + \frac{b(1-e)\beta N}{\epsilon b} \bar{z} \right)^2 \\
&= \frac{1}{2}be \left(\frac{\alpha N}{\epsilon b} - \frac{N}{\epsilon b} \bar{p} + \frac{b(1-e)\beta N}{\epsilon b} \bar{z} \right)^2 \\
&= \frac{1}{2}be \left(\frac{\alpha^2 N^2}{\epsilon^2 b^2} + \frac{N^2}{\epsilon^2 b^2} \bar{p}^2 + \frac{\beta^2 b^2 (1-e)^2 N^2}{\epsilon^2 b^2} \bar{z}^2 - \frac{2\alpha N^2}{\epsilon^2 b^2} \bar{p} + \frac{2\alpha\beta b(1-e) N^2}{\epsilon^2 b^2} \bar{z} - \frac{2\beta b(1-e) N^2}{\epsilon^2 b^2} \bar{p}\bar{z} \right) \\
&= \frac{\alpha^2 e N^2}{2\epsilon^2 b} + \frac{N^2 e}{2\epsilon^2 b} \bar{p}^2 + \frac{\beta^2 b^2 (1-e)^2 N^2 e}{2\epsilon^2 b} \bar{z}^2 - \frac{\alpha N^2 e}{\epsilon^2 b} \bar{p} + \frac{\alpha\beta b(1-e) N^2 e}{\epsilon^2 b} \bar{z} - \frac{\beta b(1-e) N^2 e}{\epsilon^2 b} \bar{p}\bar{z}
\end{aligned}$$

$$\begin{aligned}
\beta b(1-e) \int q_i z_i di &= \beta b(1-e) \int \left(\frac{\alpha}{\epsilon b} - \frac{1}{b(1-e)} p_i + \frac{eN}{\epsilon b(1-e)} \bar{p} + \beta z_i - \frac{beN}{\epsilon b} \beta \bar{z} \right) z_i di \\
&= \beta b(1-e) \int \left(\frac{\alpha}{\epsilon b} z_i - \frac{1}{b(1-e)} p_i z_i + \frac{eN}{\epsilon b(1-e)} \bar{p} z_i + \beta z_i^2 - \frac{beN}{\epsilon b} \beta \bar{z} z_i \right) di \\
&= \frac{\alpha \beta b(1-e) N}{\epsilon b} \bar{z} - \frac{\beta b(1-e)}{b(1-e)} \int p_i z_i di + \frac{\beta b(1-e) e N^2}{\epsilon b(1-e)} \bar{p} \bar{z} + \beta^2 b(1-e) \int z_i^2 di - \frac{be b(1-e) N^2}{\epsilon b} \beta^2 \bar{z}^2 \\
&= \frac{\alpha \beta (1-e) N}{\epsilon} \bar{z} - \beta \int p_i z_i di + \frac{\beta e N^2}{\epsilon} \bar{p} \bar{z} + \beta^2 b(1-e) \int z_i^2 di - \frac{be(1-e) N^2}{\epsilon} \beta^2 \bar{z}^2 \\
&= \frac{\alpha \beta (1-e) N}{\epsilon} \bar{z} - \beta \int \left(p_i z_i - \frac{(eN + 1 - 1 - e + e)}{\epsilon} \bar{p} \bar{z} \right) di + \beta^2 b(1-e) \int \left(z_i^2 - \frac{eN - 1 + 1 + e - e}{\epsilon} \bar{z}^2 \right) di \\
&= \frac{\alpha \beta (1-e) N}{\epsilon} \bar{z} - \beta \int \left(p_i z_i - \bar{p} \bar{z} + \frac{(1-e)}{\epsilon} \bar{p} \bar{z} \right) di + \beta^2 b(1-e) \int \left(z_i^2 - \bar{z}^2 + \frac{(1-e)}{\epsilon} \bar{z}^2 \right) di \\
&= \frac{\alpha \beta (1-e) N}{\epsilon} \bar{z} - \beta \int (p_i z_i - \bar{p} \bar{z}) di - \frac{\beta(1-e) N}{\epsilon} \bar{p} \bar{z} + \beta^2 b(1-e) \int (z_i^2 - \bar{z}^2) di + \frac{\beta^2 b(1-e)^2 N}{\epsilon} \bar{z}^2 \\
&= \frac{\alpha \beta (1-e) N}{\epsilon} \bar{z} - \beta N \sigma_{pz} - \frac{\beta(1-e) N}{\epsilon} \bar{p} \bar{z} + \beta^2 b(1-e) N \sigma_z^2 + \frac{\beta^2 b(1-e)^2 N}{\epsilon} \bar{z}^2
\end{aligned}$$

$$\begin{aligned}
U &= q_0 + \alpha \int q_i di - \frac{1}{2}b \left[(1-e) \int q_i^2 di + e \left(\int q_i di \right)^2 \right] + \beta b(1-e) \int q_i z_i di \\
&= q_0 + \frac{\alpha^2 N}{\epsilon b} - \frac{\alpha N}{\epsilon b} \bar{p} + \frac{\alpha b(1-e)N}{\epsilon b} \beta \bar{z} - \frac{1}{2}b \left[(1-e) \int q_i^2 di + e \left(\int q_i di \right)^2 \right] + \frac{\alpha \beta (1-e) N}{\epsilon} \bar{z} - \beta N \sigma_{pz} - \frac{\beta (1-e) N}{\epsilon} \bar{p} \bar{z} + \beta^2 b(1-e) N \sigma_z^2 \\
&\quad + \frac{\beta^2 b(1-e)^2 N}{\epsilon} \bar{z}^2 \\
&= q_0 + \frac{\alpha^2 N}{\epsilon b} - \frac{\alpha N}{\epsilon b} \bar{p} + \frac{\alpha b(1-e)N}{\epsilon b} \beta \bar{z} - \left[\frac{\alpha^2 N(1-e)}{2\epsilon^2 b} + \frac{N}{2b(1-e)} \sigma_p^2 + \frac{(1+e^2-2e)N}{2\epsilon^2 b(1-e)} \bar{p}^2 + \frac{\beta^2 b(1-e)N}{2} \sigma_z^2 + \beta^2 b(1-e) \frac{b-2be+be^2}{2\epsilon^2 b} N \bar{z}^2 - \frac{(1-e)\alpha N}{\epsilon^2 b} \bar{p} \right. \\
&\quad \left. + \frac{\alpha b(1-e)^2 N}{\epsilon^2 b} \beta \bar{z} - \beta N \sigma_{pz} - \frac{\beta b(1-2e+e^2)}{\epsilon^2 b} N \bar{p} \bar{z} \right] \\
&\quad - \left[\frac{\alpha^2 e N^2}{2\epsilon^2 b} + \frac{N^2 e}{2\epsilon^2 b} \bar{p}^2 + \frac{\beta^2 b^2 (1-e)^2 N^2 e}{2\epsilon^2 b} \bar{z}^2 - \frac{\alpha N^2 e}{\epsilon^2 b} \bar{p} + \frac{\alpha \beta b(1-e) N^2 e}{\epsilon^2 b} \bar{z} - \frac{\beta b(1-e) N^2 e}{\epsilon^2 b} \bar{p} \bar{z} \right] + \frac{\alpha \beta (1-e) N}{\epsilon} \bar{z} - \beta N \sigma_{pz} \\
&\quad - \frac{\beta (1-e) N}{\epsilon} \bar{p} \bar{z} + \beta^2 b(1-e) N \sigma_z^2 + \frac{\beta^2 b(1-e)^2 N}{\epsilon} \bar{z}^2 \\
&= q_0 + \frac{\alpha^2 N}{\epsilon b} - \frac{\alpha^2 N(1-e)}{2\epsilon^2 b} - \frac{\alpha^2 e N^2}{2\epsilon^2 b} - \frac{\alpha N}{\epsilon b} \bar{p} + \frac{(1-e)\alpha N}{\epsilon^2 b} \bar{p} + \frac{\alpha e N^2}{\epsilon^2 b} \bar{p} + \frac{\alpha b(1-e)N}{\epsilon b} \beta \bar{z} - \frac{\alpha b(1-e)^2 N}{\epsilon^2 b} \beta \bar{z} - \frac{\alpha b(1-e)N^2 e}{\epsilon^2 b} \beta \bar{z} \\
&\quad + \frac{\alpha(1-e)N}{\epsilon} \beta \bar{z} - \frac{N}{2b(1-e)} \sigma_p^2 - \frac{\beta^2 b(1-e)N}{2} \sigma_z^2 + \beta^2 b(1-e) N \sigma_z^2 + \beta N \sigma_{pz} - \beta N \sigma_{pz} - \frac{(1+e^2-2e)N}{2\epsilon^2 b(1-e)} \bar{p}^2 - \frac{N^2 e}{2\epsilon^2 b} \bar{p}^2 \\
&\quad + \frac{\beta b(1-2e+e^2)}{\epsilon^2 b} N \bar{p} \bar{z} + \frac{\beta b(1-e)N^2 e}{\epsilon^2 b} \bar{p} \bar{z} - \frac{\beta(1-e)N}{\epsilon} \bar{p} \bar{z} + \frac{\beta^2 b(1-e)^2 N}{\epsilon} \bar{z}^2 - \beta^2 b(1-e) \frac{b-2be+be^2}{2\epsilon^2 b} N \bar{z}^2 - \frac{\beta^2 b^2 (1-e)^2 N^2 e}{2\epsilon^2 b} \bar{z}^2 \\
&= q_0 + \frac{N}{2\epsilon b} \alpha^2 - \frac{1}{2\epsilon b} N \bar{p}^2 + \frac{1}{2\epsilon b} \beta^2 b^2 (1-e)^2 N \bar{z}^2 + \frac{\alpha(1-e)N}{\epsilon} \beta \bar{z} - \frac{N}{2b(1-e)} \sigma_p^2 + \frac{\beta^2 b(1-e)N}{2} \sigma_z^2 \\
&= q_0 + \frac{N}{2\epsilon b} \left(\alpha^2 + \bar{p}^2 + \beta^2 b^2 (1-e)^2 \bar{z}^2 - 2\alpha \bar{p} + 2\alpha b(1-e) \beta \bar{z} - 2\bar{p} b(1-e) \beta \bar{z} \right) - \frac{N}{\epsilon b} \bar{p}^2 + \frac{N}{\epsilon b} \alpha \bar{p} + \frac{N}{\epsilon b} b(1-e) \beta \bar{p} \bar{z} - \frac{N}{2b(1-e)} \sigma_p^2 + \frac{b(1-e)N}{2} \beta^2 \sigma_z^2 \\
&= q_0 + \frac{N}{2\epsilon b} (\alpha - \bar{p} + b(1-e) \beta \bar{z})^2 - \frac{N}{\epsilon b} \bar{p}^2 + \frac{N}{\epsilon b} \alpha \bar{p} + \frac{N}{\epsilon b} b(1-e) \beta \bar{p} \bar{z} - \frac{N}{2b(1-e)} \sigma_p^2 + \frac{b(1-e)N}{2} \beta^2 \sigma_z^2 \\
&= q_0 + \frac{N}{2\epsilon b} (\alpha - \bar{p} + b(1-e) \beta \bar{z})^2 + \frac{(\alpha - \bar{p} + b(1-e) \beta \bar{z}) N}{\epsilon b} \bar{p} - \frac{N}{2b(1-e)} \sigma_p^2 + \frac{b(1-e)N}{2} \beta^2 \sigma_z^2 \\
&= q_0 + Q \bar{p} - \frac{N}{b(1-e)} \sigma_p^2 + \frac{N}{2\epsilon b} (\alpha - \bar{p} + b(1-e) \beta \bar{z})^2 + \frac{N}{2b(1-e)} \sigma_p^2 + \frac{b(1-e)N}{2} \beta^2 \sigma_z^2
\end{aligned}$$

It can be shown that the first three terms in the last expression combined give income I^c :

$$\begin{aligned}
I^c &= q_0 + \int p_i q_i di \\
&= q_0 + \int p_i \left(\frac{\alpha}{b\epsilon} - \frac{1}{b(1-e)} p_i + \frac{eN}{\epsilon b(1-e)} \bar{p} + \beta z_i - \frac{beN}{\epsilon b} \beta \bar{z} \right) di \\
&= q_0 + \frac{\alpha}{\epsilon b} \int p_i di - \frac{1}{b(1-e)} \int p_i^2 di + \frac{eN}{\epsilon b(1-e)} \int p_i \bar{p} di + \beta \int p_i z_i di - \frac{beN}{\epsilon b} \beta \int p_i \bar{z} di \\
&= q_0 + \frac{\alpha N}{\epsilon b} \bar{p} - \frac{1}{b(1-e)} \left[\int p_i^2 di - \frac{eN}{\epsilon} \int p_i \bar{p} di \right] + \beta N \bar{p} \bar{z} - \frac{beN}{\epsilon b} \beta N \bar{p} \bar{z} \\
&= q_0 + \frac{\alpha N}{\epsilon b} \bar{p} - \frac{N}{b(1-e)} \left[\frac{1}{N} \int p_i^2 di - \bar{p}^2 \right] - \frac{N}{\epsilon b} \bar{p}^2 + \frac{\epsilon b - beN}{\epsilon b} \beta N \bar{p} \bar{z} \\
&= q_0 + \frac{\alpha N}{\epsilon b} \bar{p} - \frac{N}{b(1-e)} \left[\frac{1}{N} \int p_i^2 di - \bar{p}^2 \right] - \frac{N}{\epsilon b} \bar{p}^2 + \frac{b(1-e)}{\epsilon b} \beta N \bar{p} \bar{z} \\
&= q_0 + \frac{(\alpha - \bar{p} + \beta b(1-e)\bar{z})N}{\epsilon b} \bar{p} - \frac{N}{b(1-e)} \sigma_p^2 \\
&= q_0 + \bar{p}Q - \frac{N}{b(1-e)} \sigma_p^2
\end{aligned}$$

where the last line follows since $\frac{(\alpha - \bar{p} + \beta b(1-e)\bar{z})N}{\epsilon b} = Q$; from the expression for indirect demand,

$$p_i = a + \beta b(1-e)z_i - b[(1-e)q_i + eQ]$$

we can derive the expression for Q above:

$$\begin{aligned}
\int p_i di &= \int a di + \beta b(1-e) \int z_i di - b \int [(1-e)q_i + eQ] di \\
N\bar{p} &= N\alpha + \beta b(1-e)N\bar{z} - b(1-e)Q - beNQ \\
b(1-e+eN)Q &= N\alpha - N\bar{p} + \beta b(1-e)N\bar{z} \\
Q &= \frac{N\alpha - N\bar{p} + \beta b(1-e)N\bar{z}}{(1-e+eN)b} \\
Q &= \frac{(\alpha - \bar{p} + \beta b(1-e)\bar{z})N}{\epsilon b}
\end{aligned}$$

Hence, returning to the expression of overall utility, we have:

$$\begin{aligned}
U &= I^c + \frac{N}{2\epsilon b} (\alpha - \bar{p} + b(1-e)\beta\bar{z})^2 + \frac{1}{2} \frac{N}{b(1-e)} \sigma_p^2 + \frac{1}{2} b(1-e)N\beta^2\sigma_z^2 \\
&= I^c + \frac{N}{2\epsilon b} (\alpha - \bar{p} + B\bar{z})^2 + \frac{N}{2b(1-e)} [\sigma_p^2 + B^2\sigma_z^2]
\end{aligned}$$

3.8.6 Trade Integration and Gains from Trade

Modularity of Optimized Profit Function:

$$\begin{aligned}
\pi &= \frac{\varepsilon_\lambda L}{4b(1-e)} (c_D - c)^2 \\
\frac{\partial \pi}{\partial c} &= -\frac{\varepsilon_\lambda L}{2b(1-e)} (c_D - c) \\
\frac{\partial \pi^2}{\partial c \partial L} &= -\frac{\varepsilon_\lambda L}{2b(1-e)} \frac{\partial c_D}{\partial L} + (c_D - c) \left[-\frac{\varepsilon_\lambda}{2b(1-e)} - \frac{B \frac{\partial \lambda}{\partial L}}{2b(1-e)} L \right] \\
&= -\frac{1}{2b(1-e)} \left\{ \varepsilon_\lambda L \frac{\partial c_D}{\partial L} + (c_D - c) \left[\varepsilon_\lambda + B \lambda \frac{\partial \lambda}{\partial L} \frac{L}{\lambda} \right] \right\} \\
&= -\frac{\varepsilon_\lambda}{2b(1-e)} \left\{ -L \frac{\varepsilon_\lambda c_D}{L(n+2)} + (c_D - c) [1 + B \lambda] \right\} \\
&= -\frac{\varepsilon_\lambda^2}{2b(1-e)} \left\{ -\frac{c_D}{n+2} + c_D - c \right\} \\
&= -\frac{\varepsilon_\lambda^2}{2b(1-e)} \left(\frac{n+1}{n+2} c_D - c \right) \\
\frac{\partial \pi^2}{\partial c \partial L} &< 0 \text{ for } c < \frac{n+1}{n+2} c_D \text{ (hence sub-modular).}
\end{aligned}$$

Proposition 18: Sub-modularity of Revenues:

$$\begin{aligned}
r &= \frac{\varepsilon_\lambda^2 L}{4b(1-e)} (c_D - c)^2 + \frac{\varepsilon_\lambda L}{2b(1-e)} (c_D - c) c \\
\frac{\partial r}{\partial c} &= -\frac{\varepsilon_\lambda L}{2b(1-e)} [B \lambda (c_D - c) + c] \\
\frac{\partial r^2}{\partial c \partial L} &= -\frac{\varepsilon_\lambda L}{2b(1-e)} \left[\frac{B \lambda \varepsilon_\lambda}{L} \left(\frac{n+1}{n+2} c_D - c \right) \right] + [B \lambda (c_D - c) + c] \left[-\frac{\varepsilon_\lambda}{2b(1-e)} - \frac{\varepsilon_\lambda}{2b(1-e)} \frac{\beta B L}{2\theta - \beta B L} \right] \\
&= -\frac{\varepsilon_\lambda}{2b(1-e)} \left[\frac{B \lambda \varepsilon_\lambda}{L} \left(\frac{n+1}{n+2} c_D - c \right) + [B \lambda (c_D - c) + c] (1 + B \lambda) \right] \\
&= -\frac{\varepsilon_\lambda^2}{2b(1-e)} \left[\frac{B \lambda}{L} \left(\frac{n+1}{n+2} c_D - c \right) + B \lambda (c_D - c) + c \right] \\
&= -\frac{\varepsilon_\lambda^2}{2b(1-e)} \left[\left(\frac{B \lambda}{L} \frac{n+1}{n+2} + B \lambda \right) c_D - \left(\frac{B \lambda}{L} + B \lambda - 1 \right) c \right] \\
\frac{\partial r^2}{\partial c \partial L} &< 0
\end{aligned}$$

if $c < \frac{n+1}{n+2} c_D$ or if coeff on $c_D >$ coeff on c i.e. $\left(\frac{2\theta}{\beta B L} - 1 \right) L (n+2) > 1$.

Proposition 19: Sub-modularity of Optimized Quality Function:

$$\begin{aligned}
 z &= \lambda(c_D - c) \\
 \frac{\partial z}{\partial c} &= -\lambda \\
 \frac{\partial z^2}{\partial c \partial L} &= -\frac{\partial \lambda}{\partial L} < 0 \text{ (hence sub-modular)}
 \end{aligned}$$

Proposition 20: Average Prices and Quality:

$$\frac{\partial \bar{p}}{\partial L} = \frac{2n + \varepsilon_\lambda}{2(n+1)} \frac{\partial c_D}{\partial L} + \frac{1}{2(n+1)} \frac{\partial \varepsilon_\lambda}{\partial L} c_D \quad (3.74)$$

$$= \frac{\varepsilon_\lambda c_D}{2(n+1)} \left[\frac{\lambda B(n+1) - 2n - 1}{(n+2)L} \right] \quad (3.75)$$

$$> 0 \text{ if } \lambda B(n+1) > 2n + 1 \quad (3.76)$$

$$\text{or if } \beta > \left[\frac{(2n+1)2\theta}{(3n+2)b(1-e)L} \right]^{\frac{1}{2}} \quad (3.77)$$

$$\frac{\partial \bar{z}}{\partial L} = \frac{\lambda \varepsilon_\lambda}{(n+2)L} c_D > 0 \quad (3.78)$$

Welfare rises as long as:

$$\frac{\partial \bar{p}}{\partial L} - B \frac{\partial \bar{z}}{\partial L} < 0.$$

From equations (3.75) and (3.78) we thus have:

$$\begin{aligned}
 \frac{\partial \bar{p}}{\partial L} - B \frac{\partial \bar{z}}{\partial L} &= \frac{\varepsilon_\lambda c_D}{2(n+1)} \left[\frac{\lambda B(n+1) - 2n - 1}{(n+2)L} \right] - \frac{B \lambda \varepsilon_\lambda}{(n+2)L} c_D \\
 &= \frac{\varepsilon_\lambda c_D}{(n+2)L} \left[\frac{\lambda B(n+1) - 2n - 1 - 2\lambda B(n+1)}{2(n+1)} \right] \\
 &= -\frac{\varepsilon_\lambda c_D}{2(n+2)L} \left[\lambda B + \frac{2n+1}{n+1} \right] \\
 &= -\frac{\varepsilon_\lambda c_D}{2(n+2)L} \left[\varepsilon_\lambda + \frac{n}{n+1} \right] \\
 &< 0.
 \end{aligned}$$

Proposition 21: Mass of Varieties:

$$\begin{aligned}
N &= \frac{2(n+1)(1-e)(a-c_D)}{e(1+\lambda B)c_D} \\
&= \frac{2(n+1)(1-e)}{e(1+\lambda B)} \left(\frac{a}{c_D} - 1 \right) \\
\frac{dN}{dL} &= \frac{2(n+1)(1-e)}{e(1+\lambda B)} \left(-\frac{a}{c_D^2} \frac{\partial c_D}{\partial L} \right) - \left(\frac{a}{c_D} - 1 \right) \frac{2(n+1)(1-e)}{e(1+\lambda B)^2} B \frac{\partial \lambda}{\partial L} \\
&= \frac{2(n+1)(1-e)}{e(1+\lambda B)} \left[\left(-\frac{a}{c_D^2} \frac{\partial c_D}{\partial L} \right) - \left(\frac{a}{c_D} - 1 \right) \frac{B}{(1+\lambda B)} \frac{\partial \lambda}{\partial L} \right] \\
&= \frac{2(n+1)(1-e)}{e(1+\lambda B)} \left[\left(-\frac{a}{c_D^2} \frac{\partial c_D}{\partial L} \right) - \left(\frac{a-c_D}{c_D} \right) \frac{B}{(1+\lambda B)} \frac{\partial \lambda}{\partial L} \right] \\
&= \frac{2(n+1)(1-e)}{e(1+\lambda B)c_D} \left[-\frac{a}{c_D} \frac{\partial c_D}{\partial L} - \frac{B(a-c_D)}{1+\lambda B} \frac{\partial \lambda}{\partial L} \right] \\
&= \frac{2(n+1)(1-e)}{e(1+B\lambda)c_D} \left[\frac{a}{n+2} \frac{1}{L} + \left(\frac{a}{n+2} + c_D - a \right) \frac{B}{1+B\lambda} \frac{\partial \lambda}{\partial L} \right] \\
&= \frac{2(n+1)(1-e)}{e(1+B\lambda)c_D} \left[\frac{a}{n+2} \frac{1}{L} + \left(\frac{a}{n+2} + c_D - a \right) \frac{B}{1+B\lambda} (1+\lambda B) \frac{\lambda}{L} \right] \\
&= \frac{2(n+1)(1-e)}{Le(1+B\lambda)c_D} \left[\frac{a}{n+2} + \left(c_D - \frac{n+1}{n+2} a \right) B\lambda \right] \\
&= \frac{c_D^{n+1}}{eb(n+2)fc_m} \left[\frac{a}{n+2} + \left(c_D - \frac{n+1}{n+2} a \right) B\lambda \right] \leq 0.
\end{aligned}$$

$$\frac{\partial N}{\partial L} = \frac{2(n+1)(1-e)}{Le(1+B\lambda)c_D} \left[\frac{a}{n+2} + \left(c_D - \frac{n+1}{n+2} a \right) B\lambda \right] \leq 0.$$

If $\beta = 0$:

$$\frac{\partial N}{\partial L} = \frac{2a(n+1)(1-e)}{e(n+2)Lc_D} > 0.$$

The variances can be calculated as follows:

Given that:

$$\begin{aligned}
G(c) &= \left(\frac{c}{c_M} \right)^n \\
G(c_D) &= \left(\frac{c_D}{c_M} \right)^n \\
\frac{dG(c)}{dc} &= G'(c) \\
dG(c) &= G'(c)dc = n \frac{1}{c_M} \left(\frac{c}{c_M} \right)^{n-1},
\end{aligned}$$

we have for σ_z^2 and σ_p^2 :

$$\begin{aligned}
\sigma_z^2 &= \frac{\int_0^{c_D} [z(c) - \bar{z}]^2 dG(c)}{G(c_D)} \\
&= \left(\frac{c_D}{c_M}\right)^{-n} \int_0^{c_D} \left[\lambda(c_D - c) - \frac{\lambda c_D}{n+1}\right]^2 n \frac{1}{c_M} \left(\frac{c}{c_M}\right)^{n-1} dc \\
&= n \frac{1}{c_M} \left(\frac{c_D}{c_M}\right)^{-n} \left(\frac{1}{c_M}\right)^{n-1} \int_0^{c_D} \left[\lambda^2(c_D - c)^2 - 2\lambda(c_D - c) \frac{\lambda c_D}{n+1} + \frac{\lambda^2 c_D^2}{(n+1)^2}\right] c^{n-1} dc \\
&= n c_D^{-n} \int_0^{c_D} \left[\lambda^2 c_D^2 - \lambda^2 2c_D c + \lambda^2 c^2\right] - \frac{(2\lambda^2 c_D^2 - 2\lambda^2 c_D c)}{n+1} + \frac{\lambda^2 c_D^2}{(n+1)^2} \Big] c^{n-1} dc \\
&= n \lambda^2 c_D^{-n} \int_0^{c_D} \left[c_D^2 c^{n-1} - 2c_D c^n + c^{n+1} - \frac{(2c_D^2 c^{n-1} - 2c_D c^n)}{n+1} + \frac{c_D^2 c^{n-1}}{(n+1)^2}\right] dc \\
&= n \lambda^2 c_D^{-n} \left[c_D^2 \int_0^{c_D} c^{n-1} dc - 2c_D \int_0^{c_D} c^n dc + \int_0^{c_D} c^{n+1} dc - \frac{2c_D^2}{n+1} \int_0^{c_D} c^{n-1} dc + \frac{2c_D}{n+1} \int_0^{c_D} c^n dc + \frac{c_D^2}{(n+1)^2} \int_0^{c_D} c^{n-1} dc \right] \\
&= n \lambda^2 c_D^{-n} \left[\frac{c_D^{n+2}}{n} - 2 \frac{c_D^{n+2}}{n+1} + \frac{c_D^{n+2}}{n+2} - \frac{2}{n+1} \frac{c_D^{n+2}}{n} + \frac{2}{n+1} \frac{c_D^{n+2}}{n+1} + \frac{1}{(n+1)^2} \frac{c_D^{n+2}}{n} \right] \\
&= \lambda^2 \left[1 - 2 \frac{n}{n+1} + \frac{n}{n+2} - \frac{2}{n+1} + \frac{2}{n+1} \frac{n}{n+1} + \frac{1}{(n+1)^2} \right] c_D^2 \\
&= \lambda^2 \left[\frac{(n+2)(n+1)^2}{(n+2)(n+1)^2} - \frac{2n(n+2)(n+1)}{(n+1)^2(n+2)} + \frac{n(n+1)^2}{(n+2)(n+1)^2} - \frac{2(n+2)(n+1)}{(n+1)^2(n+2)} + \frac{2n(n+2)}{(n+1)^2(n+2)} + \frac{(n+2)}{(n+1)^2(n+2)} \right] c_D^2 \\
&= \frac{\lambda^2 c_D^2}{(n+2)(n+1)^2} \left[(n+2)(n+1)^2 - 2n(n+2)(n+1) + n(n+1)^2 - 2(n+2)(n+1) + 2n(n+2) + (n+2) \right] \\
&= \frac{\lambda^2 c_D^2}{(n+2)(n+1)^2} \left[-(n+2)(n+1)^2 + n(n+1)^2 + 2n(n+2) + (n+2) \right] \\
&= \frac{n \lambda^2}{(n+2)(n+1)^2} c_D^2.
\end{aligned}$$

$$\begin{aligned}
\sigma_p^2 &= \frac{\int_0^{c_D} [p(c) - \bar{p}]^2 dG(c)}{G(c_D)} \\
&= \left(\frac{c_D}{c_M}\right)^{-n} \int_0^{c_D} \left[\frac{\varepsilon_\lambda}{2} (c_D + c) - B\lambda c - \frac{2n + \varepsilon_\lambda}{2(n+1)} c_D \right]^2 n \frac{1}{c_M} \left(\frac{c}{c_M}\right)^{n-1} dc \\
&= nc_D^{-n} \int_0^{c_D} \left[\frac{B\lambda n - n}{2(n+1)} c_D + \frac{1 - B\lambda}{2} c \right]^2 c^{n-1} dc \\
&= nc_D^{-n} \int_0^{c_D} \left[\left(\frac{B\lambda n - n}{2(n+1)}\right)^2 c_D^2 + 2 \frac{B\lambda n - n}{2(n+1)} c_D \frac{1 - B\lambda}{2} c + \left(\frac{1 - B\lambda}{2}\right)^2 c^2 \right] c^{n-1} dc \\
&= nc_D^{-n} \left(\frac{B\lambda n - n}{2(n+1)}\right)^2 c_D^2 \int_0^{c_D} c^{n-1} dc + nc_D^{-n} \frac{B\lambda n - n}{(n+1)} c_D \frac{1 - B\lambda}{2} \int_0^{c_D} c c^{n-1} dc + nc_D^{-n} \left(\frac{1 - B\lambda}{2}\right)^2 \int_0^{c_D} c^2 c^{n-1} dc \\
&= \left(\frac{B\lambda - 1}{2(n+1)}\right)^2 n^2 c_D^2 + n^2 \frac{B\lambda - 1}{(n+1)^2} \frac{1 - B\lambda}{2} c_D^2 + \frac{n}{n+2} \left(\frac{1 - B\lambda}{2}\right)^2 c_D^2 \\
&= \frac{1}{4} nc_D^2 \left[\frac{(n+2)(B\lambda - 1)^2 n}{(n+2)(n+1)^2} + \frac{2n(B\lambda - 1)(1 - B\lambda)(n+2)}{(n+2)(n+1)^2} + \frac{(1 - B\lambda)^2 (n+1)^2}{(n+2)(n+1)^2} \right] \\
&= \frac{1}{4} nc_D^2 \left[\frac{(n^2 + 2n)(B^2\lambda^2 - 2B\lambda + 1)}{(n+2)(n+1)^2} + \frac{(B\lambda - B^2\lambda^2 - 1 + B\lambda)(2n^2 + 4n)}{(n+2)(n+1)^2} + \frac{(1 - 2B\lambda + B^2\lambda^2)(n^2 + 2n + 1)}{(n+2)(n+1)^2} \right] \\
&= \frac{1}{4} nc_D^2 \left[\frac{n^2 B^2\lambda^2 - 2n^2 B\lambda + n^2 + 2n B^2\lambda^2 - 4n B\lambda + 2n}{(n+2)(n+1)^2} + \frac{2n^2 B\lambda - 2n^2 B^2\lambda^2 - 2n^2 + 2n^2 B\lambda + 4n B\lambda - 4n B^2\lambda^2 - 4n + 4n B\lambda}{(n+2)(n+1)^2} \right] \\
&\quad + \frac{1}{4} nc_D^2 \left[\frac{n^2 - 2n^2 B\lambda + n^2 B^2\lambda^2 + 2n - 4n B\lambda + 2n B^2\lambda^2 + 1 - 2B\lambda + B^2\lambda^2}{(n+2)(n+1)^2} \right] \\
&= \frac{1}{4} nc_D^2 \left[\frac{(1 - 2B\lambda + B^2\lambda^2)}{(n+2)(n+1)^2} \right] \\
&= \frac{1}{4} nc_D^2 \left[\frac{(B\lambda - 1)^2}{(n+2)(n+1)^2} \right] \\
&= \frac{1}{4} \frac{n(\varepsilon_\lambda - 2)^2}{(n+2)(n+1)^2} c_D^2.
\end{aligned}$$

We thus have:

$$\begin{aligned}
\frac{\partial \sigma_p^2}{\partial L} &= \frac{1}{2} \frac{nc_D (B\lambda - 1)}{(n+2)(n+1)^2} \left[B \left(\lambda \frac{\partial c_D}{\partial L} + c_D \frac{\partial \lambda}{\partial L} \right) - \frac{\partial c_D}{\partial L} \right] \\
&= \frac{1}{2} \frac{nc_D (B\lambda - 1)}{(n+2)(n+1)^2} \left[\frac{n+1}{n+2} \frac{B\lambda \varepsilon_\lambda c_D}{L} - \frac{\partial c_D}{\partial L} \right] \\
&> 0 \text{ if } B\lambda > 1 \\
&< 0 \text{ if } 0 \leq B\lambda < 1
\end{aligned}$$

The quality variance on the other hand can be shown to be unambiguously increasing in market size:

$$\begin{aligned}
\frac{\partial \sigma_z^2}{\partial L} &= \frac{2n\lambda c_D}{(n+2)(n+1)^2} \left(\lambda \frac{\partial c_D}{\partial L} + c_D \frac{\partial \lambda}{\partial L} \right) \\
&= \frac{2n\lambda c_D}{(n+2)(n+1)^2} \left(\frac{n+1}{n+2} \frac{\lambda \varepsilon_\lambda c_D}{L} \right) \\
&= \frac{2n\varepsilon_\lambda \lambda^2}{(n+2)^2 (n+1)L} c_D^2 > 0
\end{aligned}$$

Indirect Utility in terms of the Cost Cut-off only: In order to derive welfare in terms of the cost cut-off only, we need N , \bar{c} , \bar{p} , \bar{z} , σ_p^2 , σ_z^2 :

$$\begin{aligned}
N &= \frac{1}{\varepsilon_\lambda} \frac{2(n+1)(1-e)(a-c_D)}{e c_D} \\
\bar{c} &= \frac{nc_D}{n+1} \\
\bar{p} &= \frac{2n + \varepsilon_\lambda}{2(n+1)} c_D \\
\bar{z} &= \frac{\lambda c_D}{n+1} \\
\sigma_p^2 &= \frac{1}{4} \frac{n(\varepsilon_\lambda - 2)^2}{(n+2)(n+1)^2} c_D^2 \\
\sigma_z^2 &= \frac{n\lambda^2}{(n+2)(n+1)^2} c_D^2
\end{aligned}$$

Substituting into

$$U = 1 + \frac{N}{2eb} (\alpha - \bar{p} + B\bar{z})^2 + \frac{1}{2b(1-e)} (\sigma_p^2 + B^2 \sigma_z^2)$$

we obtain:

$$\begin{aligned}
U &= 1 + \frac{\frac{2(n+1)(1-e)}{e(1+B\lambda)} \frac{(a-c_D)}{c_D}}{2b \left(1 - e + e \frac{2(n+1)(1-e)}{e(1+B\lambda)} \frac{(a-c_D)}{c_D} \right)} \left(\alpha - \frac{2n+1+B\lambda}{2(n+1)} c_D + \frac{B\lambda}{n+1} c_D \right)^2 \\
&\quad + \frac{1}{2b(1-e)} \frac{2(n+1)(1-e)}{e(1+B\lambda)} \frac{(a-c_D)}{c_D} \left(\frac{1}{4} \frac{n(B\lambda-1)^2}{(n+2)(n+1)^2} c_D^2 + B^2 \frac{n\lambda^2}{(n+2)(n+1)^2} c_D^2 \right) \\
&= 1 + \frac{1}{2eb} \frac{2(n+1)(a-c_D)}{(1+B\lambda)c_D + 2(n+1)(a-c_D)} \left(\frac{2(n+1)(\alpha-c_D) + c_D(1+B\lambda)}{2(n+1)} \right)^2 \\
&\quad + \frac{1}{2eb} (a-c_D) \left(\frac{1}{2} \frac{n(B\lambda-1)^2}{(n+2)(n+1)(1+B\lambda)} c_D + \frac{2nB^2\lambda^2}{(n+2)(n+1)(1+B\lambda)} c_D \right) \\
&= 1 + \frac{1}{2eb} (a-c_D) \frac{2(n+1)(\alpha-c_D) + c_D(1+B\lambda)}{2(n+1)} + \frac{1}{2eb} (a-c_D) \left(\frac{1}{2} \frac{n(B\lambda-1)^2}{(n+2)(n+1)(1+B\lambda)} c_D + \frac{4nB^2\lambda^2}{2(n+2)(n+1)(1+B\lambda)} c_D \right) \\
&= 1 + \frac{1}{2eb} (a-c_D) \left[\alpha - \frac{2(n+1)(n+2)(1+B\lambda)}{2(n+1)(n+2)(1+B\lambda)} c_D + \frac{(n+2)(1+B\lambda)^2}{2(n+1)(n+2)(1+B\lambda)} c_D + \frac{n(B\lambda-1)^2}{2(n+1)(n+2)(1+B\lambda)} c_D + \frac{4nB^2\lambda^2}{2(n+1)(n+2)(1+B\lambda)} c_D \right] \\
&= 1 + \frac{1}{2eb} (a-c_D) \left[\alpha - \frac{(2n^2+2n+4n+4+2n^2B\lambda+2nB\lambda+4nB\lambda+4B\lambda)}{2(n+1)(n+2)(1+B\lambda)} c_D + \frac{n+2nB\lambda+nB^2\lambda^2+2+4B\lambda+2B^2\lambda^2}{2(n+1)(n+2)(1+B\lambda)} c_D + \frac{nB^2\lambda^2-2nB\lambda+n}{2(n+1)(n+2)(1+B\lambda)} c_D \right. \\
&\quad \left. + \frac{4nB^2\lambda^2}{2(n+1)(n+2)(1+B\lambda)} c_D \right] \\
&= 1 + \frac{1}{2eb} (a-c_D) \left[\alpha + \frac{2B^2\lambda^2 + 6nB^2\lambda^2 - 2n^2 - 4n - 2 - 2n^2B\lambda - 6nB\lambda}{2(n+1)(n+2)(1+B\lambda)} c_D \right] \\
&= 1 + \frac{1}{2eb} (a-c_D) \left[\alpha + \frac{(1+B\lambda)(n+1)B\lambda - (1+B\lambda)(n+1)^2 - 2nB\lambda + 2nB^2\lambda^2}{(n+1)(n+2)(1+B\lambda)} c_D \right] \\
&= 1 + \frac{1}{2eb} (a-c_D) \left[\alpha - \frac{n+1-B\lambda}{(n+2)} c_D + \frac{2nB\lambda(B\lambda-1)}{(n+1)(n+2)(1+B\lambda)} c_D \right] \\
&= 1 + \frac{1}{2eb} (\alpha - c_D) \left\{ \alpha - \frac{n+1}{n+2} c_D + \frac{B\lambda}{n+2} \left[1 + \frac{2n(B\lambda-1)}{(n+1)(1+B\lambda)} \right] c_D \right\} \\
&= 1 + \frac{1}{2eb} (\alpha - c_D) \left\{ \alpha - \frac{n+1}{n+2} c_D + \frac{\varepsilon_\lambda - 1}{n+2} \left[1 + \frac{2n}{n+1} \left(1 - \frac{2}{\varepsilon_\lambda} \right) \right] c_D \right\}
\end{aligned}$$

3.8.6.1 Welfare Comparative Statics

Proposition 22: We have that

$$\begin{aligned}
 U &= 1 + \frac{1}{2eb} (\alpha - c_D) \left\{ \alpha - \frac{n+1}{n+2} c_D + \frac{\varepsilon_\lambda - 1}{n+2} \left[1 + \frac{2n}{n+1} \left(1 - \frac{2}{\varepsilon_\lambda} \right) \right] c_D \right\} \\
 &= 1 + \frac{1}{2eb} (\alpha - c_D) \left\{ \alpha - \frac{n+1}{n+2} c_D + \frac{B\lambda}{n+2} \left[1 + \frac{2n(B\lambda - 1)}{(n+1)(1+B\lambda)} \right] c_D \right\} \quad (3.79)
 \end{aligned}$$

We know that in the benchmark case without quality upgrading (where $B\lambda = 0$), symmetric trade integration unambiguously implies welfare gains:

$$\frac{\partial U}{\partial L} = -\frac{1}{2eb} \left(\frac{2n+3}{n+2} \alpha - \frac{2n+2}{n+2} c_D \right) \frac{\partial c_D}{\partial L} > 0,$$

since $a > c_D$ and $\frac{\partial c_D}{\partial L} < 0$. This result carries over directly from Melitz and Ottaviano (2008).

For $B\lambda > 0$, it can be shown that the additional term $\left[1 + \frac{2n(B\lambda - 1)}{(n+1)(1+B\lambda)} \right] \frac{B\lambda}{n+2} c_D$ in equation (3.79) is increasing in L , such that the above welfare result of positive gains from trade remains:

$$\frac{\partial}{\partial L} \left(\frac{B\lambda c_D}{n+2} \right) = \frac{(n+1)}{(n+2)^2} \frac{B\lambda \varepsilon_\lambda c_D}{L} > 0.$$

Further

$$\begin{aligned}
 \frac{\partial}{\partial L} \left(\frac{B\lambda - 1}{1+B\lambda} \right) &= \frac{2B}{(1+B\lambda)^2} \frac{\partial \lambda}{\partial L} \\
 &= \frac{2B\lambda}{(1+B\lambda)L} > 0.
 \end{aligned}$$

It is hence the case that $\frac{\partial U}{\partial L} > 0$.

3.8.7 Variable Cost of Quality: Closed Economy

Output FOC (VC):

$$\begin{aligned}
 \pi_i &= \left(p_i - \frac{1}{\varphi} c_i z_i^\varphi \right) x_i \\
 &= \left(a_i - \tilde{b} [(1-e)x_i + eX] - \frac{1}{\varphi} c_i z_i^\varphi \right) x_i \\
 \frac{\partial \pi_i}{\partial x_i} &= \left(p_i - \frac{1}{\varphi} c_i z_i^\varphi \right) + x_i \left(-\tilde{b}(1-e) \right) = 0 \\
 p_i &= \tilde{b}(1-e)x_i + \frac{1}{\varphi} c_i z_i^\varphi
 \end{aligned}$$

Quality FOC (VC):

$$\begin{aligned}
 \pi_i &= \left(\alpha + \beta b(1-e)z_i - \tilde{b} [(1-e)x_i + eX] - \frac{1}{\varphi} c_i z_i^\varphi \right) x_i \\
 \frac{\partial \pi_i}{\partial z_i} &= \beta b(1-e)x_i - c_i x_i z_i^{\varphi-1} = 0 \\
 z_i &= \left[\frac{\beta b(1-e)}{c_i} \right]^{\frac{1}{\varphi-1}} = \left[\frac{B}{c_i} \right]^{\frac{1}{\varphi-1}}
 \end{aligned}$$

Substituting into the FOC for price, we get:

$$p_i = \tilde{b}(1-e)x_i + \frac{1}{\varphi} B^{\frac{\varphi}{\varphi-1}} c_i^{\frac{1}{1-\varphi}}.$$

Second Order Conditions Hessian for variable cost case:

$$H = \begin{vmatrix} -2\tilde{b}(1-e) & B - c_i z_i^{\varphi-1} \\ B - c_i z_i^{\varphi-1} & -(\varphi-1) c_i x_i z_i^{\varphi-2} \end{vmatrix}$$

$$\det |H| = 2\tilde{b}(1-e)(\varphi-1) c_i x_i z_i^{\varphi-2} - \left(B - c_i z_i^{\varphi-1} \right)^2 > 0$$

$$\text{given } z_i = \left[\frac{B}{c_i} \right]^{\frac{1}{\varphi-1}}$$

$$2\tilde{b}(1-e)(\varphi-1) c_i x_i \left[\frac{B}{c_i} \right]^{\frac{\varphi-2}{\varphi-1}} > 0 \text{ if } \varphi > 1.$$

Expressing the Remaining Variables of Interest in terms of the Cost Cut-off

c_D

$$\begin{aligned}
 p_i &= \tilde{b}(1-e) \left[\frac{\alpha}{\tilde{\epsilon}\tilde{b}} - \frac{1}{\tilde{b}(1-e)} p_i + \frac{eN}{\tilde{\epsilon}\tilde{b}(1-e)} \bar{p} + \beta L z_i - \frac{\beta b e N}{\tilde{b}\tilde{\epsilon}} \bar{z} \right] + \frac{1}{\varphi} B^{\frac{\varphi}{\varphi-1}} c_i^{\frac{1}{1-\varphi}} \\
 &= \frac{\alpha(1-e)}{\tilde{\epsilon}} - p_i + \frac{eN}{\tilde{\epsilon}} \bar{p} + \beta b(1-e) z_i - \frac{\beta b(1-e)eN}{\tilde{\epsilon}\tilde{b}} \bar{z} + \frac{1}{\varphi} B^{\frac{\varphi}{\varphi-1}} c_i^{\frac{1}{1-\varphi}} \\
 2p_i &= c_D + \left(\frac{1+\varphi}{\varphi} \right) B^{\frac{\varphi}{\varphi-1}} c_i^{\frac{1}{1-\varphi}} \\
 p_i(c_D, c_i) &= \frac{1}{2} \left[c_D + \left(\frac{1+\varphi}{\varphi} \right) B^{\frac{\varphi}{\varphi-1}} c_i^{\frac{1}{1-\varphi}} \right] \\
 &= \frac{1}{2} \left[c_D + \left(\frac{1+\varphi}{\varphi} \right) \left(\frac{B^\varphi}{c_i} \right)^{\frac{1}{\varphi-1}} \right] \\
 x_i(c_D, c_i) &= \frac{p_i - \frac{1}{\varphi} B^{\frac{\varphi}{\varphi-1}} c_i^{\frac{1}{1-\varphi}}}{\tilde{b}(1-e)} \\
 &= \frac{L}{2b(1-e)} c_D + \frac{L(1+\varphi)}{2\varphi b(1-e)} \left(\frac{B^\varphi}{c_i} \right)^{\frac{1}{\varphi-1}} - \frac{L}{\varphi b(1-e)} \left(\frac{B^\varphi}{c_i} \right)^{\frac{1}{\varphi-1}} \\
 &= \frac{L}{2b(1-e)} c_D + \frac{L(\varphi-1)}{2\varphi b(1-e)} \left(\frac{B^\varphi}{c_i} \right)^{\frac{1}{\varphi-1}} \\
 &= \frac{L}{2b(1-e)} \left[c_D + \frac{\varphi-1}{\varphi} \left(\frac{B^\varphi}{c_i} \right)^{\frac{1}{\varphi-1}} \right] \\
 \pi_i(c_D, c_i) &= \left(p_i - \frac{1}{\varphi} c_i z_i^\varphi \right) x_i \\
 &= \left\{ \frac{1}{2} \left[c_D + \left(\frac{1+\varphi}{\varphi} \right) \left(\frac{B^\varphi}{c_i} \right)^{\frac{1}{\varphi-1}} \right] - \frac{1}{\varphi} \left(\frac{B^\varphi}{c_i} \right)^{\frac{1}{\varphi-1}} \right\} \frac{L}{2b(1-e)} \left[c_D + \frac{\varphi-1}{\varphi} \left(\frac{B^\varphi}{c_i} \right)^{\frac{1}{\varphi-1}} \right] \\
 &= \frac{L}{4b(1-e)} \left[c_D + \frac{\varphi-1}{\varphi} \left(\frac{B^\varphi}{c_i} \right)^{\frac{1}{\varphi-1}} \right]^2.
 \end{aligned}$$

Parametrizing using Pareto, we get an implicit solution for the cut-off:

$$f = E\pi = \int_0^{c_D} \frac{L}{4b(1-e)} \left[c_D + \frac{\varphi-1}{\varphi} \left(\frac{B^\varphi}{c} \right)^{\frac{1}{\varphi-1}} \right]^2 dG(c)$$

$$\begin{aligned}
G(c) &= \left(\frac{c}{c_M}\right)^n, \quad c \in [0, c_M] \\
\frac{dG(c)}{dc} &= G'(c) \\
dG(c) &= G'(c)dc = n \frac{1}{c_M} \left(\frac{c}{c_M}\right)^{n-1} dc.
\end{aligned}$$

$$\begin{aligned}
f &= \frac{L}{4b(1-e)} \int_0^{c_D} \left[c_D + \frac{\varphi-1}{\varphi} \left(\frac{B^\varphi}{c}\right)^{\frac{1}{\varphi-1}} \right]^2 n \frac{1}{c_M} \left(\frac{c}{c_M}\right)^{n-1} dc \\
&= \frac{Lnc_M^{-n}}{4b(1-e)} \int_0^{c_D} \left[c_D + \frac{\varphi-1}{\varphi} \left(\frac{B^\varphi}{c}\right)^{\frac{1}{\varphi-1}} \right]^2 c^{n-1} dc \\
&= \frac{Lnc_M^{-n}}{4b(1-e)} \int_0^{c_D} \left[c_D^2 + \frac{2(\varphi-1)}{\varphi} \left(\frac{B^\varphi}{c}\right)^{\frac{1}{\varphi-1}} c_D + \left(\frac{\varphi-1}{\varphi}\right)^2 \left(\frac{B^\varphi}{c}\right)^{\frac{2}{\varphi-1}} \right] c^{n-1} dc \\
&= \frac{Lnc_M^{-n}}{4b(1-e)} \left[c_D^2 \int_0^{c_D} c^{n-1} dc + \frac{2(\varphi-1)}{\varphi} c_D \int_0^{c_D} \left(\frac{B^\varphi}{c}\right)^{\frac{1}{\varphi-1}} c^{n-1} dc + \left(\frac{\varphi-1}{\varphi}\right)^2 \int_0^{c_D} \left(\frac{B^\varphi}{c}\right)^{\frac{2}{\varphi-1}} c^{n-1} dc \right] \\
&= \frac{Lnc_M^{-n}}{4b(1-e)} \left[\frac{1}{n} c_D^{n+2} + \frac{2(\varphi-1) B^{\frac{\varphi}{\varphi-1}}}{\varphi} c_D \int_0^{c_D} c^{n-1-\frac{1}{\varphi-1}} dc + \left(\frac{(\varphi-1) B^{\frac{\varphi}{\varphi-1}}}{\varphi}\right)^2 \int_0^{c_D} c^{n-1-\frac{2}{\varphi-1}} dc \right] \\
&= \frac{Lnc_M^{-n}}{4b(1-e)} \left\{ \frac{1}{n} c_D^{n+2} + \frac{2(\varphi-1) B^{\frac{\varphi}{\varphi-1}}}{\varphi} \frac{1}{n-\frac{1}{\varphi-1}} c_D^{n+2-\frac{\varphi}{\varphi-1}} + \left[\frac{(\varphi-1) B^{\frac{\varphi}{\varphi-1}}}{\varphi}\right]^2 \frac{1}{n-\frac{2}{\varphi-1}} c_D^{n+2-\frac{2\varphi}{\varphi-1}} \right\}
\end{aligned}$$

$$\frac{4b(1-e)fc_M^n}{L} = c_D^{n+2} \left\{ 1 + 2 \left[\frac{\varphi-1}{\varphi} \left(\frac{B}{c_D}\right)^{\frac{\varphi}{\varphi-1}} \right] \frac{n}{n-\frac{1}{\varphi-1}} + \left[\frac{\varphi-1}{\varphi} \left(\frac{B}{c_D}\right)^{\frac{\varphi}{\varphi-1}} \right]^2 \frac{n}{n-\frac{2}{\varphi-1}} \right\}$$

Mass of firms N : The equilibrium mass of firms can be derived from the expression for the cost cut-off:

$$c_D = \frac{1}{\epsilon} [\alpha(1-e) + eN\bar{p} - BeN\bar{z}]$$

We can express average cost as

$$\bar{c} = \frac{nc_D}{n+1}$$

and average price as

$$\bar{p} = \frac{1}{2} \left[c_D + \left(\frac{1+\varphi}{\varphi} \right) \left(\frac{(n+1)B^\varphi}{nc_D} \right)^{\frac{1}{\varphi-1}} \right]$$

and average quality as

$$\bar{z} = \left[\frac{(n+1)B}{nc_D} \right]^{\frac{1}{\varphi-1}}$$

Rewriting c_D and substituting for \bar{p} , \bar{z} and ϵ , we can derive the mass of firms N :

$$\begin{aligned} c_D &= \frac{\alpha(1-e) + eN \frac{1}{2} \left[c_D + \left(\frac{1+\varphi}{\varphi} \right) \left(\frac{(n+1)B^\varphi}{nc_D} \right)^{\frac{1}{\varphi-1}} \right] - BeN \left[\frac{(n+1)B}{nc_D} \right]^{\frac{1}{\varphi-1}}}{1-e+eN} \\ (1-e)c_D + eNc_D &= \alpha(1-e) + eN \frac{1}{2} \left[c_D + \left(\frac{1+\varphi}{\varphi} \right) \left(\frac{(n+1)B^\varphi}{nc_D} \right)^{\frac{1}{\varphi-1}} \right] - BeN \left[\frac{(n+1)B}{nc_D} \right]^{\frac{1}{\varphi-1}} \\ \alpha(1-e) - (1-e)c_D &= eNc_D - eN \frac{1}{2} \left[c_D + \left(\frac{1+\varphi}{\varphi} \right) \left(\frac{(n+1)B^\varphi}{nc_D} \right)^{\frac{1}{\varphi-1}} \right] + BeN \left[\frac{(n+1)B}{nc_D} \right]^{\frac{1}{\varphi-1}} \\ (1-e)(a-c_D) &= \left\{ c_D - \frac{1}{2} \left[c_D + \left(\frac{1+\varphi}{\varphi} \right) \left(\frac{(n+1)B^\varphi}{nc_D} \right)^{\frac{1}{\varphi-1}} \right] + B \left[\frac{(n+1)B}{nc_D} \right]^{\frac{1}{\varphi-1}} \right\} eN \\ (1-e)(a-c_D) &= \left\{ \frac{1}{2}c_D + \left[1 - \frac{1}{2} \left(\frac{1+\varphi}{\varphi} \right) \right] \left[\frac{(n+1)B^\varphi}{nc_D} \right]^{\frac{1}{\varphi-1}} \right\} eN \\ (1-e)(a-c_D) &= \left\{ c_D + \frac{\varphi-1}{\varphi} \left[\frac{(n+1)B^\varphi}{nc_D} \right]^{\frac{1}{\varphi-1}} \right\} \frac{e}{2}N \\ N &= \frac{2(1-e)(a-c_D)}{e \left[c_D + \frac{\varphi-1}{\varphi} \left[\frac{(n+1)B^\varphi}{nc_D} \right]^{\frac{1}{\varphi-1}} \right]} \end{aligned}$$

3.8.7.1 Variable Cost Comparative Statics

Effect of Market Size α on the Cut-off The implicit solution for the cut-off c_D is given by:

$$\frac{A}{L} = c_D^{n+2} \left\{ 1 + 2 \left[\frac{\varphi-1}{\varphi} \left(\frac{B}{c_D} \right)^{\frac{\varphi}{\varphi-1}} \right] \frac{n}{n - \frac{1}{\varphi-1}} + \left[\frac{\varphi-1}{\varphi} \left(\frac{B}{c_D} \right)^{\frac{\varphi}{\varphi-1}} \right]^2 \frac{n}{n - \frac{2}{\varphi-1}} \right\},$$

where $B > 0$, $A > 0$, $n > 0$; and $\varphi > 1$ by SOC.

In order to find the relationship between the cut-off c_D and market size, L , I differentiate implicitly.

I let:

$$\begin{aligned}
X &= 2 \left[\frac{\varphi-1}{\varphi} B^{\frac{\varphi}{\varphi-1}} \right] \frac{n}{n - \frac{1}{\varphi-1}}, \\
Y &= \left[\frac{\varphi-1}{\varphi} B^{\frac{\varphi}{\varphi-1}} \right]^2 \frac{n}{n - \frac{2}{\varphi-1}}, \\
H &= \left[1 + X c_D(L)^{-\frac{\varphi}{\varphi-1}} + Y c_D(L)^{-\frac{2\varphi}{\varphi-1}} \right].
\end{aligned}$$

$$\begin{aligned}
\frac{d}{dL} \left[\frac{A}{L} \right] &= \frac{d}{dL} \left[c_D(L)^{n+2} \left[1 + X c_D(L)^{-\frac{\varphi}{\varphi-1}} + Y c_D(L)^{-\frac{2\varphi}{\varphi-1}} \right] \right] \\
-\frac{A}{L^2} &= (n+2) c_D(L)^{n+1} \frac{dc_D}{dL} H \\
&\quad + c_D(L)^{n+2} \left[-\frac{\varphi}{\varphi-1} X c_D(L)^{-\frac{\varphi}{\varphi-1}-1} \frac{dc_D}{dL} - \frac{2\varphi}{\varphi-1} Y c_D(L)^{-\frac{2\varphi}{\varphi-1}-1} \frac{dc_D}{dL} \right] \\
\frac{-A}{L^2 c_D(L)^{n+1}} &= \left[(n+2) H - \frac{\varphi}{\varphi-1} X c_D(L)^{-\frac{\varphi}{\varphi-1}} - \frac{2\varphi}{\varphi-1} Y c_D(L)^{-\frac{2\varphi}{\varphi-1}} \right] \frac{dc_D}{dL} \\
&= \left\{ (n+2) \left[1 + X c_D(L)^{-\frac{\varphi}{\varphi-1}} + Y c_D(L)^{-\frac{2\varphi}{\varphi-1}} \right] - \frac{\varphi}{\varphi-1} X c_D(L)^{-\frac{\varphi}{\varphi-1}} - \frac{2\varphi}{\varphi-1} Y c_D(L)^{-\frac{2\varphi}{\varphi-1}} \right\} \frac{dc_D}{dL} \\
&= \left\{ n+2 + \left[n+2 - \frac{\varphi}{\varphi-1} \right] X c_D(L)^{-\frac{\varphi}{\varphi-1}} + \left[n+2 - \frac{2\varphi}{\varphi-1} \right] Y c_D(L)^{-\frac{2\varphi}{\varphi-1}} \right\} \frac{dc_D}{dL}
\end{aligned}$$

A sufficient condition for $\frac{dc_D}{dL}$ to be negative is $n > \frac{2\varphi}{\varphi-1}$.

Submodularity of Revenues Given the implicit solution for the cut-off which makes cut-off comparative statics intractable, I consider prices and output separately. For prices we have:

$$\frac{\partial p_i}{\partial c_i} = -\frac{(1+\varphi)}{(\varphi-1)\varphi} \left(\frac{B}{c_i} \right)^{\frac{\varphi}{\varphi-1}} < 0$$

and for output:

$$\begin{aligned}
\frac{\partial x_i}{\partial c_i} &= -\frac{L}{2b(1-e)} \frac{\varphi-1}{(\varphi-1)\varphi} \left(\frac{B}{c_i} \right)^{\frac{\varphi}{\varphi-1}} < 0 \\
\frac{\partial^2 x_i}{\partial c_i \partial L} &= -\frac{1}{2b(1-e)} \frac{\varphi-1}{(\varphi-1)\varphi} \left(\frac{B}{c_i} \right)^{\frac{\varphi}{\varphi-1}} < 0.
\end{aligned}$$

Combining the two results, we can see that revenues are submodular in cost and market size.

3.8.8 Open Economy

The derivation of the equilibrium that follows is based on Antoniadou (2008) with the preference structure by Eckel et al (2011) used also for the closed economy version. The basic set-up for the production sector is as described for the closed economy above. In addition, firms now face variable trade costs for their exports. If a firm in l exports to h , its delivered cost is $\tau^{lh}c$, where τ^{lh} are iceberg trade costs. Note that I assume $\tau^{hl} = \tau^{lh} > 1$ for $l \neq h$ and that I normalize $\tau^{ll} = 1$. Markets are segmented, so firms independently maximise profits for each market. Recall that q_0 is the non-tradeable numeraire good which is produced at unit cost with CRS technology and sold on a perfectly competitive market. Wages are hence pinned down at unity.

Consider first a firm's pricing and quality decision in an open economy. The firm's profit maximising price for the domestic and export market respectively, must satisfy:

$$p_D^l(c) = \tilde{b}^l (1 - e) x_D^l + c \quad (3.80)$$

$$p_X^l(c) = \tilde{b}^h (1 - e) x_X^l + \tau^{lh}c \quad (3.81)$$

Further, its profit maximising level of quality for the domestic and foreign markets respectively are given by the first-order conditions:

$$z_D^l(c) = \frac{\beta b (1 - e) x_D^l}{\theta} \quad (3.82)$$

$$z_X^l(c) = \frac{\beta b (1 - e) x_X^l}{\theta} \quad (3.83)$$

Using equation (3.6) and defining as c_D^l the cost of the marginal firm which has $c = p^{l \max}$ and therefore produces zero output and does not invest in quality ($z_D^l(c) = 0$ for $x_D^l(c) = 0$ from equations (3.82) and (3.83)), we can write:

$$c_D^l = \frac{1}{e^l} \left[\alpha (1 - e) + e N^l \bar{p}^l - \beta b (1 - e) e N^l \bar{z}^l \right] = p^{l \max} \quad (3.84)$$

$$c_X^l = \frac{p^{h \max}}{\tau^{lh}} = \frac{c_D^h}{\tau^{lh}}. \quad (3.85)$$

Following Melitz and Ottaviano (2008) and Antoniadou (2008), I substitute x_i from equation (3.5) into equations (3.80) and (3.81) and rearrange, so that I can express the optimal price and all

other variables of interest as functions of the cut-off c_D and a firm's cost c :

$$p_D^l(c_D, c, z_D^l) = \frac{1}{2}(c_D^l + c) + \frac{\beta b(1-e)}{2} z_D^l \quad (3.86)$$

$$p_X^l(c_X, c, z_X^l) = \frac{\tau^{lh}}{2}(c_X^l + c) + \frac{\beta b(1-e)}{2} z_X^l. \quad (3.87)$$

From equations (3.80)/(3.81) and (3.86)/(3.87), profits are (note that firms here have to incur the fixed cost of quality investment once for the home market and once for every export market):

$$\pi_D^l(c_D, c, z_D^l) = \frac{L^l}{4b(1-e)}(c_D^l - c)^2 + \frac{\beta L^l}{2} z_D^l (c_D^l - c) + \frac{\beta^2 b(1-e)L^l - 2\theta}{4} z_D^l{}^2, \quad (3.88)$$

$$\pi_X^l(c_X, c, z_X^l) = \frac{L^h(\tau^{lh})^2}{4b(1-e)}(c_X^l - c)^2 + \frac{\beta L^h \tau^{lh}}{2} z_X^l (c_X^l - c) + \frac{\beta^2 b(1-e)L^h - 2\theta}{4} z_X^l{}^2. \quad (3.89)$$

Maximising equations (3.88) and (3.89) with respect to z_i , the optimal level of quality z^* for the domestic and export market respectively, is:

$$z_D^{l*}(c_D^l, c) = \lambda_D^l (c_D^l - c) \quad (3.90)$$

$$z_X^{l*}(c_X^l, c) = \lambda_X^l \tau^{lh} (c_X^l - c) \quad (3.91)$$

where

$$\lambda_D^l = \frac{\beta L^l}{2\theta^{(l)} - \beta^2 b(1-e)L^l} \quad (3.92)$$

$$\lambda_X^l = \frac{\beta L^h}{2\theta^{(l)} - \beta^2 b(1-e)L^h}. \quad (3.93)$$

Substituting into equations (3.90) and (3.91), export prices and quantities for firms in country l exporting to country h can be written as functions of firms' relative efficiencies $v = (c_D^h - \tau^{lh}c)$:

$$\begin{aligned} p_X^{lh}(c_D, c) &= \frac{\varepsilon_\lambda^{lh}}{2} (c_D^h - \tau^{lh}c) + \tau^{lh}c \\ x_X^{lh}(c_D, c) &= \frac{L^h \varepsilon_\lambda^{lh}}{2b(1-e)} (c_D^h - \tau^{lh}c) \\ r_X^{lh}(c_D, c) &= \frac{L^h \varepsilon_\lambda^{lh}}{2b(1-e)} (c_D^h - \tau^{lh}c) \left[\frac{\varepsilon_\lambda^{lh}}{2} (c_D^h - \tau^{lh}c) + \tau^{lh}c \right] \\ &= \frac{L^h \varepsilon_\lambda^{lh}}{4b(1-e)} \left[(c_D^h)^2 - (\tau^{lh}c)^2 + B\lambda^h (c_D^h - \tau^{lh}c)^2 \right] \end{aligned} \quad (3.94)$$

where

$$\varepsilon_\lambda^{lh} = 1 + B\lambda^{lh} = 1 + B \frac{\beta L^h}{2\theta^{(l)} - \beta^2 b(1-e)L^h}$$

is the elasticity of λ_X^l with respect to market size L^h . It gives an indication of the scope for quality upgrading for l -country firms in export market h . Exporters will be limited by their own technology, θ^l and the size of the foreign market, L^h .

Deriving the Gravity Equation The gravity equation associated with this model is for exports from firms in l to country h :

$$\begin{aligned} EXP^{lh} &= N_E^l \int_0^{c_X^{lh}} r_X^{lh}(c) dG^l(c) \\ &= \frac{L^h \varepsilon_\lambda^h}{4b(1-e)} N_E^l \int_0^{c_D^h/\tau^{lh}} \left[(c_D^h)^2 - (\tau^{lh}c)^2 + B\lambda^h (c_D^h - \tau^{lh}c)^2 \right] dG^l(c) \\ &= \frac{L^h \varepsilon_\lambda^h}{4b(1-e)} N_E^l \int_0^{c_D^h/\tau^{lh}} \left[(c_D^h)^2 - (\tau^{lh}c)^2 + B\lambda^h (c_D^h)^2 - 2B\lambda^h c_D^h \tau^{lh}c + B\lambda^h (\tau^{lh}c)^2 \right] dG^l(c) \\ &= \frac{L^h \varepsilon_\lambda^h}{4b(1-e)} N_E^l \int_0^{c_D^h/\tau^{lh}} \left[(c_D^h)^2 - (\tau^{lh}c)^2 + B\lambda^h (c_D^h)^2 - 2B\lambda^h c_D^h \tau^{lh}c + B\lambda^h (\tau^{lh}c)^2 \right] n \frac{1}{c_M^l} \left(\frac{c}{c_M^l} \right)^{n-1} dc \\ &= \frac{L^h n c_M^{-n} \varepsilon_\lambda^h}{4b(1-e)} N_E^l \int_0^{c_D^h/\tau^{lh}} \left[(c_D^h)^2 - (\tau^{lh}c)^2 + B\lambda^h (c_D^h)^2 - 2B\lambda^h c_D^h \tau^{lh}c + B\lambda^h (\tau^{lh}c)^2 \right] c^{n-1} dc \end{aligned}$$

$$\begin{aligned}
&= \frac{L^h n c_M^{-n} \varepsilon_\lambda^h}{4b(1-e)} N_E^l \left\{ \left[\left(c_D^h \right)^2 \int_0^{c_D^h/\tau^{lh}} c^{n-1} dc - \int_0^{c_D^h/\tau^{lh}} \left(\tau^{lh} c \right)^2 c^{n-1} dc + B\lambda^h \left(c_D^h \right)^2 \int_0^{c_D^h/\tau^{lh}} c^{n-1} dc - 2B\lambda^h c_D^h \tau^{lh} \int_0^{c_D^h/\tau^{lh}} c^n dc + B\lambda^h \int_0^{c_D^h/\tau^{lh}} \left(\tau^{lh} c \right)^2 c^{n-1} dc \right] \right\} \\
&= \frac{L^h n c_M^{-n} \varepsilon_\lambda^h}{4b(1-e)} N_E^l \left\{ \left[\left(c_D^h \right)^{n+2} \frac{1}{(\tau^{lh})^n n} - \left(c_D^h \right)^{n+2} \frac{1}{(\tau^{lh})^n (n+2)} + B\lambda^h \left(c_D^h \right)^{n+2} \frac{1}{(\tau^{lh})^n n} - 2B\lambda^h \left(c_D^h \right)^{n+2} \frac{1}{(\tau^{lh})^n (n+1)} + B\lambda^h \left(c_D^h \right)^{n+2} \frac{1}{(\tau^{lh})^n (n+2)} \right] \right\} \\
&= \frac{L^h n c_M^{-n} \varepsilon_\lambda^h}{4b(1-e)} \frac{(c_D^h)^{n+2}}{(\tau^{lh})^n} N_E^l \left\{ \left[\frac{1}{n} - \frac{1}{(n+2)} + B\lambda^h \frac{1}{n} - 2B\lambda^h \frac{1}{(n+1)} + B\lambda^h \frac{1}{(n+2)} \right] \right\} \\
&= \frac{L^h n c_M^{-n} \varepsilon_\lambda^h}{4b(1-e)} \frac{(c_D^h)^{n+2}}{(\tau^{lh})^n} N_E^l \left\{ \left[\frac{(n+1)(n+2)}{n(n+1)(n+2)} - \frac{n(n+1)}{n(n+1)(n+2)} + B\lambda^h \frac{(n+1)(n+2)}{n(n+1)(n+2)} - B\lambda^h \frac{2n(n+2)}{n(n+2)(n+1)} + B\lambda^h \frac{n(n+1)}{n(n+1)(n+2)} \right] \right\} \\
&= \frac{L^h n c_M^{-n} \varepsilon_\lambda^h}{4b(1-e)} \frac{(c_D^h)^{n+2}}{(\tau^{lh})^n} N_E^l \left\{ \left[\frac{2}{n(n+2)} + B\lambda^h \frac{2}{n(n+1)(n+2)} \right] \right\} \\
&= \frac{L^h c_M^{-n} \varepsilon_\lambda^h}{2b(1-e)(n+2)} \frac{(c_D^h)^{n+2}}{(\tau^{lh})^n} N_E^l \left[1 + \frac{B\lambda^h}{(n+1)} \right] \\
&= \frac{L^h c_M^{-n} \varepsilon_\lambda^h (n+1 + B\lambda^h)}{2b(1-e)(n+2)(n+1)} \frac{(c_D^h)^{n+2}}{(\tau^{lh})^n} N_E^l \\
&= \frac{\varepsilon_\lambda^h (n+1 + B\lambda^h)}{n+1} \frac{1}{2b(1-e)(n+2)} N_E^l c_M^{-n} L^h \left(c_D^h \right)^{n+2} \left(\tau^{lh} \right)^{-n} \\
&= \frac{\varepsilon_\lambda^h (n + \varepsilon_\lambda^h)}{n+1} \frac{1}{2b(1-e)(n+2)} N_E^l c_M^{-n} L^h \left(c_D^h \right)^{n+2} \left(\tau^{lh} \right)^{-n}
\end{aligned}$$

The import share of country h from firms in country l is:

$$\begin{aligned}
\lambda_{lh} &= \frac{X_{lh}}{\sum_k X_{kh}} \\
&= \frac{\frac{(1+B\lambda^h)(n+1+B\lambda^h)L^h(c_D^h)^{n+2}}{2b(1-e)(n+2)(n+1)} N_E^l (c_M^l)^{-n} (\tau^{lh})^{-n}}{\frac{(1+B\lambda^h)(n+1+B\lambda^h)L^h(c_D^h)^{n+2}}{2b(1-e)(n+2)(n+1)} \sum_k N_E^k (c_M^k)^{-n} (\tau^{kh})^{-n}} \\
&= \frac{N_E^l (c_M^l)^{-n} (\tau^{lh})^{-n}}{\sum_k N_E^k (c_M^k)^{-n} (\tau^{kh})^{-n}}
\end{aligned}$$

Chapter 4

Sparkling Trade Flows: Does Export Market Size Amplify Quality Advantage?

4.1 Introduction¹

The objective of this chapter is to drill deeper into the mechanisms by which globalization affects industry aggregates in a heterogeneous firms setting, in particular, aggregate quality. The empirical analysis carried out in this chapter, thus links in with the theoretical analysis in Chapter 3 regarding the relationship between market size and product quality. In a quality-augmented heterogeneous firms model with flexible mark-ups, as the one presented in Chapter 3, three specific mechanisms are at play: aggregate quality can change via (i) asymmetric pro-competitive effects on the intensive margin, i.e. a relatively greater expansion in sales for the high quality firms; (ii) the extensive margin via selection;

¹**Acknowledgments:** I would like to thank Beata Javorcik and Peter Neary for their guidance with this chapter. I am also grateful to the CEPII in Paris for hosting me as a visiting researcher, Patrice Dumont at French Customs for helping to obtain data access, and Matthieu Crozet for sharing code. Furthermore, I would like to thank Richard Baldwin, Debopam Bhattacharya, Matthieu Crozet, Banu Demir, Carsten Eckel, Lionel Fontagné, Martina Kirchberger, and Thierry Mayer for very helpful discussions, and seminar participants at Aarhus, the CEPII, Essex, LMU Munich, LSE, Oxford, PSE, and participants of ETSG 2013 for insightful comments.

and (iii) quality upgrading by the most productive firms.² In this chapter, I provide novel empirical results for the intensive margin channel.

Theoretically, the market size effects studied here arise when mark-ups are flexible in a monopolistically competitive setting and firms are heterogeneous. With flexible mark-ups and monopolistic competition, globalization implies downward pressure on prices; when firms are at the same time heterogeneous in their productivity, these mark-up reductions are skewed in such a way that sales expand relatively more for higher productivity firms (as implied by the model in Melitz and Ottaviano, 2008). The evidence presented in this chapter supports this mechanism for a quality-augmentation of Melitz and Ottaviano (2008), where higher productivity firms produce higher quality: I demonstrate that a larger market is associated with sales being skewed towards the higher quality firms. The analysis thus confirms a key prediction of the quality-augmented Melitz-Ottaviano (2008) model presented in the previous chapter and supports the assumption of flexible mark-ups over CES preferences. This is an important result in light of the fact that the nature of preferences has been shown to matter greatly for the efficiency of the market outcome and welfare.³ In the present chapter, this prediction is tested in the context of the champagne industry.

I use a dataset by Crozet, Head and Mayer (2012), which is unique in containing a direct measure of firm-level quality. The authors combine confidential French firm-destination level export data with producer-level star ratings taken from the world's most comprehensive champagne guide by Juhlin (2008). The key idea underlying the empirical strategy is that the impact of export market size on firm-level export sales should vary with firm quality as captured by Juhlin's (2008) star ratings. More specifically, the theory leads us to expect the coefficient on the interaction between market size and producer ratings to be increasing in a firm's rating. I identify my parameters of interest by relying on within-firm variation in export sales across French export destinations with exogenously

²The latter effect is only present if scale effects are important for quality investment.

³e.g. Dixit and Stiglitz, 1977; Mrazova and Neary, 2013.

varying market sizes. This identification strategy is based on Mayer, Melitz and Ottaviano (2014), who estimate the impact of market size on within-firm allocation of resources across varieties for multi-product firms.⁴ Following the literature, I capture market size using GDP in my main specifications. In addition, I use champagne absorption (total destination champagne exports) as a closer proxy for the relevant market size.

I find strong support of the intensive margin hypothesis in the data. Initially, I run a simple OLS regression of export sales on interactions of market size with quality ratings. However, the champagne trade matrix contains many zeroes: of the 40,586 observations in the dataset, approximately 7.5% correspond to positive export flows. This makes selection into export markets an important issue which needs to be addressed econometrically. I follow Crozet, Head and Mayer (2012) in estimating a Tobit model as my preferred specification. Using Monte Carlo simulations, the authors show that Tobit performs very well in the context of quality selection issues.

I conduct three robustness checks: firstly, I re-estimate the model using firm-destination export quantities as the dependent variable. Secondly, I estimate the model using a Heckman approach. Finally, I control for GDP per capita effects. Strictly, income effects should not feature in an empirical application of the model given the assumption of quasilinear preferences. GDP per capita has, however, also been linked to differences in taste. I therefore include a robustness check which controls for GDP per capita interactions.⁵

4.1.1 Literature

This chapter builds on three important strands of the trade and IO literature: (i) contributions exploring the pro-competitive/market size effects which can accompany trade

⁴An alternative strategy would be to consider trade liberalization episodes, using variation in the trade environment over time. Iacovone and Javorcik (2012) and Verhoogen (2008) for example rely on this strategy in their studies on quality upgrading by Mexican firms in the context of Mexico's NAFTA entry (though they do not consider market size effects per se). However, France has not had liberalization episodes recently which are suitable to capture exogenous changes in market size.

⁵In the appendix, I also consider the price component of export revenues in order to investigate whether there is any evidence for quality upgrading. I provide evidence for within-firm price discrimination across export markets using a price decomposition suggested by Harrigan, Ma and Shlychkov (2012). However, I find that these price discrimination patterns are not systematically related to market size.

integration; (ii) contributions from the trade and IO literature which investigate the consequences of complementarities in firms' production functions (mathematically, supermodularity); (iii) a strand of the recent trade literature which establishes a systematic relationship between product quality and characteristics of the trade environment, in particular market size.

Market Size Effects Since Krugman's (1979) seminal contribution on pro-competitive effects, many researchers have investigated the consequences of trade integration in a setting of imperfect competition (both in a context of monopolistic competition and oligopoly). The introduction of firm heterogeneity into the monopolistic competition/variable elasticity of demand (VED) preference-setting adds another dimension. It allows to capture the heterogeneous effect of market size on individual firms with different productivities.

Some, but not yet many, contributions have presented evidence consistent with the assumption of endogenous mark-ups in combination with firm heterogeneity: findings by Syverson (2004) and Campbell and Hopenhayn (2005), based on data on US states, are consistent with theoretical predictions regarding the effect of market size on firm performance measures. Both studies consider regional US markets and find that a larger market size is associated with larger firm size on average. Evidence on selection on the other hand is ambiguous: while Campbell and Hopenhayn (2005) find that the firm size distribution is more disperse in a larger market, Syverson (2004) finds evidence in line with tougher selection, i.e. the distribution is less disperse. Iacovone, Rauch and Winters (2013) find heterogeneous effects of import competition from China on the intensive margin of Mexican firms of different productivities (as inferred by their size). Here I present novel evidence which is consistent with heterogeneous market size effects on the intensive margin.

Further evidence of market size effects can be found in the multi-product firms literature. Iacovone and Javorcik (2010) show that firms concentrate increasingly on their core products as competition gets tougher (in their case, as Mexican firms are exposed to more

competition post-NAFTA accession). Mayer, Melitz and Ottaviano (2014) establish that the size of the destination market is an important determinant of the export behaviour of multi-product firms in terms of their exported product mix; like Iacovone and Javorcik (2010), they find strong evidence that in markets with tougher competition, multi-product firms skew their exports towards their best performing products. This chapter adds to this literature by providing some first empirical evidence on this skewing of export sales towards the higher quality firms.

Supermodularity Mathematically, the key concept studied here is that of supermodularity or what Mrazova and Neary (2011) call the “Matthew Effect”. The best firms benefit the most from trade integration, or as Mrazova and Neary (2011, p.6) put it: “to those who have, more shall be given”. The Matthew Effect arises from complementarities between firm characteristics and market characteristics which play out as a consequence of changes in the trade environment. Mrazova and Neary (2011) theoretically study complementarities between variable trade costs and inverse productivity.⁶ The case I consider here is characterised by a complementarity between firm productivity and market size by which firms gain more from an increase in market size the more favourable their productivity draw. Here, these are also the highest quality firms.

Quality and Market Size Several recent contributions have considered the relationship between market size and product quality using trade data. In doing so, they have mostly exploited variation in market size over the cross-section of a country’s export markets rather than variation in market size over time. These empirical investigations have been conducted at different levels of aggregation, mainly at the product level and further

⁶These types of complementarities have been studied widely outside the trade context, in particular in the industrial organization literature. For example, Milgrom and Roberts (1990) study these mechanisms in modern manufacturing processes. Topkis (1978) is the seminal paper which formulates the idea that complementarities (mathematically, the property of supermodularity) imply monotone comparative statics for firm-level decisions. Bache and Laugesen (2013) build on these results to derive conditions for industry-level monotone comparative statics for environments where firm-level decisions are affected also by changes in the competitive environment and may thus individually not exhibit monotone comparative statics - such as a large class of heterogeneous firms trade models.

disaggregated at the firm level. While there is no agreement on the sign of the market size-quality relationship at the product level, the firm-level investigations have yielded more consistent results. In what follows, I cast the results to date in terms of the three quality mechanisms discussed above - the intensive, extensive and upgrading margins (see Table 4.1).

At the product level, the three mechanisms cannot be distinguished. Studies which have worked at the product level, have taken the average unit value of exports as a proxy for the embedded quality. The average export price of a particular product may vary across destination markets due to price discrimination (one reason for which may be that the same firm chooses to export different levels of quality to different markets) or due to a different composition of the group of exporting firms. Composition in turn changes if exporters have different market shares in different markets (via the intensive margin mechanism) or if there is an altogether different group of exporters present (via changes on the extensive margin). Baldwin and Harrigan (2011) find that the relationship between market size and product quality is negative on average for the universe of products being exported by US firms. Kneller and Yu (2008) consider exports of Chinese firms at the product level and find that the sign of the relationship depends on the industry under consideration: it is positive for twelve of the 19 industries in their sample, negative for three and no relationship can be detected for four industries. While mainly interested in firm-level relationships, Manova and Zhang (2012) also benchmark their results against the existing product-level literature: they establish a negative relationship overall.

Only recently have researchers started looking at firm-level pricing behaviour across export markets. Within-firm prices vary considerably across destination markets and several studies have found a positive significant relationship with export market size. These studies include Manova and Zhang (2012) for Chinese exporters, Bastos and Silva (2010) for Portugal, and Görg, Halpern and Murakozy (2010) for Hungary. Results in Harrigan, Ma and Shlychkov (2012) point to a weakly positive relationship in the US export data. Only Martin (2012) finds no such relationship for French exporting firms.

The overall evidence is thus consistent with the quality discrimination hypothesis by which firms on average export a higher level of quality to larger markets. Two studies present evidence of quality upgrading over time, both in the context of Mexico's NAFTA accession. While not explicitly considering market size as a mechanism, Iacovone and Javorcik (2012) present direct evidence of Mexican firms' upgrading their product quality (measured as an increase in unit values) in anticipation of entering the US market. Verhoogen (2008) shows patterns in wages of white and blue collar workers in the years following Mexico's NAFTA entry that are also consistent with quality upgrading - however, the underlying theoretical mechanism is one of non-homothetic preferences rather than market size effects.

We currently do not have much evidence on how the extensive margin reacts to increases in market size. Crozet, Head and Mayer (2009 WP) consider the extensive margin with respect to changes in market "attractiveness". Since their model is characterised by CES preferences, they do not consider market size effects per se; their measure for market attractiveness is positively related to market size, but also includes other factors. Their analysis of the champagne industry suggests that the simple average of quality is decreasing in market attractiveness, implying that a more attractive market makes it easier for low quality firms to enter.

The subsequent analysis of the intensive margin suggests that even though simple average quality may be falling in market size due to the extensive margin, weighted average quality will behave differently due to a positive effect arising from the intensive margin. This is highly relevant from a welfare perspective. Changes in relative sales of high quality and low quality firms in favour of the high quality suppliers will have a positive effect on average quality. I decompose the revenue effect further to show that the variation in the value of export sales is driven by quantities rather than prices.

The contribution of this chapter is to present some first empirical evidence on the intensive margin channel. Taken together with the evidence presented in this chapter, the firm level results discussed above thus throw new light on the ambiguous nature of the market size-quality relationship at the product level: the evidence suggests that

Authors	Margins	Quality - Mkt Size	Dep Var
Kneller-Yu (2008)	ext+int+upgr	+/-	product unit value
Baldwin-Harrigan (2011)	ext+int+upgr	-	product unit value
Manova-Zhang (2012)	ext+int+upgr	-/0	product unit value
Bastos-Silva (2010)	upgrading	+	firm-product unit value
Iacovone-Javorcik (2012)	upgrading	+	firm-product unit value
Manova-Zhang (2012)	upgrading	+	firm-product unit value
Martin (2012)	upgrading	0	firm-product unit value
Harrigan et al (2012)	upgrading	(+)	firm-product unit value
Görg et al (2010)	upgrading	+	firm-product unit value
this chapter	intensive margin	+	firm-product revenue

Table 4.1: Quality-Market Size Relationship in the Literature

aggregate quality is increasing in market size thanks to quality upgrading and more than proportionate increases in sales for high quality firms while some of this effect may be offset by the entry of lower quality firms. The evidence at the product level suggests the strength of these conflicting effects varies by industry and market characteristics of the export destination.

The paper proceeds as follows: Section 4.2 presents the theoretical mechanism that will guide the analysis along with the baseline specification. Section 4.3 discusses the data. Section 4.4 presents results including robustness checks and Section 4.5 concludes.

4.2 Theoretical Background and Baseline Specification

Key Mechanism The empirical analysis in the present chapter is guided by a key theoretical mechanism for the aggregate quality impact of globalization in a quality-augmented Melitz-Ottaviano (2008) model: a larger market is associated with a disproportionate increase in sales for high productivity firms, i.e. there is an asymmetric effect of market size on firms' intensive margin in favour of the higher productivity firms. Since optimal product quality in the model is monotonically increasing in firm productivity, the intensive margin effect translates to the quality dimension (this is true independently of whether quality incurs a fixed cost investment or additional variable costs as shown in Chapter 3). It is therefore consistent with the model to capture this effect in the quality context as I

do in the present chapter.

More generally, the effect is due to an underlying complementarity in firms' optimized profit and revenue functions. The key mechanism driving the intensive margin effect arises from a complementarity between firm productivity and market size. Mrazova and Neary (2011) introduce the term "Matthew Effect" to the trade literature, to capture the phenomenon by which the best firms benefit the most from a trade liberalization.^{7,8} In order to generate the Matthew effect related to market size, the optimized revenue function needs to be twice differentiable and multiplicative in market size and the inverse of firms' cost draws. Furthermore, it needs to be sub-modular with respect to market size and cost (supermodular with respect to market size and inverse cost): firm-level revenues need to be increasing in market size while the rate at which this happens is decreasing in a firm's cost draw, i.e. the revenue "gap" between high and low cost firms is getting larger as market size increases. More formally, the Matthew Effect in the current context is given by $\frac{\partial r^2}{\partial L \partial c} < 0$, where r are firm-level revenues, L is market size and c is a firm's cost draw; we can capture this effect in the quality dimension if firm-level quality is monotonically related to firms' productivity draws.

I now turn to the specific functional forms introduced in Chapter 3 and derive the main testable prediction. I focus on the case of fixed quality cost, though the same effect can also be shown to hold for the variable cost case. In the subsequent empirical analysis, I identify parameters of interest by relying on exogenous variation in market size across French export markets. The identification strategy thus requires that the effect also hold in an open economy set-up for within-firm variation in export revenues across export markets. In what follows, I show that this is indeed the case. Using the open economy set-up presented in Chapter 3, export revenues, r_X^l , for a firm with cost draw c exporting

⁷The term Matthew Effect was originally coined by the Sociologist Robert Merton (1968) in reference to the Gospel of Matthew: "For unto every one that hath shall be given, and he shall have abundance: but from him that hath not shall be taken even that which he hath." (Matthew, 25:29, King James Bible)

⁸Mrazova and Neary (2011) consider a different type of complementarity, namely that between inverse firm productivity and variable trade costs; they do so in the context of a heterogeneous firms trade model with general preferences: here, a reduction in per unit trade costs will bring the largest benefits to the firms selling the most units, which in Melitz (2003) type models are the firms with the highest productivities.

from country l to country h were given by equation (3.94, Ch.3 Appendix section 3.8.8):

$$r_X^l = \frac{L^h \varepsilon_\lambda^{lh}}{2b(1-e)} (c_D^h - \tau^{lh}c) \left[\frac{\varepsilon_\lambda^{lh}}{2} (c_D^h - \tau^{lh}c) + \tau^{lh}c \right], \quad (4.1)$$

where $\varepsilon_\lambda^{lh} = 1 + B\lambda_X^l = 1 + B\frac{\beta L^h}{2\theta^{(l)} - \beta^2 b(1-e)L^h}$ is the elasticity of λ with respect to export market size for l -country firms. In the appendix, I derive the open economy cut-off for a 2-country world economy. Analogous to the closed economy case, we can then show that:

$$\frac{\partial (r_X^l)^2}{\partial c \partial L^h} = -\frac{(\varepsilon_\lambda^{lh})^2}{2b(1-e)} \left[\frac{B\lambda_X^l}{L^h} \left(\frac{n+1}{n+2} c_D^h - \tau^{lh}c \right) + B\lambda_X^l (c_D^h - \tau^{lh}c) + \tau^{lh}c \right] \quad (4.2)$$

where a sufficient condition for submodularity (i.e. for this expression to be negative) is $\tau^{lh}c < \frac{n+1}{n+2}c_D^h$.

Given $z_X^l = \lambda_X^l (c_D^h - \tau^{lh}c)$ (equation 3.91, section 3.8.8), where z_X^l is the level of quality exported by a firm in country l to country h , it is also the case that $\frac{\partial z_X^l}{\partial c} < 0$; that is, in the model optimal quality choice is monotonically increasing in a firm's productivity. This validates the use of observed product quality as a proxy for unobservable productivity. Overall, we thus get the prediction that the size of the export market has a positive effect on firm-level sales, and this effect is increasing in the level of observed product quality.

Below I test for the existence of the Matthew Effect, taking a reduced form view of quality. I use an empirical quality measure, Z , which is firm-specific and fixed across export markets, as a proxy for productivity. Any quality upgrading that might also be happening in a larger market is not reflected in a change in the empirical quality measure used in this chapter. This is valid as long as the ranking of producers stays the same across markets, which theory suggests it does. I thus test: $\frac{\partial (r_X^l)^2}{\partial L^h \partial Z} > 0$.

Given that productivity is unobserved and is fairly difficult to estimate (Olley and Pakes, 1996; Levinsohn and Petrin, 2003; Akerberg, Caves and Frazer, 2006), a direct quality measure as the one employed here is arguably a better way to test for the Matthew Effect than productivity estimates.

Main Hypothesis & Baseline Specification In what follows I test the prediction that $\frac{\partial^2(r_{fd}^l)}{\partial L^h \partial Z} > 0$. I use the following baseline specification which regresses an interaction of firm quality and market size on firm-destination export revenue. I estimate the following export value relationship for firm f exporting to destination d :

$$\ln r_{fd}^{FOB} = \beta Z_f * \ln L_d + \gamma \ln L_d + \delta \mathbf{X}_d + \theta_f + \varepsilon_{fd}. \quad (4.3)$$

Here, $\ln r_{fd}^{FOB}$ are the export revenues of firm f in destination d , β is the coefficient of interest on the market size-quality interaction, and Z_f is an indicator for producer quality. Furthermore, $\ln L_d$ denotes the log of market size and \mathbf{X}_d is a vector of controls. θ_f are firm fixed effects, which are needed to capture the within-firm variation in export revenues as market size increases. The prediction is thus that $\beta > 0$.⁹

This specification has the basic features of a gravity equation.¹⁰ If there are no zeroes in the trade matrix, equation (4.3) can be estimated using OLS. A particular advantage of OLS is that it is very well suited for estimations involving fixed effects. However, if firms do not export to all markets, OLS estimation no longer yields the maximum likelihood estimator for equation (4.3). This is relevant for the estimations carried out in this chapter, as zeroes are a frequent occurrence in the firm-destination champagne export matrix. From a theoretical point of view, the recent trade literature has argued that these zeroes arise due to selection of firms into export markets. If we assume that this is the correct model, a zero would thus be observed if a firm is not good enough to export to a particular market.

Head and Mayer (2014) review the performance of a series of estimators in their recent Handbook chapter on gravity estimation for the case with many structural zeroes. Their Monte Carlo simulations suggest that Eaton and Kortum's (2001) Tobit estimator (the EK Tobit hereafter) performs best by a wide margin when it comes to handling zeroes.

⁹If fixed quality costs are important, the effect is amplified by additional market-size-induced quality upgrading by the best firms. If quality incurs only variable cost, the estimate of the effect (i.e. the size of the coefficient) can be seen as a lower bound. The prediction that $\beta > 0$ is the same in both cases.

¹⁰The gravity literature, starting with Tinbergen (1962), has established one of the most robust empirical relationships in international economics, namely that the bilateral trade volume between a country pair is proportional to the trade partners' economic sizes and inversely related to the distance between them.

The EK Tobit is thus the preferred specification in this chapter. Eaton and Kortum (2001) suggest a censoring point for their Tobit estimator in line with the recent trade theory: they show that the value of minimum destination exports is a maximum likelihood estimator of the censoring point as implied by models with fixed export costs; exports are only observed once a firm has high enough sales to cover the fixed costs of entry to a market. Models where selection is induced by fixed costs thus imply a strictly positive censoring point. A model where selection happens via a choke price such as Melitz and Ottaviano (2008) implies a censoring point of zero, since the marginal exporter here has a zero mass. Head and Mayer (2014), however, argue that zero censoring is problematic econometrically since sign and significance of estimators in this case becomes sensitive to the units of measurement of the export flows. They also show that Poisson Pseudo Maximum Likelihood estimators do not perform well when the frequency of structural zeroes is very high as in the present case.¹¹

Another way to deal with selection bias is a two-stage Heckman estimator. The Heckman approach has the advantage that it imposes less structure in terms of the error terms than the Tobit model. The assumption of normally distributed errors is necessary only for the Probit stage but not for the export value equation (Harrigan, Ma and Shlychkov, 2012). The implementation of the Heckman approach relies on a valid exclusion restriction. The latter is not trivial to establish. It requires the identification of a variable, which affects firms' export decisions, but not the value of their exports - a fixed export cost in the model used here. Helpman, Melitz and Rubinstein (2008) identify two such variables, however, the data structure with France being the only exporter makes it impossible to adopt their exclusion restrictions. The Heckman estimator can theoretically nevertheless be identified off functional form. I include it as a robustness check.

¹¹Head and Mayer (2014) find a bias already in simulations with 25% structural zeroes; the dataset used in the present chapter has 93% zero trade flows, such that the problem will be exacerbated.

4.3 Data

In order to test the key prediction of the model, I use a dataset constructed by Crozet, Head and Mayer (2012), which matches confidential French firm-product-destination level data of champagne exports with producer quality ratings.¹² I consider a cross-section for the year 2005.

Empirical Measure of Product Quality Despite the proliferation of empirical trade and quality work over the last decade, it has proven a challenge to find a suitable empirical measure of product quality. The vast majority of the literature has employed unit values of exports. This measure has the advantage that it is widely available in trade data sets and allows a consistent comparison of quality effects across industries. However, variation in price may come to a significant extent from variation in cost rather than quality-induced demand effects. Khandelwal (2010) suggests a refinement of this measure based on Sutton’s (2012) definition of quality as a demand shifter, which addresses this issue: for a given price, demand should be higher for a higher quality product. In practice, the identification of the alternative empirical quality measure proposed by Khandelwal (2010) therefore relies on information on market shares conditional on price.

Here, I test the key prediction in the context of the Champagne industry, which allows the use of a very direct empirical measure of product quality: I use a direct quality rating from the world’s most comprehensive Champagne guide, the 2008 Juhlin Guide.¹³ As explained in Crozet et al (2012), Juhlin (2008) assigns ratings of one to five stars to 487 producers which are based on scores for 6500 individual champagnes. Juhlin gives one star to “producers whose wines have aroused my interest”. Five stars are given to the “perfect” Champagne. Juhlin (2008) is a strict grader, with approximately 40% of the included producers receiving a rating of one star such that two stars can be interpreted as average and more stars as above average. The guidebook provides ratings for producers

¹²Other recent papers which use wine ratings are Macchiavello (2010) and Chen and Juvenal (2013);

¹³Juhlin’s ratings correlate highly with other less comprehensive French and international guides.

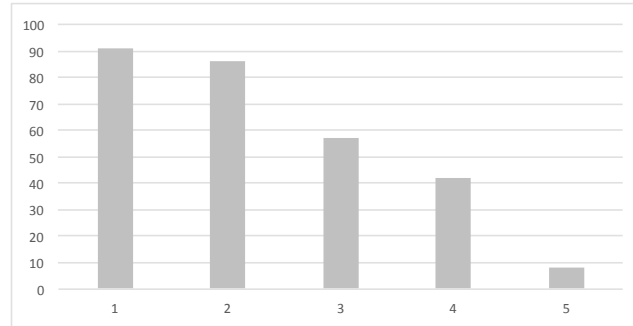


Figure 4.1: Number of Exporters by Star Rating

which together cover approximately 90% of all champagne shipments within France and to international destinations. While Champagne producers often produce several varieties and might hence be seen as multiproduct firms, I abstract from this issue and focus on the quality of their overall brand, which corresponds to the level of aggregation of the available quality measure¹⁴: Juhlin (2008) assigns two ratings at the producer level, one for the latest vintage and one historical rating. I follow Crozet et al (2012) in using the historical rating.

Not all Juhlin rated producers are also exporters. Of the 487 rated producers, 285 export. Figure 4.1 shows the distribution of stars across exporting firms: approximately one third of exporters are one star firms, just under one third are rated two stars, 20% have three stars, 15% have four stars and just 3% have the top star rating of five.

I use three variants of the quality measure in an interaction with different measures of market size. Product quality is captured by three types of indicator: (i) a high quality dummy which takes a value of 1 when Juhlin assigns either two, three, four or five stars and 0 if Juhlin assigns only one star; (ii) a dummy for each quality level from two to five stars, using the one star group as the base category; and (iii) a continuous quality variable from one to five stars.

As Crozet et al (2012) argue, Champagne is a fitting product for this analysis for many reasons¹⁵: (i) it is one of very few products for which a comprehensive producer quality

¹⁴See Eckel, Iacovone, Javorcik and Neary (2011) for a discussion of brand vs variety quality in the context of multi-product firms.

¹⁵See Crozet, Head and Mayer (2012) p. 616-618

rating exists. Furthermore, it is common for Champagne producers to blend vintages in order to guarantee a stable quality such that these ratings remain valid over time; (ii) the industry structure closely resembles the monopolistically competitive structure assumed in the model: the Champagne industry consists of many small producers (Herfindahl index of 0.033), who produce differentiated varieties; (iii) 80% of Champagne is exported by firms classified either as grape-growers or wine-makers, and only 13% is exported by wholesalers; (iv) of those direct exports, 94% in 2005 came from firms which can be matched to Juhlin ratings. Much more detail can be found in Crozet, Head and Mayer (2012).

Export Data I use confidential French export data which is disaggregated at the firm-product-destination-year level. The data comes from declarations made by French exporters to French Customs (compulsory reporting applies above a minimum exporting threshold, however, Crozet et al (2012) establish that this does not pose any issues for the analysis of the champagne data). The fact that firms report their exports by destination makes it possible to exploit within-firm variation in export sales and quantities. Information about export flows is collected annually at the 8-digit level according to the EU NC8 nomenclature. Conveniently, champagne has its own 8-digit product code (22041011) in this nomenclature. I use export flows for 2005 in order to make results comparable to those obtained by Crozet et al (2012). Customs record the values of export flows on a free-on-board (fob) basis, i.e. excluding transport costs, insurance etc., as well as export quantities. Figure (4.2) shows average exports per firm in million euros by star rating. With 30 million euros per year, four star firms export the most on average, followed by five star firms with just under 20 million euros, followed by three, two and one star firms with averages under 5 million.

Table 4.2 shows summary statistics on the number of export destinations by star rating: the number of destinations is systematically increasing by star rating. The average one star firm exports to five markets, with the best one star firm having a reach of thirty markets. The firm with the largest number of destinations is a four star firm which sells

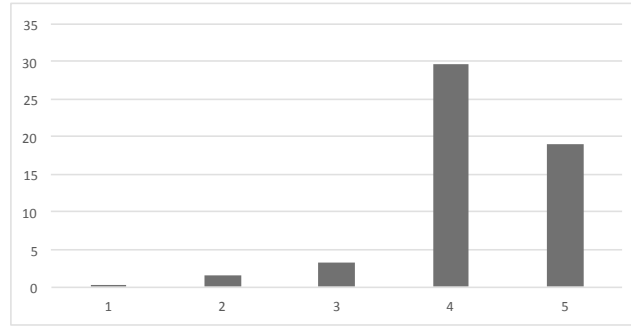


Figure 4.2: Average Exports per Firm by Star Rating (in million euros)

Juhlin rating	# observations	mean	median	75% ile	std dev
1 star	91	4.89	3	7	5.11
2 star	86	7.56	6	10	8.03
3 star	57	11.79	10	17	10.71
4 star	42	25.52	13	34	29.58
5 star	8	45.75	48.5	57.5	15.78

Table 4.2: Summary Statistics: Export Destinations per Firm

in more than 100 markets; however, on average, five star firms serve the largest number of destination markets with a mean of 46.

In order to test for the presence of the intensive margin effect, I consider the log of fob firm-destination export values as the dependent variable. Table 4.3 shows summary statistics for destination export values for each star rating. I also conduct robustness checks using firm-destination export quantities. I discuss results on the impact of market size on export unit values in the appendix.

Of the Juhlin-rated firms, in 2005, 284 can be matched with exporting firms which export to 157 countries, yielding a sample of 44,586 observations once two price outliers are removed.¹⁶ 3205 of these observations correspond to positive export flows. A full dataset with all relevant gravity controls is available for 38,574 observations of which 2882 are non-zero export flows.¹⁷

¹⁶The champagne exporters which were not rated by Juhlin, are currently not included in the sample. They account for approximately 6% of exports.

¹⁷GDP data is not available for the following 19 countries to which France exports Champagne: Aruba, Anguilla, Andorra, Netherlands Antilles, Bahamas, Bermuda, Cuba, Cayman Islands, Cyprus, Gibraltar, Iraq, New Caledonia, Oman, French Polynesia, San Marino, Saint Pierre and Miquelon, Turks and Caicos Islands, British Virgin Islands, Wallis and Futuna.

Juhlin rating	# observations	mean	median	75% ile	std dev
1 star	91	2,601	542	3,537	4,512
2 star	86	9,878	1,139	4,080	31,226
3 star	57	21,064	2,346	10,679	56,921
4 star	42	188,861	5,164	49,978	535,889
5 star	8	121,161	103,186	189,987	106,344

Table 4.3: Summary Statistics: Firm Destination Export Value (in euro)

Market Size In establishing the intensive margin mechanism, I employ different measures of market size. Following the tradition of the gravity literature, the most widely used proxy for market size in the trade literature is GDP. This includes Mayer, Melitz and Ottaviano’s (2014) recent contribution, which investigates market size effects on the relative export sales across the range of products exported by multiproduct firms. GDP as a measure of market size has the advantage of being exogenous to the value and volume of Champagne exports.¹⁸

A second measure which I employ to capture market size is the log of absorption based on Eaton, Kortum and Kramarz (2004). Eaton et al (2004) define absorption as gross production + imports - exports, which I implement at the product level. This measure captures the true level of consumption. In their discussion of structural gravity estimation, Head and Mayer (2014) argue that strictly, absorption should be used to capture import market size, and not GDP. Since champagne is produced only in France, champagne absorption in a destination market consists only of France’s total exports to that destination. While variation in log GDP is arguably more exogenous, log absorption is a better proxy for the size of the relevant market. The measure assumes that champagne is not substitutable with other alcoholic beverages, which is reasonable given that champagne has a distinct image even compared to other sparkling wines. Ideally, one would want to use destination-specific total alcoholic beverage absorption; however, this data is not readily available for the 157 countries in the dataset. As proxies for market size, GDP and champagne absorption lie at opposite extremes of the spectrum. Any results obtained

¹⁸See appendix table 4.8 for source.

using those two measures should therefore be interpreted as bounds on the true market size effect.

Controls In addition to market size, I control for destination geography and bilateral trade barriers/enhancers. The geography variable is needed to control for the level of competition in the destination market arising from proximity to third countries. All controls used in the estimations are destination-level variables. I can hence account for these factors either explicitly using a set of gravity variables or implicitly using destination fixed effects. While the direct impact of market size and geography in the latter case is absorbed by the destination fixed effects, the main coefficient of interest on the (firm-destination) quality-market size interaction is always identified.

For the specifications which control explicitly for geography and bilateral factors, I adopt the strategy in Mayer et al (2014). As a control for geography, the authors suggest a variation on Redding and Venables' (2004) measure of supply potential which, unlike Redding and Venables' (2004) measure, is independent of country-level information on the destination country. The measure is defined as “the aggregate predicted exports to a destination based on a bilateral trade gravity equation (in logs) with both exporter and importer fixed effects and the standard bilateral measures of trade barriers/enhancers” (Mayer et al, 2014, p.25). Following Head and Mayer (2014), they thus construct log *foreign* supply potential which drops importer fixed effects. This is the measure which I also employ here. I control for characteristics of the bilateral relationship using the standard gravity variables provided by the CEPII: distance, contiguity, colonial links, common-language, RTA membership, GATT/WTO membership, and membership of a common currency area.¹⁹ Alternatively, I control for these factors using destination fixed effects, identifying only the interaction term in my regressions.

I account for the fact that there may be unobserved destination level characteristics which affect all exporters to a particular destination in the same way. In the specifications

¹⁹See appendix table 4.8 for detailed descriptions and source.

with destination fixed effects I cluster standard errors at the destination country level. This addresses correlations in the error term which would otherwise lead to standard errors being biased downward.

Firm Fixed Effects All specifications contain firm fixed effects.

4.4 Estimations

In this section I test for the presence of the intensive margin effect, controlling for other factors that are known to influence bilateral export flows. I control for these factors either explicitly, using a set of gravity variables or by means of destination country fixed effects. I use the baseline specification in equation (4.3) when the quality indicator takes the form of either the high quality dummy or the quality index. With individual star dummies as quality indicators, where Z^s are dummies for s =two, three, four and five star firms, this specification becomes:

$$\ln r_{fd}^{FOB} = \sum_{s=2}^5 \beta_1^s Z_f^s * \ln L_d + \gamma \ln L_d + \delta \mathbf{X}_d + \theta_f + \varepsilon_{fd}. \quad (4.4)$$

In the specifications where destination fixed effects (θ_d) are included, I estimate:

$$\ln r_{fd}^{FOB} = \beta_2 Z_f * \ln L_d + \theta_d + \theta_f + \varepsilon_{fd}, \quad (4.5)$$

and

$$\ln r_{fd}^{FOB} = \sum_{s=2}^5 \beta_3^s Z_f^s * \ln L_d + \theta_d + \theta_f + \varepsilon_{fd}. \quad (4.6)$$

4.4.1 Results

I discuss results for the OLS and EK Tobit estimations in turn. While magnitudes of market size effects vary across specifications, they are present and highly significant in all of them.

OLS In a first step, I estimate the revenue-market size relationship using OLS. Table 4.4 shows results for the high quality dummy interactions with both market size proxies. The first four columns control for destination market characteristics explicitly using foreign supply potential and gravity variables while columns (5) and (6) do so using destination fixed effects. Results in columns (1)-(4) suggest that market size has a positive effect on export sales of one star firms, and all of columns (1)-(6) are consistent with the main hypothesis that higher quality firms are in a better position to take advantage of a larger market. The size of the coefficients on the interaction terms is barely affected by the way in which destination characteristics are controlled for.

Table 4.5 shows results for the other two quality indicators, the quality index (columns 1 and 2) and the individual star ratings (columns 3 and 4). All specifications in Table 4.5 include both firm- and destination-fixed effects. An advantage of OLS estimation is that the inclusion of fixed effects does not pose any estimation issues. Quality interaction terms with both market size proxies are again positive and highly significant as predicted by the theory. Furthermore, t-tests reveal that interactions with the star dummies are monotonically increasing in the quality rating (with the exception of the coefficients on the 4 and 5 star interactions which are not significantly different from each other). This is fully consistent with the prediction that the market size effect should be stronger, the higher a firm's quality rating.

There is, however, a source of bias which OLS cannot address: empirical estimations of models involving quality selection are subject to a specific type of bias as shown by Crozet et al (2012). Within the framework of their model, a low quality firm will only be observed to be exporting to a tough market if it has experienced a positive demand shock. There is hence a negative correlation between quality conditional on exporting and unobservable demand shocks which leads to OLS estimators being biased. The authors conduct Monte Carlo simulations to show that an EK Tobit estimator can correct for this bias. I next discuss results for the EK Tobit specification.

Table 4.4: Export Values (OLS)

	(1)	(2)	(3)	(4)	(5)	(6)
	ln export	ln export	ln export	ln export	ln export	ln export
ln GDP	0.199*** (0.0454)		0.241*** (0.0460)			
ln GDP*quality	0.372*** (0.0485)		0.362*** (0.0473)		0.364*** (0.0468)	
ln ch-absorption		0.295*** (0.0360)		0.316*** (0.0367)		
ln ch-absorption*quality		0.352*** (0.0380)		0.346*** (0.0381)		0.356*** (0.0423)
ln foreign supply potential	0.274*** (0.0235)	0.0379 (0.0209)	-0.160** (0.0497)	0.00319 (0.0449)		
ln distance			-0.667*** (0.0798)	-0.189** (0.0705)		
contiguity			-0.00509 (0.106)	-0.0944 (0.0958)		
colonial relation post-45			-0.221 (0.181)	0.327* (0.151)		
shared language			0.841*** (0.119)	0.0801 (0.104)		
GATT/WTO			0.496** (0.171)	-0.214 (0.119)		
RTA			-0.618*** (0.135)	-0.239* (0.118)		
common legal system			-0.0656 (0.0862)	-0.00803 (0.0749)		
common religion			-0.794*** (0.157)	-0.397** (0.138)		
currency union			0.451*** (0.107)	0.117 (0.0969)		
firm fe	yes	yes	yes	yes	yes	yes
destination fe	no	no	no	no	yes	yes
Observations	2882	3024	2882	3013	3004	3205
Adjusted R^2	0.273	0.413	0.316	0.422	0.555	0.544

Standard errors in parentheses

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Table 4.5: Export Values (OLS)

	(1)	(2)	(3)	(4)
	ln export	ln export	ln export	ln export
ln GDP*index	0.128*** (0.0140)			
ln ch-absorption*index		0.131*** (0.0175)		
ln GDP*2star			0.170** (0.0527)	
ln GDP*3star			0.298*** (0.0426)	
ln GDP*4star			0.460*** (0.0534)	
ln GDP*5star			0.475*** (0.0509)	
ln ch-abs*2star				0.186*** (0.0452)
ln ch-abs*3star				0.262*** (0.0400)
ln ch-abs*4star				0.479*** (0.0568)
ln ch-abs*5star				0.476*** (0.0579)
firm fe	yes	yes	yes	yes
destination fe	yes	yes	yes	yes
Observations	3004	3205	3004	3205
Adjusted R^2	0.563	0.555	0.564	0.557

Standard errors in parentheses

Note: s.e. clustered at country level

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

EK Tobit Table 4.6 shows the results for Tobit estimations with EK censoring and the high quality dummy as quality indicator. Again results are in line with the key prediction on the intensive margin effect. Within-firm export revenues are increasing in market size for all firms, and they increase more than proportionately for the high quality firms. Estimations underlying columns 1-4 contain only firm fixed effects and control explicitly for destination and bilateral characteristics: the first two columns control for competition effects via foreign supply potential only, while columns 3 and 4 add the standard bilateral gravity controls. Foreign supply potential in this case loses its significance in that case due to collinearity issues with the distance variable. Columns 5 and 6 have both firm and destination fixed effects. Coefficients on the market size-quality interaction become larger the more destination-level factors are controlled for. Most of the coefficients on the interaction terms are larger than their counterparts estimated by OLS.

Table 4.7 shows results for the other two quality indicators, the quality index and the individual star ratings. Here I take again the most conservative approach and include both firm and destination fixed effects in all four columns.²⁰ Estimations thus only identify coefficients on the interaction terms. Columns (1)-(4) confirm previous results. Producers with the highest star ratings experience the largest boost from an increase in market size. In columns (3) and (4), the size of the effect is monotonically increasing when market size is proxied by champagne absorption and the ranking is almost monotonic when GDP is used instead. T-tests on the coefficients show that coefficients in the EK Tobit estimation are statistically weakly monotonically increasing in the producer star rating.²¹

²⁰Greene (2002) shows that fixed effects estimators in Tobit models are not affected by incidental parameter problems (unlike Probit and Logit). Slope estimators are thus unbiased and consistent. Ancillary parameter problems can arise with the estimated disturbance variance, with standard errors biased towards zero. However, Greene (2002) also shows that the bias in the variance estimator is falling very quickly in “T” (here, the number of destinations, which is large). In addition, in the present case, the number of fixed effects is small compared to the number of observations, which reduces the issue further. Crozet, Head and Mayer (2012) run Monte Carlo simulations on the EK Tobit estimator with the same order of magnitude of fixed effects and show that the EK Tobit indeed performs very well.

²¹Wooldridge (2002) shows that t-tests can be used on Tobit interaction coefficients (cf Chapter 16 Wooldridge (2002) and Ai and Norton (2003) on Tobit with interaction terms).

Table 4.6: Export Values (Tobit EK censored)

	(1)	(2)	(3)	(4)	(5)	(6)
	ln export	ln export	ln export	ln export	ln export	ln export
ln GDP	0.993*** (0.181)		0.880*** (0.199)			
ln GDP*quality	0.351*** (0.102)		0.396*** (0.0883)		0.449*** (0.0601)	
ln ch-absorption		1.018*** (0.0886)		0.938*** (0.0859)		
ln ch-absorption*quality		0.327*** (0.0792)		0.358*** (0.0743)		0.389*** (0.0647)
ln foreign supply potential	1.107*** (0.252)	0.364*** (0.106)	-0.0382 (0.340)	0.0609 (0.252)		
ln distance			-1.006 (0.680)	-0.430 (0.338)		
contiguity			1.465 (0.862)	0.925* (0.422)		
colonial relation post-45			-1.138 (0.754)	0.0957 (0.460)		
shared language			2.577*** (0.774)	0.743 (0.446)		
GATT/WTO			1.619* (0.687)	-0.304 (0.308)		
RTA			-0.789 (0.711)	-0.364 (0.385)		
common legal system			-0.847 (0.490)	-0.743** (0.273)		
common religion			-0.789 (0.837)	-0.0569 (0.441)		
currency union			1.024 (0.680)	-0.0536 (0.365)		
firm fe	yes	yes	yes	yes	yes	yes
destination fe	no	no	no	no	yes	yes
Observations	38622	42030	38622	41462	39190	44586
Pseudo R^2	0.330	0.393	0.356	0.401	0.424	0.419

Standard errors in parentheses

Note: s.e. clustered at country level

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Table 4.7: Export Values (Tobit EK censored)

	(1)	(2)	(3)	(4)
	ln export	ln export	ln export	ln export
ln GDP*index	0.125*** (0.0220)			
ln ch-absorption*index		0.116*** (0.0280)		
ln GDP*2star			0.360*** (0.0627)	
ln GDP*3star			0.448*** (0.0637)	
ln GDP*4star			0.501*** (0.0697)	
ln GDP*5star			0.480*** (0.0866)	
ln ch-abs*2star				0.318*** (0.0600)
ln ch-abs*3star				0.348*** (0.0611)
ln ch-abs*4star				0.438*** (0.0872)
ln ch-abs*5star				0.479*** (0.0967)
firm fe	yes	yes	yes	yes
destination fe	yes	yes	yes	yes
Observations	39190	44586	39190	44586
Pseudo R^2	0.423	0.419	0.424	0.419

Standard errors in parentheses

Note: s.e. clustered at country level

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

4.4.2 Robustness

4.4.2.1 Quantity Effects

I next estimate quantity effects using the EK Tobit model to check for robustness of the revenue results. I include destination fixed effects and estimate coefficients for all three quality indicators; the baseline specification is:

$$\ln q_{fd} = \beta_4 Z_f * \ln L_d + \theta_d + \theta_f + \varepsilon_{fd}, \quad (4.7)$$

where q_{fd} is the volume of champagne exported by firm f to destination d . Results are shown in table 4.10 in the Appendix. While coefficients differ slightly in magnitude compared to the estimations which have export revenues as their dependent variable, results are perfectly in line with the revenue estimations - i.e. these results suggest that revenue effects are to a large extent driven by quantity adjustments.

4.4.2.2 Heckman Selection Model

I also check for robustness of results using a two-stage Heckman estimator:

$$\Pr(r_{fd}^{FOB} > 0) = \Phi\left(\sum_{s=2}^5 \beta_5^s Z_f * \ln L_d + \gamma \ln L_d + \delta \ln \mathbf{X}_d + \Sigma \kappa^s Z_f\right) \quad (4.8)$$

$$\ln r_{fd}^{FOB} = \sum_{s=2}^5 \beta_6^s Z_f * \ln L_d + \xi \hat{\lambda}_{fd} + \theta_d + \theta_f + u_{fd} \quad (4.9)$$

where $\hat{\lambda}_{fd}$ is Heckman's lambda. Furthermore, for quantity we have:

$$\Pr(q_{fd} > 0) = \Phi\left(\sum_{s=2}^5 \beta_7^s Z_f^s * \ln L_d + \gamma \ln L_d + \delta \ln \mathbf{X}_d + \Sigma \kappa^s Z_f^s\right) \quad (4.10)$$

$$\ln q_{fd} = \sum_{s=2}^5 \beta_8^s Z_f^s * \ln L_d + \xi \hat{\lambda}_{fd} + \theta_d + \theta_f + u_{fd} \quad (4.11)$$

Note that the selection equation does not include fixed effects. Fixed effects are problematic in a Probit specification as they lead to bias in the estimators (Greene, 2002;

Norton, Wang and Ai, 2004). Without fixed effects, star ratings and destination/bilateral characteristics therefore need to be included on their own in addition to the interaction terms.

Again, results are fully in line with the theoretical predictions (see tables 4.11 and 4.12 in the Appendix). The Heckman results support the hypothesis most strongly since all four variations of the star dummy estimation have coefficients which are significantly different from each other such that there is a strict monotonic increase in the market size effect for higher ratings (with the exception that the 4 and 5 star interaction coefficients are never significantly different from each other).

The results from the selection equation can tell us something about the differential effects of market size on behaviour of the extensive margin: in terms of entry probabilities, an increase in market size seems to have the largest benefits for two, three and five star firms. This could be taken as evidence that a larger market is relatively more difficult to enter for the lowest quality firms.

4.4.2.3 GDP per Capita

I also account for differences in consumer taste for quality across destination markets. While income effects per se are outside a model with an outside good (such as a quality-augmentation of Melitz-Ottaviano, 2008), I use per capita GDP and its quality interactions to control for differences in quality preferences. Demand for quality has empirically been linked to per capita income and has been formalized in models with non-homothetic preferences (Fieler, 2011; Fajgelbaum et al, 2011). In the model presented in Chapter 3, the parameter β corresponds to consumers' preference for quality. Controlling for per capita GDP acknowledges that β might be increasing in consumer income.

In table 4.13 I control for an interaction of quality with GDP per capita. I again take a conservative approach which controls for destination characteristics using fixed effects. The coefficient on both market size quality interactions shrinks slightly compared to the specifications which do not include the GDP per capita interaction, however it remains

large and highly significant. Depending on the proxy for market size, the magnitude of the coefficient on the quality-market size interaction is between $1/3$ and $1/2$ that of the income interaction. This suggests that higher quality firms sell disproportionately more in high income destinations. However, as these results demonstrate, the market size mechanism which skews sales towards the higher quality firms exists independently of the income channel.

4.4.3 Other Margins of Adjustment

In the Appendix, I present an analysis which checks for the existence of a quality upgrading channel among champagne producers. Since this analysis requires an empirical quality measure which can vary across export destinations, I use unit values as a proxy for quality. Results are inconclusive. This might be due to the fact that an increase in market size has an ambiguous effect on unit values due to conflicting effects of the competition and quality channels. Future work should focus on separating out the competition from the quality mechanism. The inconclusive result might also be due to the fact that export market specific fixed quality costs (such as marketing expenditure) are not important enough in the champagne industry. In a quality-augmented Melitz-Ottaviano (2008) model, we should see quality upgrading only where such fixed costs are important. A promising avenue for future research would be to widen the scope of the analysis by differentiating between industries where fixed and variable quality costs are important.

Evidence on the behaviour of the extensive margin and selection in response to changes in market size is also sparse in the quality context. In their paper on quality sorting, Crozet, Head and Mayer (2012) work within a theoretical framework with CES preferences, and thus do not consider market size effects. Their empirical analysis therefore does not consider this issue. The theoretical model underlying the present analysis suggests that selection should get tougher as market size increases whereby the overall mass of firms may be increasing or decreasing depending on consumers' preference for quality. Future work which establishes these relationships in the data would provide another important piece

in the puzzle on which factors are driving aggregate quality in response to globalization. In particular, it would allow to establish the relative sizes of the demand vs competition effect of an increase in market size: in a first instance, firms benefit from access to a larger market as overall demand is higher; with free entry, as in the case considered here, firms, however, also experience tougher competition generated by entry and/or quality upgrading. An overall fall in aggregate quality would be an indication that selection gets laxer in market size, implying that the demand effect outweighs the competition effect and vice versa.²²

The empirical patterns found above were interpreted in light of a theoretical model with monopolistic competition and firms which are infinitesimally small. However, they may also be consistent with a market structure which has a certain number of firms that are of a finite mass and interact strategically and which coexist with a monopolistically competitive fringe as in Neary (2010) and Parenti (2012). Such an industry structure might arise if high quality champagnes are not substitutable with other types of champagne nor with other sparkling wines, while low quality champagnes are. As market size increases, it is hence the low quality champagne producers that mainly have to struggle with increased competition from new entrants. As a consequence, compared to the high quality producers, they see their relative sales decline in the larger market.

4.5 Conclusion

The results presented in this chapter add granularity to what we currently know about the relationship between quality and market size and give an indication of how globalization has affected aggregate quality. To the best of my knowledge, this is the first contribution to investigate the intensive margin mechanism.

In the context of a quality-augmented Melitz-Ottaviano model, an increase in market size can affect aggregate quality via three mechanisms: an intensive margin channel,

²²The results on the behaviour of aggregate quality and its components are interesting in light of Bache and Laugesen's (2013) analysis of the conditions for firm and industry level monotone comparative statics.

an extensive margin/selection channel and - if fixed quality costs are important - quality upgrading. The estimations presented in this chapter have yielded results which are consistent with an intensive margin channel, or what Mrazova and Neary (2011) have termed the Matthew Effect. The data suggest that higher quality firms expand their sales relatively more compared to low quality producers as market size increases. I establish that this effect is driven by quantity adjustments rather than prices. If one were to translate results from the cross-section to a time-series perspective, the data suggest a disproportionate boost to competitiveness in the face of progressing globalization from being a high quality producer. Viewed in terms of the welfare analysis in Chapter 3, the analysis suggests a positive contribution of the intensive quality margin to overall welfare.

Furthermore, the existence of a market size effect in the data supports the assumption of variable elasticity of demand over CES preferences. This is an important finding given existing insights regarding the sensitivity of welfare results to the exact properties of preference structures (e.g. Dixit and Stiglitz, 1977; Mrazova and Neary, 2013).

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4.6 Appendix

4.6.1 Theory - Submodularity of Optimized Export Revenues

Deriving the Cost Cut-offs in the 2 Country Open Economy From the open economy derivation in Chapter 3, we have for firms exporting from l to h (section 3.8.8):

$$\begin{aligned}
 p_X^l &= \frac{\varepsilon_\lambda^{lh}}{2} (c_D^h - \tau^{lh}c) + \tau^{lh}c \\
 x_X^l &= \frac{L^h \varepsilon_\lambda^{lh}}{2b(1-e)} (c_D^h - \tau^{lh}c) \\
 z_X^l &= \lambda_X^l (c_D^h - \tau^{lh}c) \text{ where } \lambda_X^l = \frac{\beta L^h}{2\theta^{(l)} - \beta^2 b(1-e)L^h}.
 \end{aligned}$$

$$\begin{aligned}
\pi_X^l &= (p_X^l - \tau^{lh}c)x_X^l - \frac{\theta}{2} (z_X^l)^2 \\
&= \left(\frac{\varepsilon_\lambda^{lh}}{2} (c_D^h - \tau^{lh}c) + \tau^{lh}c - \tau^{lh}c \right) \frac{L^h \varepsilon_\lambda^{lh}}{2b(1-e)} (c_D^h - \tau^{lh}c) - \frac{\theta}{2} (\lambda_X^l (c_D^h - \tau^{lh}c))^2 \\
&= \frac{L^h (\varepsilon_\lambda^{lh})^2}{4b(1-e)} (c_D^h - \tau^{lh}c)^2 - \frac{\theta}{2} (\lambda_X^l)^2 (c_D^h - \tau^{lh}c)^2 \\
&= \left(\frac{L^h (\varepsilon_\lambda^{lh})^2}{4b(1-e)} - \frac{\theta}{2} (\lambda_X^l)^2 \right) (c_D^h - \tau^{lh}c)^2 \\
&= \frac{L^h}{4b(1-e)} (c_D^h - \tau^{lh}c)^2 \left(1 + 2B\lambda_X^l + B^2\lambda_X^{l2} - \frac{2\theta (\lambda_X^l)^2 b(1-e)}{L^h} \right) \\
&= \frac{L^h}{4b(1-e)} (c_D^h - \tau^{lh}c)^2 \left(1 + \left[2B + \frac{\beta L^h B^2}{2\theta^{(l)} - \beta^2 b(1-e) L^h} - \frac{2\theta B}{2\theta^{(l)} - \beta^2 b(1-e) L^h} \right] \lambda_X^l \right) \\
&= \frac{L^h}{4b(1-e)} (c_D^h - \tau^{lh}c)^2 \left(1 + \left[\frac{4\theta^{(l)} - 2\beta B L^h + \beta B L^h - 2\theta}{2\theta^{(l)} - \beta B L^h} \right] B\lambda_X^l \right) \\
&= \frac{L^h}{4b(1-e)} (c_D^h - \tau^{lh}c)^2 (1 + B\lambda_X^l) \\
&= \frac{L^h}{4b(1-e)} \tau^{lh2} (1 + B\lambda_X^l) (c_X^l - c)^2
\end{aligned}$$

Analogously for domestic profits π_D^l , giving the two profit expressions needed to calculate the domestic and export cut-off using the free entry condition:

$$\begin{aligned}
\pi_D^l &= \frac{\varepsilon_\lambda^{ll} L^l}{4b(1-e)} (c_D^l - c)^2 \\
\pi_X^l &= \frac{\varepsilon_\lambda^{lh} L^h}{4b(1-e)} \tau^{lh2} (c_X^l - c)^2
\end{aligned}$$

For a two-country world economy, we can thus derive the domestic and exporting cut-offs:

$$\begin{aligned}
f_E &= E\pi = \int_0^{c_D^l} \pi_D^l(c) dG(c) + \int_0^{c_X^l} \pi_X^l(c) dG(c) \\
&= \frac{\varepsilon_\lambda^{ll} L^l}{4b(1-e)} \int_0^{c_D^l} (c_D^l - c)^2 dG(c) \\
&\quad + \frac{\varepsilon_\lambda^{lh} L^h}{4b(1-e)} \tau^{lh^2} \int_0^{c_X^l} (c_X^l - c)^2 dG(c) \\
\varepsilon_\lambda^{ll} L^l (c_D^l)^{n+2} + \varepsilon_\lambda^{lh} L^h \tau^{lh^2} (c_X^l)^{n+2} &= b(1-e)\phi \\
\varepsilon_\lambda^{ll} L^l (c_D^l)^{n+2} + \varepsilon_\lambda^{lh} L^h \rho^{hl} (c_D^h)^{n+2} &= b(1-e)\phi \text{ where } \rho^{hl} = (\tau^{hl})^{-n} \\
\varepsilon_\lambda^{hh} L^h (c_D^h)^{n+2} + \varepsilon_\lambda^{hl} L^l \rho^{lh} (c_D^l)^{n+2} &= b(1-e)\phi \\
L^h &= \frac{b(1-e)\phi - \varepsilon_\lambda^{hl} L^l \rho^{lh} (c_D^l)^{n+2}}{\varepsilon_\lambda^{hh} (c_D^h)^{n+2}} \\
\varepsilon_\lambda^{ll} L^l (c_D^l)^{n+2} + \varepsilon_\lambda^{lh} \rho^{hl} (c_D^h)^{n+2} \frac{b(1-e)\phi - \varepsilon_\lambda^{hl} L^l \rho^{lh} (c_D^l)^{n+2}}{\varepsilon_\lambda^{hh} (c_D^h)^{n+2}} &= b(1-e)\phi \\
\varepsilon_\lambda^{ll} L^l (c_D^l)^{n+2} + \frac{\varepsilon_\lambda^{lh} \rho^{hl}}{\varepsilon_\lambda^{hh}} \left(b(1-e)\phi - \varepsilon_\lambda^{hl} L^l \rho^{lh} (c_D^l)^{n+2} \right) &= b(1-e)\phi \\
c_D^l &= \left[\frac{b(1-e)\phi \left(1 - \frac{\varepsilon_\lambda^{lh}}{\varepsilon_\lambda^{hh}} \rho^{hl} \right)}{\left(1 - \frac{\varepsilon_\lambda^{lh}}{\varepsilon_\lambda^{hh}} \frac{\varepsilon_\lambda^{hl}}{\varepsilon_\lambda^{ll}} \rho^{hl} \rho^{lh} \right) \varepsilon_\lambda^{ll} L^l} \right]^{\frac{1}{n+2}} \\
c_X^l &= \frac{c_D^h}{\tau^{lh}} \\
&= \frac{1}{\tau^{lh}} \left[\frac{b(1-e)\phi \left(1 - \frac{\varepsilon_\lambda^{hl}}{\varepsilon_\lambda^{ll}} \rho^{lh} \right)}{\left(1 - \frac{\varepsilon_\lambda^{lh}}{\varepsilon_\lambda^{hh}} \frac{\varepsilon_\lambda^{hl}}{\varepsilon_\lambda^{ll}} \rho^{hl} \rho^{lh} \right) \varepsilon_\lambda^{hh} L^h} \right]^{\frac{1}{n+2}}
\end{aligned}$$

If countries have the same technology and trade costs are symmetric, the expressions for the domestic and export cut-off reduce to:

$$c_D^l = \left[\frac{b(1-e)\phi}{(1+\rho)\varepsilon_\lambda^l L^l} \right]^{\frac{1}{n+2}} \quad (4.12)$$

$$c_X^l = \frac{1}{\tau^{lh}} \left[\frac{b(1-e)\phi}{(1+\rho)\varepsilon_\lambda^h L^h} \right]^{\frac{1}{n+2}}. \quad (4.13)$$

Submodularity of Export Revenues Analogous to the closed economy case, we can show:

$$r_X^l = \frac{L^h \varepsilon_\lambda^h}{2b(1-e)} \left(c_D^h - \tau^{lh} c \right) \left[\frac{\varepsilon_\lambda^h}{2} \left(c_D^h - \tau^{lh} c \right) + \tau^{lh} c \right],$$

where $c_D^h = \left[\frac{b(1-e)\phi}{(1+\rho)\varepsilon_\lambda^h L^h} \right]$ and $\varepsilon_\lambda^h = 1 + B\lambda_X^l = 1 + B\frac{\beta L^h}{2\theta - \beta^2 b(1-e)L^h}$. Then:

$$\frac{\partial (r_X^l)^2}{\partial c \partial L^h} = -\frac{(\varepsilon_\lambda^h)^2}{2b(1-e)} \left[\frac{B\lambda_X^l}{L^h} \left(\frac{n+1}{n+2} c_D^h - \tau^{lh} c \right) + B\lambda_X^l (c_D^h - \tau^{lh} c) + \tau^{lh} c \right].$$

A sufficient condition for submodularity,

$$\frac{\partial (r_X^l)^2}{\partial c \partial L^h} < 0,$$

is $\tau^{lh} c < \frac{n+1}{n+2} c_D^h$.

4.6.2 Definition of Gravity Variables

Source for the Gravity Dataset: http://www.cepii.fr/CEPII/en/bdd_modele/presentation.asp?id=8, see also Head, Mayer and Ries (2010) “The erosion of colonial trade linkages after independence”, *Journal of International Economics*, 81(1):1-14.

For description of variables see table 4.8 on the next page.

4.6.3 Market Size, Unit Values and Quality Upgrading

A further prediction of the model presented in Chapter 3 is that aggregate quality can change in market size due to quality upgrading. I showed that if fixed quality costs are important, we should observe the best firms taking advantage of the larger market by investing in more quality and raising mark-ups, while at the same time more competition puts downward pressure on all firms’ mark-ups. If the quality channel is strong enough, a larger market will manifest itself in within-firm prices which are rising faster for high quality relative to low quality firms. Theory tells us that the strength of the quality effect depends both on the importance of fixed quality costs and the strength of consumers’ quality preferences. With only variable quality cost, optimal firm quality choice is independent of market size (i.e. there is no adaptation of the production

Variable	Description	CEPII Source
GDP	destination GDP in 2005 (nominal)	World Bank World Development Indicators (WDI)
GDP per capita	destination GDP per capita in 2005 (nominal)	World Bank World Development Indicators (WDI)
foreign supply potential	as defined in the main text	n/a, provided by Thierry Mayer
distance	population-weighted great circle distance between large cities of the France and export destination	CEPII distances database http://www.cepii.fr/anglaisgraph/bdd/distances.htm
contiguity	1 if export market shares a border with France	CIA World Factbook https://www.cia.gov/library/publications/the-world-factbook/
colonial post-45	1 if there was a colonial link with France post-1945	CIA World Factbook https://www.cia.gov/library/publications/the-world-factbook/
common language	1 if official language of export destination is French	CEPII distances database http://www.cepii.fr/anglaisgraph/bdd/distances.htm
GATT/WTO membership	1 if export destination is a member of the WTO	WTO website www.wto.org
RTA membership	1 if export destination has an RTA with France	Table 3 of Baier and Bergstrand (2007) supplemented with the WTO web site (http://www.wto.org/english/tratop_e/region_e/summary_e.xls) and qualitative information contained in Frankel (1997).
common legal system	1 if export destination shares has the same legal system as France	Andrei Shleifer's website: http://post.economics.harvard.edu/faculty/shleifer/Data/qgov_web.xls .
common religion	1 if export destination shares a common religion with France	CIA World Factbook https://www.cia.gov/library/publications/the-world-factbook/
membership of a common currency area	1 if export destination is a member of the euro	updated and extended version of the list provided by Glick and Rose (2002)

Table 4.8: Definition of Gravity Variables from CEPII Gravity Dataset

method/ingredients to export markets of different size). This has the important implication that any change in relative price must be coming from differential adjustments of mark-ups.

I consider firm-destination unit values, which vary across export markets, as the dependent variable. Using his own estimates of quality, Khandelwal (2010) shows that unit values are a good proxy for quality for markets characterised by long quality ladders (or high scope for quality differentiation). I check for evidence of the upgrading prediction by analysing the sources of variation in unit values across destination markets. While Champagne producers do not vary the substance of their products across export markets, quality upgrading can also be interpreted as adapting the scale of advertising campaigns to the size of a given export market.²³ I control for any market-specific differences in the overall competitive environment by using destination fixed effects.

Customs record the values of export flows on a free-on-board (FOB) basis, i.e. excluding transport costs, insurance etc., as well as export quantities. From this information, it is possible to calculate firm-destination-product prices (unit values) as $\ln p_{fd}^{FOB} = \ln\left(\frac{x_{fd}^{FOB}}{q_{fd}}\right)$, where f indexes firms and d indexes export destinations. I clean these unit values of outliers following the method employed in Crozet et al (2012). Subsequently, I first decompose the champagne prices into within- and across-firm variation over destination markets. I then check for evidence of quality upgrading in the within-firm variation of unit values.

4.6.3.1 Price Decomposition

The price decomposition follows Harrigan, Ma and Shlychkov (2012) and shows for champagne that within-firm variation is a relatively larger source of price variation across markets than industry composition effects. The deviation of destination average price, \bar{p}_d , from the average world price, \bar{p} , can be decomposed as follows:

$$\bar{p}_d - \bar{p} = \underbrace{\sum_{f=1}^N (p_{fd} - \bar{p}_f) \bar{w}_f}_{\text{price discrimination}} + \underbrace{\sum_{f=1}^N (w_{fd} - \bar{w}_f) \bar{p}_f}_{\text{industry composition}} + \underbrace{\sum_{f=1}^N (p_{fd} - \bar{p}_f)(w_{fd} - \bar{w}_f)}_{\text{interaction term}}.$$

²³Where exporters are multi-product firms, any observed within-firm price effects could also arise from a change in export product mix; rather than upgrading quality, firms might change their product mix in favour of premium varieties, for example vintage champagnes. However, this mechanism is outside the model presented in Chapter 3.

%ile	price disc	mkt share	interaction
5	-12.93024	-1.908474	-14.90586
10	-7.38087	-.7414563	-9.619112
25	-1.364731	-.0645392	-2.223278
50	1.651816	.1916454	-.7016925
75	3.131027	.5206336	2.165871
90	10.06632	1.353846	7.67339
95	15.3994	3.647792	12.44544

Table 4.9: Price Decomposition

where p_{fd} is the price charged by firm f in destination d ; w_{fd} is firm f 's quantity market share in destination d : $w_{fd} = \frac{q_{fd}}{\sum_{f=1}^N q_{fd}}$; and \bar{w}_f is "firm f 's average quantity market share in the world market": $\bar{w}_f = \frac{\sum_{d=1}^D q_{fd}}{\sum_{d=1}^D \sum_{f=1}^N q_{fd}}$ (Harrigan et al, 2012, p.4). Table 4.9 summarizes the components at various percentiles of the distribution. These patterns are consistent with other studies which present evidence of substantial within-firm price variation across export destinations, including Harrigan, Ma and Shlychkov (2012) (Fontagné et al, 2009; Görg et al, 2010; di Comite, Thisse and Vandebussche, 2011; Manova and Zhang, 2012; Martin, 2012).²⁴ Indeed, if we have learnt one thing from the recent trade literature, it is that markets are still highly fragmented by fixed and variable trade costs (Eaton, Kortum and Kramarz, 2004).

4.6.3.2 Price Effects

I subsequently estimate the differential impact of market size on price (fob unit values), controlling for destination characteristics.

I use both OLS as in Crozet et al (2012) and a three-stage estimator suggested by Harrigan et al (2012) to estimate market size effects on unit values. A linear projection of fob log champagne export prices of a variety produced by firm f exported to destination market d can be written as:

$$\ln p_{fd}^{FOB} = \Sigma \beta^s Z_f * \ln L_d + \theta_d + \theta_f + \varepsilon_{fd}$$

Parameters and variables are defined as in the export value equations.

The alternative approach by Harrigan et al (2012) controls explicitly for firms' selection into exporting also in the price equation by using a three-stage estimator. While the selection

²⁴Price rankings across varieties on the other hand are stable across markets, suggesting an important role for vertical differentiation; cf. di Comite et al, 2011; Kee and Krishna, 2008.

equations could be estimated using Tobit, Harrigan et al (2012) argue that a two-stage Heckman procedure requires the least assumptions (normal errors are assumed only for the Probit stage, rather than both stages as in Tobit). More specifically, I estimate:

$$\Pr(x_{fd}^{FOB} > 0) = \Phi\left(\sum_{s=2}^5 \beta^s Z^s * \ln L_d + \gamma \ln L_d + \delta \ln X_d + \Sigma \kappa^s Z^s\right) \quad (4.14)$$

$$\ln x_{fd}^{FOB} = \sum_{s=2}^5 \beta^s Z^s * \ln L_d + \gamma \ln L_d + \delta \ln X_d + \xi \hat{\lambda}_{fd} + \theta_f + u_{fd} \quad (4.15)$$

where $\hat{\lambda}_{fd}$ is again Heckman's lambda. The estimated residuals, \hat{u}_{fd} , from the export value equation are then used to control for selection in the pricing equation:

$$\ln p_{fd}^{FOB} = \sum_{s=2}^5 \beta^s Z^s * \ln L_d + \vartheta \hat{u}_{fd} + \theta_d + \theta_f + \varepsilon_{fd}. \quad (4.16)$$

Tables 4.11, 4.12 and 4.14 show results for the Heckman and OLS estimations respectively (the former for both revenue and quantity equations in the second stage). They reveal that unit values are orthogonal to market size in the present context. The coefficients on market size as well as all the market size-quality interactions are insignificant in all specifications. This is consistent with a competition and a quality channel which offset each other as far as variation in mark-ups is concerned.

4.6.4 Additional Results

Table 4.10: Export Quantities (Tobit EK censored)

	(1)	(2)	(3)	(4)	(5)	(6)
	ln qty	ln qty	ln qty	ln qty	ln qty	ln qty
ln GDP*quality	0.441*** (0.0424)					
ln ch-absorption*quality		0.378*** (0.0683)				
ln GDP*index			0.113*** (0.0236)			
ln ch-absorption*index				0.103*** (0.0297)		
ln GDP*2star					0.374*** (0.0636)	
ln GDP*3star					0.463*** (0.0683)	
ln GDP*4star					0.478*** (0.0730)	
ln GDP*5star					0.426*** (0.0901)	
ln ch-abs*2star						0.330*** (0.0631)
ln ch-abs*3star						0.356*** (0.0673)
ln ch-abs*4star						0.416*** (0.0930)
ln ch-abs*5star						0.419*** (0.102)
firm fe	yes	yes	yes	yes	yes	yes
destination fe	yes	yes	yes	yes	yes	yes
Observations	39190	44586	39190	44586	39190	44586
Pseudo R^2	0.418	0.413	0.417	0.412	0.418	0.413

Standard errors in parentheses

Note: s.e. clustered at country level

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Table 4.11: 3-Stage Heckman Selection Model with Export Values

	(1)	(2)	(3)	(4)
	ln export	ln price	ln export	ln price
ln GDP*2star	0.226*** (0.0541)	0.00158 (0.0134)		
ln GDP*3star	0.353*** (0.0508)	0.00148 (0.0168)		
ln GDP*4star	0.495*** (0.0452)	-0.000854 (0.0235)		
ln GDP*5star	0.509*** (0.0510)	-0.0224 (0.0246)		
resid		-0.0181 (0.0463)		-0.0503 (0.0548)
ln ch-abs*2star			0.208*** (0.0502)	0.00718 (0.0122)
ln ch-abs*3star			0.302*** (0.0449)	0.00838 (0.0147)
ln ch-abs*4star			0.496*** (0.0493)	0.0160 (0.0257)
ln ch-abs*5star			0.500*** (0.0491)	0.00966 (0.0264)
d=1 if export>0				
ln GDP*2star	0.102*** (0.0192)			
ln GDP*3star	0.104*** (0.0191)			
ln GDP*4star	-0.0138 (0.0166)			
ln GDP*5star	0.0895*** (0.0263)			
ln ch-abs*2star			0.0818*** (0.0159)	
ln ch-abs*3star			0.0754*** (0.0159)	
ln ch-abs*4star			-0.0119 (0.0144)	
ln ch-abs*5star			0.227*** (0.0316)	
Observations	38622	3004	41462	3205
Adjusted R^2		0.477		0.473

Standard errors in parentheses

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Table 4.12: 3-Stage Heckman Selection Model with Export Quantities

	(1)	(2)	(3)	(4)
	ln qty	ln price	ln qty	ln price
ln GDP*2star	0.227*** (0.0558)	0.00154 (0.0133)		
ln GDP*3star	0.357*** (0.0525)	0.00145 (0.0167)		
ln GDP*4star	0.506*** (0.0466)	-0.000812 (0.0236)		
ln GDP*5star	0.542*** (0.0524)	-0.0220 (0.0256)		
resid		-0.0178 (0.0456)		-0.0664 (0.0404)
ln ch-abs*2star			0.174*** (0.0493)	0.00825 (0.0114)
ln ch-abs*3star			0.286*** (0.0458)	0.0122 (0.0154)
ln ch-abs*4star			0.551*** (0.0478)	0.0276 (0.0226)
ln ch-abs*5star			0.533*** (0.0505)	0.0199 (0.0234)
d=1 if export>0				
ln GDP*2star	0.102*** (0.0192)			
ln GDP*3star	0.104*** (0.0191)			
ln GDP*4star	-0.0138 (0.0166)			
ln GDP*5star	0.0893*** (0.0263)			
ln ch-abs*2star			0.0823*** (0.0159)	
ln ch-abs*3star			0.0742*** (0.0159)	
ln ch-abs*4star			-0.0102 (0.0144)	
ln ch-abs*5star			0.217*** (0.0322)	
Observations	38622	3004	41462	3205
Adjusted R^2		0.477		0.473

Standard errors in parentheses

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Table 4.13: Export Values (Tobit EK censored)

	(1)	(2)
	ln export	ln export
ln GDP*quality	0.286*** (0.0591)	
ln GDP pc*quality	0.494*** (0.103)	0.514*** (0.137)
ln ch-absorption*quality		0.186* (0.0842)
firm fe	yes	yes
destination fe	yes	yes
Observations	38906	38906
Pseudo R^2	0.424	0.424

Standard errors in parentheses

Note: s.e. clustered at country level

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Table 4.14: FOB Export Prices

	(1)	(2)	(3)	(4)
	ln price	ln price	ln price	ln price
ln GDP dest	0.00918 (0.00740)			
ln GDP*quality	-0.00675 (0.00693)		-0.0109 (0.00698)	
ln ch-absorption		-0.00370 (0.00579)		
ln ch-absorption*quality		-0.00239 (0.00572)		-0.00807 (0.00687)
firm fe	yes	yes	yes	yes
destination fe	no	no	yes	yes
Observations	2882	3013	3004	3205
Adjusted R^2	0.408	0.411	0.476	0.474

Standard errors in parentheses

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Chapter 5

Quality vs Variety: Efficiency and Welfare under Monopolistic Competition with Endogenous Quality

5.1 Introduction¹

The recent trade literature has seen renewed interest in the classic question of the size and nature of gains from trade.² In particular, contributions have considered settings of imperfect competition where gains can arise from the fact that increased competition in a larger market addresses underlying distortions in the economy. This chapter studies the distortions that are driving welfare results in the presence of endogenous product quality and whether there is a role for trade integration in addressing them. To this end, I introduce a simple model of monopolistic competition, variable elasticity of demand (VED) preferences and quality investment. Firms are assumed to be symmetric. The model is identical to the one presented in Chapter 3 with the exception of the firm heterogeneity

¹**Acknowledgments:** I would like to thank Peter Neary for his guidance with this chapter and Kala Krishna and Tony Venables for suggesting this extension.

²Arkolakis, Costinot and Rodriguez-Clare, 2012; Arkolakis, Costinot, Donaldson and Rodriguez-Clare, 2012; Simonovska and Waugh, 2013; Dhingra and Morrow, 2012; Mrazova and Neary, 2013; Nocco, Ottaviano and Salto, 2013; Melitz and Redding, 2013.

assumption being dropped. A comparison of the results generated by the simplified set-up in the present chapter and those in Chapter 3 can thus serve to draw out the role of firm heterogeneity in driving results.

In a first instance, I analyse whether the market allocation of resources is efficient in the present set-up. The preference structure by Eckel, Iacovone, Javorcik and Neary (2011) which characterises the model makes it possible to separate out the quality dimension by assigning a quality preference parameter β which can be switched on and off. I derive the market equilibrium as well as the constrained and unconstrained social planner's outcome for the general case where $\beta > 0$. I then study the sources of any distortions that may be present. When analysing the efficiency of the resource allocation, I initially abstract from the quality dimension by setting $\beta = 0$. Comparing the three outcomes under this restriction allows me to draw out the distortion introduced by monopolistic competition under VED preferences. I then let $\beta > 0$ such that firms have an incentive to invest in quality, and compare the three outcomes, analysing additional distortions caused by the presence of product quality. Finally, I consider to what extent an increase in market size can bring welfare gains by addressing distortions present in the market outcome. I subsequently compare the response of the market outcomes under the heterogeneous firms assumption in Chapter 3 and the symmetric firms scenario considered in the present chapter in order to isolate the role of firm heterogeneity in driving results.

The set-up developed in this chapter thus allows for a simple comparison of the market outcome under imperfect competition with the social planner's solution as well as a comparison of the comparative statics of market outcomes under firm heterogeneity and symmetry in response to globalization. In terms of outcome variables, the analysis will focus on a potential bias in the quality level provided by monopolistically competitive firms as well as in the mass of varieties available in the market (Spence, 1975, 1976; Dixit-Stiglitz 1977).

The contribution made by this chapter is related to several strands of the IO and trade literature. The chapter ties in to an older IO literature concerned with quality and market

size (Shaked and Sutton, 1983; Sutton, 1989, 1991; Berry and Waldfogel, 2004) as well as the optimality of quality provision (Spence 1975, 1976). However, there are two important departures from the models considered by this literature: (i) here I assume a representative consumer, while the classic contributions in this field assume heterogeneity in consumers' tastes for quality; (ii) the choice of quality here is not strategic, with firms acting as price-index and aggregate quality takers, given the assumed market structure of monopolistic competition. In the traditional vertical differentiation IO models, firms strategically choose their place on the quality spectrum. Here, firms invest in quality to raise consumers' willingness to pay, but not to differentiate themselves from their competitors.

Spence (1975, 1976) compares the market equilibrium with the social planner's outcome in a monopoly setting with heterogeneous consumers. He notes that the social planner will choose quality according to the preference of the average consumer. The monopolist, on the other hand, will choose according to the marginal consumer, thereby introducing a distortion in the optimal provision of quality. This distortion can go either way depending on the underlying nature of consumer heterogeneity. As opposed to the heterogeneous consumers case, distortions in quality in the present chapter will arise due to sub-optimal firm scale under the monopolistically competitive market outcome.

This chapter is also related to a literature which considers the efficiency of market outcomes under monopolistic competition with and without firm heterogeneity. Dixit and Stiglitz (1977) is the seminal contribution for this analysis with symmetric firms. More recent contributions include Bilbiie et al (2006), Dhingra and Morrow (2012), Mrazova and Neary (2013), Nocco, Ottaviano and Salto (2013) and Melitz and Redding (2013). Dhingra and Morrow (2012) as well as Mrazova and Neary (2013) also consider to what extent globalization (in a frictionless world) can address distortions introduced by monopolistic competition. In the present chapter, I conduct this thought experiment in the presence of quality investment. The overall message from this literature is that assumptions about the demand structure matter a lot for welfare results and that CES is a very special case.

Recent empirical contributions have provided evidence consistent with the VED pref-

erence assumption made in this chapter. This includes the empirical analysis in Chapter 4 of this thesis, which provides evidence of asymmetric market size effects at the firm level. Earlier contributions by Syverson (2004) and Campbell and Hopenhayn (2005) establish support for this assumption by providing evidence of larger markets being characterised by larger average firm size.

The paper proceeds as follows: Section 5.2 presents the set-up of the model, Section 5.3 compares the market equilibrium with the allocations chosen by a constrained and unconstrained social planner, differentiating between the quality and the no-quality case. Section 5.4 considers to what extent trade integration in a world without trade frictions can address the distortions caused by a combination of monopolistic competition, VED preferences and endogenous quality. Section 5.5 concludes.

5.2 Set-Up

The model replicates that in Chapter 3, but replaces the assumption of firm heterogeneity with an assumption of symmetric firms. The preference specification is adapted from Eckel, Iacovone, Javorcik and Neary (2011) and the cost function from Antoniades (2008).

5.2.1 Consumers

There are L consumers in the economy, who each supply one unit of labour, and consume q_0 of a homogeneous good and q_i of varieties i from a set $\tilde{\Omega}$ of a differentiated product. Consumers are assumed to have identical tastes and a preference for quality. They value perceived quality (achieved by marketing efforts) and actual quality (achieved by objective product improvements) equally. Preferences take the following form:

$$U = q_0 + u_1 + \beta u_2, \tag{5.1}$$

where

$$\begin{aligned} u_1 &= \alpha Q - \frac{1}{2}b \left[(1-e) \int_{i \in \tilde{\Omega}} q_i^2 di + eQ^2 \right] \\ u_2 &= b(1-e) \int_{i \in \tilde{\Omega}} q_i z_i di. \end{aligned}$$

We have that $Q \equiv \int_{i \in \tilde{\Omega}} q_i di$; z_i is the quality of variety i ; $0 < e < 1$ reflects the substitutability between varieties: $e \rightarrow 0$ implies demands are highly independent of each other and $e \rightarrow 1$ implies varieties are becoming perfect substitutes; β is a parameter which reflects the strength of consumers' preference for quality.

Consumers maximise utility subject to the budget constraint $q_0 + \int_{i \in \tilde{\Omega}} p_i q_i di = I$. Inverse market demand faced by firms for each variety is given by:

$$p_i = a_i - \tilde{b}[(1-e)x_i + eX], \quad (5.2)$$

where $a_i = \alpha + \beta b(1-e)z_i$ with quality acting as a demand shifter; furthermore, $\tilde{b} \equiv \frac{b}{L}$ and $X \equiv \int_{i \in \tilde{\Omega}} x_i di$. With symmetric varieties the direct demand for variety i takes the following form:

$$x_i = \frac{1}{\tilde{b}(1-e)} [\alpha + Bz_i - p_i] - \frac{e}{1-e} X, \quad (5.3)$$

where $B = \beta b(1-e)$ is a collection of demand side parameters.

5.2.2 Firms

The economy consists of two sectors, one producing a homogeneous numeraire good under perfect competition and the other varieties of a differentiated product under monopolistic competition. The focus of the analysis will be on the monopolistically competitive sector; the homogeneous goods sector provides the backdrop against which misallocations of resources towards/away from the monopolistically competitive sector are analysed. It also serves to fix the wage rate.

Firms are symmetric and have a marginal cost of $c < \alpha$. They optimize along two dimensions: firms optimally choose both output and the level of quality investment. The quality investment is one-off and is reflected in an endogenous fixed cost, which is increasing in the level of quality. The total cost function of a firm consists of three components: a variable cost, the endogenous fixed cost component associated with quality investment, and an exogenous fixed cost component F which gives rise to scale economies:

$$TC_i = cx_i + \frac{1}{2}\theta z_i^2 + F. \quad (5.4)$$

The fixed cost of quality is convex in the level of quality chosen and also depends on a parameter θ , which is country specific. Inversely, $\frac{1}{\theta}$ represents a country's technological capabilities.

5.2.3 Monopolistic Competition, Demand and Efficiency

Note that I assume variable elasticity of demand preferences with a demand elasticity which is decreasing in sales. As emphasized in a recent contribution by Mrazova and Neary (2013), theoretical welfare/efficiency results for a monopolistically competitive industry structure are highly sensitive to the assumed demand and preference structure. Dixit and Stiglitz (1977) are the classic contribution to point out that the welfare implications of CES preferences differ significantly from the welfare results implied by variable elasticity of demand preferences: they find that under CES preferences the market achieves the efficient outcome for all values of the elasticity of substitution, while under VED the market might provide too much or too little variety (the direction depends on the elasticity of utility). Bilbiie et al. (2006) establish that the market will allocate resources efficiently in a model with symmetric firms and monopolistic competition if and only if preferences are CES. Dhingra and Morrow (2012) consider a generalization of the Dixit-Stiglitz framework to heterogeneous firms as in Melitz (2003). They prove that the market achieves the first best outcome in Melitz (2003) and hence establish that the Dixit-Stiglitz result on CES

preferences carries over to the heterogeneous firms case. Under VED preferences on the other hand, the market solution will be distorted away from the first best outcome. They show that the exact nature of the distortion depends on the alignment of the inverse demand elasticity and the elasticity of utility; however, the distortion disappears as market size gets large. They argue that how effective globalization is at addressing misallocations is determined by the size of the same two demand side elasticities.

Mrazova and Neary (2013) consider the most general case and show that whether globalization (in the guise of an increase in market size as in Krugman, 1979) brings a monopolistically competitive economy closer to an efficient outcome depends on the exact nature of the assumed preferences. They show that the welfare effects of globalization depend on the relationship between the elasticity and convexity of the assumed utility function (what they call the “Utility Manifold”). They conclude that “when the initial equilibrium is not efficient, any shock has both a direct effect and an indirect effect whose implications hinge on whether it brings the economy closer to or further away from efficiency. As a result, while positive gains are guaranteed with CES preferences, losses from trade are possible with demands that are more convex than CES, and gains from trade can be greater than in the CES case when demands are less convex.”³ The assumed quadratic preference structure in the present chapter implies subconvex demands (i.e. the elasticity of demand here is decreasing in sales). Mrazova and Neary (2013) point out that this has often been considered the most intuitive assumption, including by Marshall (1920), Dixit and Stiglitz (1977) and Krugman (1979).

5.3 Market Equilibrium and Social Planner’s Outcome

In this section, I study the efficiency of the market outcome for the model introduced in Section 5.2. To this end, I derive the market solution as well as the allocations chosen by a constrained and an unconstrained social planner. I do so for the general case where $\beta > 0$,

³Mrazova and Neary (2013), p.41

i.e. consumers value quality and firms thus have an incentive to invest in it. When studying the distortions under the market equilibrium, I consider first the no-quality benchmark with $\beta = 0$, before presenting results for the general case with quality investment. Note that results for the no-quality benchmark can be shown to be equivalent to those presented in the appendix of Nocco, Ottaviano and Salto (2013) which considers the market and first best allocations in a symmetric firms case of Melitz and Ottaviano (2008).

5.3.1 Market Equilibrium

Firms simultaneously choose the optimal level of quality and output. A firm's profit maximising price must satisfy:

$$p_i = \tilde{b}(1 - e)x_i + c, \quad (5.5)$$

and its profit maximising level of quality is given by the first-order condition:

$$z_i = \frac{B}{\theta}x_i. \quad (5.6)$$

Since firms are symmetric, all firms will be producing the same output in equilibrium, allowing us to write $X = Nx$. In a first step, solving for quality, output and price in terms of the mass of varieties, N , gives:

$$x = \frac{\theta}{2\theta\tilde{b}(1 - e) + \theta\tilde{b}eN - B^2}(\alpha - c) \quad (5.7)$$

$$z = \frac{B}{2\theta\tilde{b}(1 - e) + \theta\tilde{b}eN - B^2}(\alpha - c) \quad (5.8)$$

$$p = \frac{\theta\tilde{b}(1 - e)}{2\theta\tilde{b}(1 - e) + \theta\tilde{b}eN - B^2}(\alpha - c) + c. \quad (5.9)$$

In order to find the equilibrium mass of firms, I use the free entry condition. According to the latter, exogenous and endogenous fixed costs have to equal operating profits as firms enter up to the point where the marginal firm (and all infra-marginal firms) just break

even:

$$F + \frac{1}{2}\theta z^2 = (p - c)x. \quad (5.10)$$

Substituting the intermediate solutions for output, quality and prices into the free entry condition in (5.10) and solving for N gives:

$$N^m = \frac{\left[\frac{2bL(1-e) - \frac{L^2 B^2}{\theta}}{2F} \right]^{\frac{1}{2}} (\alpha - c) + \frac{LB^2}{\theta} - 2b(1-e)}{be}. \quad (5.11)$$

Note that the limit as $e \rightarrow 0$ here is not well defined. At $e = 0$, products are no longer substitutable to any degree and N explodes as consumers prefer to have as much variety as possible.

Substituting N back into equations (5.7), (5.8), and (5.9) we can solve for the equilibrium output, quality and price (where m stands for market equilibrium):

$$x^m = \left[\frac{2FL}{2b(1-e) - \frac{LB^2}{\theta}} \right]^{\frac{1}{2}} \quad (5.12)$$

$$z^m = \frac{B}{\theta} \left[\frac{2FL}{2b(1-e) - \frac{LB^2}{\theta}} \right]^{\frac{1}{2}} \quad (5.13)$$

$$p^m = \left[\frac{b(1-e)F}{L - \frac{L^2 B^2}{2\theta b(1-e)}} \right]^{\frac{1}{2}} + c. \quad (5.14)$$

5.3.2 Social Planner's Outcome

In a next step, I derive the social planner's outcome. I first consider the unconstrained case, that is, assuming that lump-sum transfers to firms are feasible; in an ideal world, a social planner would make such lump-sum transfers to firms in order to compensate them for any losses incurred under the socially optimal allocation. Secondly, I study the case where policy makers are constrained by a zero profit condition for firms in the absence of lump-sum payments. Given the imperfect nature of competition in the product market and the assumption of VED preferences, I expect the market equilibrium to deviate from

the social planner's outcome. In the subsequent sections, I will consider biases in the distribution of resources within the differentiated sector, as well as those between the differentiated sector and the homogeneous goods sector. In particular, I will focus on distortions in the level of quality and product variety available to consumers under the different scenarios as well as the size of the differentiated goods sector.

5.3.2.1 Unconstrained Optimum

In the unconstrained case, the social planner simply maximises the difference between gross consumer surplus and the firms' total costs:⁴

$$W(x, z, N) = q_0 + \int_{i \in \tilde{\Omega}} \left[\int_0^x p(y_i, z_i, N) dy_i - cx_i - \frac{\theta}{2} z_i^2 - F \right] di \quad (5.15)$$

Fully solving the social planner's problem yields the following first best solutions for output, quality and prices:

$$x^u = \left[\frac{2FL}{b(1-e) - \frac{LB^2}{\theta}} \right]^{\frac{1}{2}}, \quad (5.16)$$

$$z^u = \frac{B}{\theta} \left[\frac{2FL}{b(1-e) - \frac{LB^2}{\theta}} \right]^{\frac{1}{2}}, \quad (5.17)$$

$$p^u = c. \quad (5.18)$$

The optimal N^u that would be chosen by an unconstrained social planner is given by:

$$N^u = \frac{\left[\frac{Lb(1-e) - \frac{L^2B^2}{\theta}}{2F} \right]^{\frac{1}{2}} (\alpha - c) + \frac{LB^2}{\theta} - b(1-e)}{be}.$$

⁴An alternative approach to solving the social planner's problem is taken by Nocco et al (2013) who maximise consumer welfare subject to a resource constraint; the two approaches yield the same result.

5.3.2.2 Constrained Optimum

In the constrained case, the social planner maximises the difference between gross consumer surplus and the firms' total cost subject to a break-even constraint for firms:

$$W(x_i, z_i, N) = q_0 + \int_{i \in \tilde{\Omega}} \left[\int_0^x p(y_i, z_i, N) dy_i - cx_i - \frac{\theta}{2} z_i^2 - F \right] di \quad (5.19)$$

subject to:

$$F + \frac{1}{2} \theta z_i^2 = (p_i - c) x_i. \quad (5.20)$$

Constrained optimization yields an equilibrium price in terms of output and variety as

$$p(x_i, N) = \tilde{\eta} b (1 - e) x_i + c, \quad (5.21)$$

where $\eta = \frac{1-e+eN}{1-e+2eN} < 1$. The first order condition for quality is again the same as in the other two cases: $z_i = \frac{B}{\theta} x_i$.

Furthermore, expressing optimal output and quality in terms of N yields:

$$x^c = \left[\frac{2FL}{2\eta b(1-e) - \frac{LB^2}{\theta}} \right]^{\frac{1}{2}}, \quad (5.22)$$

$$z^c = \frac{B}{\theta} \left[\frac{2FL}{2\eta b(1-e) - \frac{LB^2}{\theta}} \right]^{\frac{1}{2}}, \quad (5.23)$$

$$p^c = \left[\frac{\eta b(1-e)F}{L - \frac{L^2 B^2}{2\eta \theta b(1-e)}} \right]^{\frac{1}{2}} + c. \quad (5.24)$$

Substituting these into the break-even condition for firms, we can solve implicitly for N^c :

$$N^c = \frac{\left[\frac{Lb(1-e) - \frac{L^2 B^2}{2\eta \theta}}{4\eta F} \right]^{\frac{1}{2}} (\alpha - c) + \frac{LB^2}{2\eta \theta} - b(1-e)}{be}. \quad (5.25)$$

5.3.3 Market vs Social Planner without Quality

In a first instance, I abstract from the quality dimension and compare the three outcomes with $\beta = 0$.⁵ While the unconstrained social planner will set the perfectly competitive price, both the market solution and the constrained social planner's outcome are characterised by a positive mark-up. Given that $\eta = \frac{1-e+eN}{1-e+2eN} < 1$, the constrained social planner will choose a price p^c that lies somewhere between the perfectly competitive price that would be chosen by the unconstrained social planner p^u and the market price p^m :

$$p^m = \left[\frac{b(1-e)F}{L} \right]^{\frac{1}{2}} + c > p^c = \left[\frac{\eta b(1-e)F}{L} \right]^{\frac{1}{2}} + c > p^u = c \quad (5.26)$$

Furthermore, we have the lowest firm output under the market equilibrium, x^m , followed by the constrained social planner's output x^c and that of the unconstrained planner, x^u :

$$x^m = \left[\frac{2FL}{2b(1-e)} \right]^{\frac{1}{2}} < x^c = \left[\frac{2FL}{2\eta b(1-e)} \right]^{\frac{1}{2}} < x^u = \left[\frac{2FL}{b(1-e)} \right]^{\frac{1}{2}} \quad (5.27)$$

Under the monopolistically competitive equilibrium, firms thus restrict output to below what is socially optimal, causing welfare losses from foregone scale economies. At the same time, the ranking of the mass of varieties is ambiguous. We have that:

$$N^m = \frac{\left[\frac{2Lb(1-e)}{2F} \right]^{\frac{1}{2}} (\alpha - c) - 2b(1-e)}{be} \lesseqgtr N^c = \frac{\left[\frac{Lb(1-e)}{4\eta F} \right]^{\frac{1}{2}} (\alpha - c) - b(1-e)}{be} \quad (5.28)$$

$$N^m \lesseqgtr N^u = \frac{\left[\frac{Lb(1-e)}{2F} \right]^{\frac{1}{2}} (\alpha - c) - b(1-e)}{be}, \text{ and} \quad (5.29)$$

$$N^c < N^u. \quad (5.30)$$

The mass of varieties available under the second best optimum will always be less than that under the first best outcome. The inequality holds since $\lim_{N \rightarrow \infty} \eta = \frac{1}{2}$, such that $\frac{1}{2} < \eta < 1$ or $2 < 4\eta < 4$.

⁵This analysis is analogous to the one presented in the appendix of Nocco et al (2013). This can be seen by letting $b(1-e) = \gamma$ and $be = \eta$. However, I discuss it here in order to allow for a direct comparison with the quality-augmented case.

As Ottaviano and Thisse (1999) and Nocco et al (2013) point out, whether the market will underprovide or overprovide variety will depend on the degree of product differentiation and the relative importance of fixed costs: if fixed costs are relatively high or products are highly differentiated, the market is likely to underprovide variety.⁶ The firm level output delivered by the market is unambiguously too low. Thus in a situation with high fixed costs/high product differentiation, the market will generate too little variety and too little firm output, implying that the differentiated goods sector overall will be too small compared to the rest of the economy.

5.3.4 Adding Quality

I next let $\beta > 0$, such that firms have an incentive to invest in quality. In a first instance I compare the three outcomes individually with and without quality.

Market Solution Compared to the no quality case, the market solution exhibits a higher level of output and a positive level of quality which is increasing in consumers' preference for quality and decreasing in the cost of quality. The equilibrium is also characterised by higher prices due to the fact that quality acts as a demand shifter. The effect of quality on the mass of varieties is ambiguous.

Unconstrained Optimum Compared to the no quality case, the unconstrained optimum again means a higher level of optimal output and a positive level of quality. Prices are still set at the competitive level. The effect of quality on the unconstrained optimal mass of variety is ambiguous also in this case.

Constrained Optimum As for the market and unconstrained solutions, the constrained optimum is characterised by a higher optimal level of output and a positive level of quality. The constrained optimal price will be higher than in the no quality case. For the con-

⁶In particular, $N^m < N^u$ if $\alpha < c + \frac{\sqrt{2}}{\sqrt{2}-1} \left[\frac{b(1-e)F}{L} \right]^{\frac{1}{2}}$.

strained social planner, the positive effect that quality has on the optimal mass of varieties is reduced compared to the other two cases.

Summarizing, it is thus the case that the possibility to invest in quality increases optimal output for all three allocation mechanisms and implies a strictly positive level of quality at the optimum, which will depend positively on consumers' preference for quality and negatively on the cost of quality production. The effect of quality on the mass of varieties is ambiguous in all three cases (though the weight of the quality effects differs between the three allocations as I discuss below). Without quality, variety is affected positively by the size of the market relative to fixed cost and negatively by the degree of product differentiation. Product quality partially offsets both effects (note that by second order conditions it can never fully offset them): firstly, the market size effect on variety is less positive with quality; this is because quality investment is increasing in market size and so is the endogenous fixed cost associated with quality. This higher fixed cost element reduces firms' profitability and hence shrinks the number of firms that can profitably produce in a given market. At the same time, quality investment dampens the negative effect of product differentiation on the mass of varieties: as product differentiation increases, so does the scope for quality upgrading; the higher level of quality in turn shifts out demand and therefore means the market can accommodate relatively more firms.

Proposition 23. *Compared to the no-quality benchmark, for the market solution and the two social planner's outcomes, the possibility to invest in quality leads to higher optimal output and a positive optimal level of quality. The effect on the mass of varieties is ambiguous in all three cases: endogenous quality attenuates both the positive effect of market size on variety and the negative effect of product differentiation without ever fully off-setting them.*

5.3.5 Market vs Social Planner with Quality

I next compare the three solutions for the general case where $\beta > 0$. For prices we have that:

$$p^m = \left[\frac{b(1-e)F}{L - \frac{L^2 B^2}{2\theta b(1-e)}} \right]^{\frac{1}{2}} + c \leq p^c = \left[\frac{\eta b(1-e)F}{L - \frac{L^2 B^2}{2\eta\theta b(1-e)}} \right]^{\frac{1}{2}} + c > p^u = c. \quad (5.31)$$

While the unconstrained social planner still sets the perfectly competitive and therefore the lowest price, the ranking of the market and the constrained price is ambiguous. The constrained social planners' price will be higher than the equilibrium price achieved by the market if $\eta < \frac{LB^2}{2\theta b(1-e) - LB^2}$. This is more likely, the stronger is consumers' quality preference (which raises B) and the cheaper is quality production (reflected in lower θ). Without quality, the constrained planner sets a price below that achieved by the market.

In order to see why the price in the constrained optimum may be higher, consider the optimal level of output and quality under the three scenarios. The ranking of outputs in the presence of quality is unambiguous as before. We have that the market will provide the lowest firm-level output, followed by the constrained and then the unconstrained planner:

$$x^m = \left[\frac{2FL}{2b(1-e) - \frac{LB^2}{\theta}} \right]^{\frac{1}{2}} < x^c = \left[\frac{2FL}{2\eta b(1-e) - \frac{LB^2}{\theta}} \right]^{\frac{1}{2}} < x^u = \left[\frac{2FL}{b(1-e) - \frac{LB^2}{\theta}} \right]^{\frac{1}{2}} \quad (5.32)$$

Next consider quality, recalling that first order conditions for quality were the same for the social planner as they are for the market outcome, namely: $z_i = \frac{B}{\theta}x_i$. Note that this is not surprising, given Spence's (1976) result: when choosing quality, a monopolist takes into account the willingness to pay for quality of the marginal consumer, whereas the social planner considers that of the average consumer. Given that we have assumed identical consumers, the first order conditions for optimal quality under the three scenarios coincide.

The first order condition for quality tells us that optimal quality in the three scenarios is a function of firm output. Thus for a given level of output, the level of quality chosen

by firms is identical in the market equilibrium to that chosen by the social planner. However, given that firm scale is too low under the market equilibrium, the market will also underprovide quality:

$$z^m = \frac{B}{\theta} \left[\frac{2FL}{2b(1-e) - \frac{LB^2}{\theta}} \right]^{\frac{1}{2}} < z^c = \frac{B}{\theta} \left[\frac{2FL}{2\eta b(1-e) - \frac{LB^2}{\theta}} \right]^{\frac{1}{2}} < z^u = \frac{B}{\theta} \left[\frac{2FL}{b(1-e) - \frac{LB^2}{\theta}} \right]^{\frac{1}{2}}. \quad (5.33)$$

The fact that optimal quality in the constrained case is higher than in the market equilibrium can explain the ambiguous ranking of prices between the constrained and market scenarios in the quality-augmented case.

Finally, the mass of varieties is given by:

$$\begin{aligned} N^m &= \frac{\left[\frac{2Lb(1-e) - \frac{L^2 B^2}{\theta}}{2F} \right]^{\frac{1}{2}} (\alpha - c) + \frac{LB^2}{\theta} - 2b(1-e)}{be} \\ &\leq N^c = \frac{\left[\frac{Lb(1-e) - \frac{L^2 B^2}{2\eta\theta}}{4\eta F} \right]^{\frac{1}{2}} (\alpha - c) + \frac{LB^2}{2\eta\theta} - b(1-e)}{be} \\ &\leq N^u = \frac{\left[\frac{Lb(1-e) - \frac{L^2 B^2}{\theta}}{2F} \right]^{\frac{1}{2}} (\alpha - c) + \frac{LB^2}{\theta} - b(1-e)}{be} \end{aligned} \quad (5.34)$$

As opposed to the no-quality benchmark, the ranking of all three alternatives now depends on parameter values. While the no-quality case had unambiguously fewer varieties under the second best compared to the first best solution, the result on the ranking of the two scenarios is more subtle with the quality augmentation: as $\eta \rightarrow \frac{1}{2}$, the constrained and unconstrained social planner's outcomes converge. As η increases, the second best outcome is affected in opposite directions. The negative effect of product differentiation as represented by the final term in the numerator becomes relatively stronger for the constrained case; however, so does the positive effect of market size. If fixed costs are high, the negative effect will outweigh the positive effect and the constrained social optimum will thus be characterised by fewer firms than the first best outcome.

In what follows, I focus on the comparison between the market outcome and the unconstrained social planner. Recall that for both cases, quality investment acted in a dampening way on both the positive market size effect and the negative effect of product differentiation on variety. Depending on the allocation mechanism, the relative weights of these attenuations will vary: the quality effects on variety, both positive and negative, are relatively stronger for the unconstrained social planner than they are for the market mechanism. Whether the first best optimum is characterised by more or fewer firms than the market equilibrium therefore depends again on the relative importance of fixed costs and product differentiation. If fixed costs are high relative to the degree of differentiation, the market will provide a sub-optimally low mass of varieties. The social planner reacts to the positive demand effect of quality relatively more strongly by providing more variety than the market would. The opposite is true if fixed costs are relatively low. In this case, the market overprovides variety, while the unconstrained social planner trades off variety more strongly in favour of quality as market size increases.

Proposition 24. *Under the market outcome, firms produce both too little output and too little quality, while the market may over- or underprovide variety. If fixed costs are low relative to the degree of product differentiation, the market overprovides variety while the unconstrained social planner trades off variety more strongly in favour of quality; the opposite is true if fixed costs are relatively high.*

5.4 Globalization

5.4.1 Can Market Size Address Distortions?

In the previous section, I established that the market equilibrium provision of quality and variety deviates from the first and second best solutions. In the presence of information asymmetries, a government, acting as the social planner, may, however, not be best placed to implement the socially optimal solution. I therefore follow Dhingra and Morrow (2012)

and Mrazova and Neary (2013) in exploring to what extent global integration can address the misallocation of resources present under the assumed preference structure. Both studies conduct the thought experiment in Krugman (1979), who considers the positive welfare effects of increased competition brought about by an increase in market size in a model with monopolistic competition, symmetric firms and variable elasticity of demand preferences. Note that as Mrazova and Neary (2013) point out, an increase in efficiency brought about by globalization is sufficient for welfare gains but by no means necessary.

In what follows, I consider the behaviour of product variety, quality and mark-ups as market size gets large. Since we are working in a symmetric firms context, we might expect that mark-ups drop to zero as L gets very large, such that a large market can achieve the perfectly competitive limit. However, I show below that this is not the case with endogenous product quality.

Recall from equation (5.11) the expression for the mass of varieties delivered by the market equilibrium in the presence of quality:

$$N = \frac{\left[\frac{2bL(1-e) - \frac{L^2 B^2}{\theta}}{2F} \right]^{\frac{1}{2}} (\alpha - c) + \frac{LB^2}{\theta} - 2b(1-e)}{be}.$$

As market size increases equilibrium variety behaves according to:

$$\frac{\partial N}{\partial L} = \frac{(\alpha - c)}{2be} \left[\frac{2Lb(1-e) - \frac{L^2 B^2}{\theta}}{2F} \right]^{-\frac{1}{2}} \left[\frac{2b(1-e) - \frac{2LB^2}{\theta}}{2F} \right] + \frac{B^2}{\theta be} \quad (5.35)$$

We have assumed that $\alpha > c$ and we know that by second order conditions $\frac{LB^2}{2b(1-e)\theta} < 1$. The first two terms can therefore never be negative. A necessary but not sufficient condition for variety to be decreasing in market size is for the third term to be negative, which is the case when $\frac{LB^2}{b(1-e)\theta} > 1$. The parameter restrictions imposed by second order conditions indeed admit this case. Hence for large enough α , the mass of varieties provided by the market can indeed be decreasing in market size. Note that the market was underproviding

variety compared to the optimum when fixed costs were high. Here, the effect of market size on variety is more likely to be positive when fixed costs are high, thus moving the market in the right direction.

Furthermore, we can show that quality unambiguously increases in market size:

$$\frac{\partial z}{\partial L} = \frac{B}{2\theta} \left[\frac{2FL}{2b(1-e) - \frac{LB^2}{\theta}} \right]^{-\frac{1}{2}} \left[\frac{2F \left(2b(1-e) - \frac{LB^2}{\theta} \right) + \frac{2FLB^2}{\theta}}{\left(2b(1-e) - \frac{LB^2}{\theta} \right)^2} \right] > 0 \quad (5.36)$$

An increase in market size has the following effect: it means an unambiguous increase in firms' equilibrium output and level of product quality supplied by them. As firm scale increases with market size, this makes it easier for firms to recover the fixed costs associated with product quality, and therefore leads them to invest in more quality. Note that in Spence (1976) we have a quality distortion arising from consumer heterogeneity that globalization cannot address. Here globalization can address the quality distortion. Thus an increase in market size is getting us closer to the social planner's outcome as far as quality provision is concerned.

Finally, for absolute mark-ups, we have from equation (5.14):

$$p^m - c = \left[\frac{b(1-e)F}{L - \frac{L^2B^2}{2\theta b(1-e)}} \right]^{\frac{1}{2}}.$$

Therefore,

$$\frac{\partial (p^m - c)}{\partial L} = \frac{1}{2} \left[\frac{b(1-e)F}{L - \frac{L^2B^2}{2\theta b(1-e)}} \right]^{-\frac{1}{2}} \left[\frac{-b(1-e) \left(1 - \frac{LB^2}{\theta b(1-e)} \right)}{\left(L - \frac{L^2B^2}{2\theta b(1-e)} \right)^2} \right]. \quad (5.37)$$

It is thus the case that mark-ups can be increasing in market size if $1 < \frac{LB^2}{\theta b(1-e)}$. In the presence of quality, mark-ups hence do not necessarily converge to zero as market size gets large.

Proposition 25. *In the no-quality benchmark with $\beta = 0$, mark-ups are unambiguously*

falling in market size. Thus as $L \rightarrow \infty$, the market reaches the competitive limit.

This is consistent with Mrazova and Neary (2013) who argue for the case of linear additively separable preferences that as market size gets large, consumption per head of any variety goes to zero, meaning the elasticity of demand tends to infinity. Again, this implies the market reaching the competitive limit.

Proposition 26. *If quality is sufficiently important, i.e. β is sufficiently large, mark-ups may be increasing in market size due to quality investment and the market therefore does not converge to the competitive limit.*

5.4.2 The Added Value of Firm Heterogeneity

In Chapter 3, I discussed the impact of globalization on the quality-augmented market equilibrium with the added dimension of firm heterogeneity. One of the main findings of the chapter was that globalization can have conflicting effects on the different mechanisms for gains from trade when endogenous product quality is important. As the analysis in the present chapter reveals, similar conflicting effects are present also in the symmetric firms case. Importantly, the two main microeconomic mechanisms by which globalization affects welfare in this model are robust across the symmetric firms model and its heterogeneous firms extension: aggregate quality is in both cases increasing in market size, and globalization can have anti-variety effects under both sets of assumptions. There is thus a deeper mechanism by which the market trades off variety in favour of higher quality as market size gets bigger.

Firm heterogeneity, however, is crucial for the underlying micro-mechanisms which are driving industry aggregates as the theoretical and empirical analyses in Chapters 3 and 4 revealed. Taking the example of aggregate quality, I argued in Chapter 3 that industry quality can change for three reasons: the intensive margin, the extensive margin and quality upgrading. Crucially the positive intensive margin effect of market size on aggregate quality requires firm heterogeneity: it arises from the fact that higher quality

firms are able to take advantage of a larger market to a greater extent than low quality firms and therefore expand their sales disproportionately compared to their lower quality competitors. This type of complementarity has been termed the “Matthew Effect” by Mrazova and Neary (2011) and I indeed observe it in the data, which underlines the importance of explicitly modeling firm heterogeneity. More generally, Nocco, Ottaviano and Salto (2013) and Melitz and Redding (2013) argue, the difference in assumptions about the nature of firms matters for the size of the implied welfare gains and show that gains from trade implied by heterogeneous firms models are higher than in the symmetric firms case.

5.5 Conclusion

An important strand of the recent trade literature has been concerned with the relationship between trade patterns and product quality; another important strand has investigated the efficiency of the market equilibrium and welfare gains from trade for a broad class of monopolistic competition models. This chapter contributes to both strands by introducing a simple model of quality investment in a setting of monopolistic competition with variable elasticity of demand preferences and symmetric firms; by studying the efficiency of the market allocation in terms of the level of output, quality investment and variety as well as the size of the differentiated sector; and by considering to what extent an increase in market size can address any distortions present in the quality-augmented market equilibrium.

I argue that introducing the possibility of quality investment, which comes at an endogenous fixed cost, has a positive effect on individual firm output (the intensive margin) and will lead to a positive optimal level of quality which is increasing in consumers’ preference for it and decreasing in its cost; at the same time the effect on the range of product variety available in the market (the extensive margin) is ambiguous. Variety in the no-quality benchmark is driven by a positive market size effect and a negative effect of product differentiation. Quality attenuates both of these effects without off-setting them entirely.

This is true for the market outcome as well as the constrained and unconstrained social planner's solution, though the relative strengths of the quality effects vary.

Comparing the market allocation to the first and second best optimum, I show that firms systematically produce too little output and quality in the market equilibrium. While the unconstrained social planner sets the perfectly competitive and therefore the lowest price, the price set by the constrained social planner can be higher than the market price. This is because the second best optimum implies a higher level of quality than would be provided by the market, which is in turn reflected in prices. Whether the market over- or underprovides variety, depends on the relative importance of fixed costs and the degree of product differentiation characterising the market. If fixed costs are high relative to the degree of differentiation, the market will provide a sub-optimally low mass of varieties. In this case the social planner trades off quality relatively more strongly in favour of variety. The opposite result holds if fixed costs are relatively low. By raising firms' incentives to invest in more quality, globalization can address some of the underlying distortions and therefore bring efficiency gains. I also show that high relative fixed costs mean that an increase in market size is associated with an increase in product variety, which addresses the underprovision of variety by the market in that case.

Finally, the chapter set out to isolate the role of firm heterogeneity in order to explore the underlying factors which are driving welfare results. The present chapter confirms the result of conflicting welfare channels for the symmetric firms case. In both cases do we see a trade-off between the range of product variety and the level of product quality available to consumers. We can therefore conclude that the result is robust to changes in assumptions about firm heterogeneity. However, while the aggregate welfare mechanisms have a similar flavour in the two chapters, the heterogeneous firms case is characterised by more sophisticated micro-mechanisms. As Nocco, Ottaviano and Salto (2013) and Melitz and Redding (2013) argue, the difference in assumptions about the nature of firms matters for the size of welfare gains; they show that gains from trade implied by heterogeneous firms models are higher than in the symmetric firms case. I check for microeconomic

mechanisms associated with firm heterogeneity in Chapter 4 of this thesis, and indeed find support in the data.

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5.6 Appendix

5.6.1 Market Equilibrium

Inverse demand:

$$p_i = \alpha + \beta b(1 - e)z_i - \tilde{b}[(1 - e)x_i + eX]$$

First Order Conditions for price and quality:

$$\begin{aligned} p_i &= \tilde{b}(1-e)x_i + c_i \\ z_i &= \frac{B}{\theta}x_i \end{aligned}$$

Second Order Conditions:

$$H = \begin{vmatrix} -2\tilde{b}(1-e) & \beta b(1-e) \\ \beta b(1-e) & -\theta \end{vmatrix}.$$

The Matrix $H = \begin{vmatrix} a & b \\ c & d \end{vmatrix}$ is negative definite and the solution is a local maximum iff $a < 0$ and $\det|H| > 0$. Here, $-2\tilde{b}(1-e) < 0$ and $\det|H| > 0$ if $2\theta > \beta^2 b(1-e)L$ or $2b(1-e)\theta > B^2 L$, where $B = \beta b(1-e)$.

Using the first-order condition for price, we can eliminate p from the expression for direct demand:

$$x_i = \frac{1}{2\tilde{b}(1-e)} [\alpha + Bz_i - c] - \frac{e}{2(1-e)} X$$

Solving for z , p and x :

$$\begin{aligned} x_i &= \frac{1}{2\tilde{b}(1-e)} (\alpha - c_i) - \frac{\theta\tilde{b}eN}{2\theta\tilde{b}(1-e)} x_i + \frac{B^2}{2\theta\tilde{b}(1-e)} x_i \\ \left(\frac{2\theta\tilde{b}(1-e) + \theta\tilde{b}eN - B^2}{2\theta\tilde{b}(1-e)} \right) x_i &= \frac{1}{2\tilde{b}(1-e)} (\alpha - c_i) \\ x_i^* &= \frac{\theta}{2\theta\tilde{b}(1-e) + \theta\tilde{b}eN - B^2} (\alpha - c_i) \\ z_i^* &= \frac{B}{2\theta\tilde{b}(1-e) + \theta\tilde{b}eN - B^2} (\alpha - c_i) \\ p_i^* &= \frac{\theta\tilde{b}(1-e)}{2\theta\tilde{b}(1-e) + \theta\tilde{b}eN - B^2} (\alpha - c_i) + c_i \end{aligned}$$

Then solving for N using the free entry condition:

$$F + \frac{1}{2}\theta z_i^2 = (p_i - c) x_i,$$

we get:

$$\begin{aligned}
F + \frac{\theta B^2}{2 \left(2\tilde{\theta}\tilde{b}(1-e) + \tilde{\theta}\tilde{b}eN - B^2 \right)^2} (\alpha - c)^2 &= \frac{\theta^2\tilde{b}(1-e)}{\left(2\tilde{\theta}\tilde{b}(1-e) + \tilde{\theta}\tilde{b}eN - B^2 \right)^2} (\alpha - c)^2 \\
F &= \frac{2\theta^2\tilde{b}(1-e) - \theta B^2}{2 \left(2\tilde{\theta}\tilde{b}(1-e) + \tilde{\theta}\tilde{b}eN - B^2 \right)^2} (\alpha - c)^2 \\
\tilde{\theta}\tilde{b}eN &= \left[\frac{2\theta^2\tilde{b}(1-e) - \theta B^2}{2F} \right]^{\frac{1}{2}} (\alpha - c) + B^2 - 2\tilde{\theta}\tilde{b}(1-e) \\
N^m &= \left[\frac{2\theta^2\tilde{b}(1-e) - \theta B^2}{2F} \right]^{\frac{1}{2}} \frac{(\alpha - c)}{\tilde{\theta}\tilde{b}e} + \frac{B^2}{\tilde{\theta}\tilde{b}e} - \frac{2\tilde{\theta}\tilde{b}(1-e)}{\tilde{\theta}\tilde{b}e} \\
&= \left[\frac{2bL(1-e) - \frac{L^2B^2}{\theta}}{2F} \right]^{\frac{1}{2}} \frac{(\alpha - c)}{be} + \frac{LB^2}{\theta be} - \frac{2b(1-e)}{be} \\
&= \frac{\left[\frac{2bL(1-e) - \frac{L^2B^2}{\theta}}{2F} \right]^{\frac{1}{2}} (\alpha - c) + \frac{LB^2}{\theta} - 2b(1-e)}{be}.
\end{aligned}$$

Substituting back in gives:

$$\begin{aligned}
x^m &= \left[\frac{2FL}{2b(1-e) - \frac{LB^2}{\theta}} \right]^{\frac{1}{2}} \\
z^m &= \frac{B}{\theta} \left[\frac{2FL}{2b(1-e) - \frac{LB^2}{\theta}} \right]^{\frac{1}{2}} \\
p^m &= \left[\frac{b(1-e)F}{L - \frac{L^2B^2}{2\theta b(1-e)}} \right]^{\frac{1}{2}} + c
\end{aligned}$$

5.6.2 Unconstrained Social Planner

Social planner's objective:

$$W(x, z, N) = q_0 + N \left[\int_0^x \alpha + Bz_i - \tilde{b}[(1-e)y_i + eNy_i] dy_i - cx_i - \frac{\theta}{2}z_i^2 - F \right]$$

FOCs:

$$\begin{aligned}
\frac{\partial W}{\partial x_i} &= Np(x_i, z_i, N) - Nc = 0 \\
\therefore p(x_i, z_i, N) &= c \\
\frac{\partial W}{\partial z} &= N \int_0^x B dy - N\theta z_i = 0 \\
\therefore z_i &= \frac{B}{\theta} x_i \\
\frac{\partial W}{\partial N} &= \int_0^x p(y_i, z_i, N) dy - cx_i - \frac{\theta}{2} z_i^2 - F - N\tilde{b}e \int_0^x y dy = 0 \\
&= \alpha x_i + Bz_i x_i - \frac{1}{2L} b [(1-e)x_i^2 + eNx_i^2] - cx_i - \frac{\theta}{2} z_i^2 - F - \frac{1}{2L} N b e x_i^2 \\
&= \alpha x_i + Bz_i x_i - \frac{1}{2L} b (1-e)x_i^2 - cx_i - \frac{\theta}{2} z_i^2 - F - \frac{1}{L} b e N x_i^2 = 0 \\
\therefore N &= \frac{L}{b e x_i^2} \left[\alpha x_i + Bz_i x_i - \frac{1}{2L} b (1-e)x_i^2 - cx_i - \frac{\theta}{2} z_i^2 - F \right].
\end{aligned}$$

Summarizing FOCs for unconstrained SP:

$$\begin{aligned}
c &= \alpha + Bz - \frac{b}{L} (1-e + eN) x \\
z &= \frac{B}{\theta} x \\
N &= \frac{L}{b e x_i^2} \left[\alpha x_i + Bz_i x_i - cx_i - \frac{\theta}{2} z_i^2 - F \right] - \frac{(1-e)}{2e}.
\end{aligned}$$

Solving:

$$\begin{aligned}
x &= \frac{L}{\frac{b(1-e)}{2} + \frac{L}{x_i^2} \left[\alpha x_i + Bz_i x_i - cx_i - \frac{B^2}{2\theta} x_i^2 - F \right] - \frac{LB^2}{\theta}} (\alpha - c) \\
&= \frac{(\alpha - c)}{\frac{b(1-e)}{2L} + \frac{1}{x_i^2} \left[\alpha x_i + Bz_i x_i - cx_i - \frac{B^2}{2\theta} x_i^2 - F \right] - \frac{B^2}{\theta}} \\
\alpha - c &= \frac{xb(1-e)}{2L} + \alpha + Bz_i - c - \frac{B^2}{2\theta} x_i - \frac{F}{x} - \frac{xB^2}{\theta} \\
0 &= \frac{xb(1-e)}{2L} + \frac{B^2}{\theta} x_i - \frac{B^2}{2\theta} x_i - \frac{F}{x} - \frac{B^2}{\theta} x \\
\frac{F}{x^2} &= \frac{\theta b(1-e) - LB^2}{2\theta L} \\
x^u &= \left[\frac{2LF}{b(1-e) - \frac{LB^2}{\theta}} \right]^{\frac{1}{2}} \\
z^u &= \frac{B}{\theta} \left[\frac{2LF}{b(1-e) - \frac{LB^2}{\theta}} \right]^{\frac{1}{2}}
\end{aligned}$$

N under the unconstrained SP is:

$$\begin{aligned}
N &= \frac{L}{bex_i^2} \left[\alpha x_i + Bz_i x_i - cx_i - \frac{\theta}{2} z_i^2 - F \right] - \frac{(1-e)}{2e} \\
&= \frac{L}{bex_i^2} \left[\alpha x_i + \frac{B^2}{2\theta} x_i^2 - cx_i - F \right] - \frac{(1-e)}{2e} \\
&= \frac{L}{bex_i} \left[\alpha - c - \frac{F}{x_i} \right] + \frac{LB^2}{2\theta be} - \frac{(1-e)}{2e} \\
&= \frac{L(\alpha - c)}{bex_i} - \frac{FL}{bex_i^2} + \frac{LB^2}{2\theta be} - \frac{(1-e)}{2e} \\
&= \left[\frac{b(1-e) - \frac{LB^2}{\theta}}{2FL} \right]^{\frac{1}{2}} \frac{L(\alpha - c)}{be} - \frac{b(1-e) - \frac{LB^2}{\theta}}{2be} + \frac{LB^2}{2\theta be} - \frac{b(1-e)}{2be} \\
&= \left[\frac{b(1-e) - \frac{LB^2}{\theta}}{2FL} \right]^{\frac{1}{2}} \frac{L(\alpha - c)}{be} - \frac{b(1-e)}{be} + \frac{LB^2}{\theta be} \\
N^u &= \frac{\left[\frac{Lb(1-e) - \frac{L^2 B^2}{\theta}}{2F} \right]^{\frac{1}{2}} (\alpha - c) - b(1-e) + \frac{LB^2}{\theta}}{be}
\end{aligned}$$

5.6.3 Constrained Social Planner

The constrained optimisation problem is:

$$\begin{aligned}
\mathcal{L}(x, z, N, \lambda) &= Lq_0 + N \left[\int_0^x p(y_i, z_i, N) dy - cx_i - \frac{\theta}{2} z_i^2 - F \right] - \lambda N \left[F + \frac{1}{2} \theta z_i^2 + cx_i - p(x_i, z_i, N) x_i \right] \\
&= Lq_0 + N \left[\int_0^x \alpha + Bz_i - \tilde{b}[(1 - e + eN) y_i] dy - cx_i - \frac{\theta}{2} z_i^2 - F \right] \\
&\quad - \lambda N \left[F + \frac{1}{2} \theta z_i^2 + cx_i - p(x_i, z_i, N) x_i \right] \\
\frac{\partial \mathcal{L}}{\partial x_i} &= Np(x_i, z_i, N) - Nc - \lambda Nc + \lambda Np(x_i, z_i, N) + \lambda N x_i \frac{\partial p}{\partial x_i} = 0 \\
\therefore p(x_i, z_i, N) &= \frac{\lambda \tilde{b}(1 - e + eN)}{1 + \lambda} x_i + c \\
\frac{\partial \mathcal{L}}{\partial z_i} &= N \int_0^x B dy - N\theta z_i - \lambda N\theta z_i + \lambda N x_i \frac{\partial p}{\partial z_i} = 0 \\
\therefore z_i &= \frac{B}{\theta} x_i \\
\frac{\partial \mathcal{L}}{\partial N} &= \int_0^x p(y_i, z_i, N) dy - cx_i - \frac{\theta}{2} z_i^2 - F - N\tilde{b}e \int_0^x y dy \\
&\quad - \lambda \left[F + \frac{1}{2} \theta z_i^2 + cx_i - p(x_i, z_i, N) x_i \right] + \lambda N x_i \frac{\partial p}{\partial N} = 0 \\
\frac{\partial \mathcal{L}}{\partial \lambda} &= F + \frac{1}{2} \theta z_i^2 - [p(x_i, z_i, N) - c] x_i = 0
\end{aligned}$$

Solving for λ , where $\epsilon = 1 - e + eN$:

$$\begin{aligned}
\frac{\partial \mathcal{L}}{\partial N} &= \int_0^x (\alpha + Bz_i - \tilde{b}\epsilon y_i) dy - cx_i - \frac{\theta}{2} z_i^2 - F - N\tilde{b}e \int_0^x y dy \\
&\quad - \lambda \left[F + \frac{1}{2} \theta z_i^2 + cx_i - p(x_i, z_i, N) x_i \right] + \lambda N x_i \frac{\partial p}{\partial N} = 0 \\
&= \alpha x_i + Bz_i x_i - \frac{\tilde{b}\epsilon}{2} x_i^2 - cx_i - \frac{\theta}{2} z_i^2 - F - \frac{\tilde{b}e}{2} N x_i^2 - \lambda N \tilde{b}e x_i^2 = 0 \\
&= \left(\alpha + Bz_i - \tilde{b}\epsilon x_i \right) x_i - cx_i - \frac{\theta}{2} z_i^2 - F - \frac{\tilde{b}e}{2} N x_i^2 - \lambda N \tilde{b}e x_i^2 = -\frac{\tilde{b}\epsilon}{2} x_i^2 \\
&= p(x_i, z_i, N) x_i - cx_i - \frac{\theta}{2} z_i^2 - F - \frac{\tilde{b}e}{2} N x_i^2 - \lambda N \tilde{b}e x_i^2 = -\frac{\tilde{b}\epsilon}{2} x_i^2 \\
\lambda N \tilde{b}e x_i^2 &= \frac{\tilde{b}(1 - e)}{2} x_i^2 \\
\therefore \lambda &= \frac{1 - e}{2eN}
\end{aligned}$$

Constrained Social Planner's FOC:

$$p(x_i, z_i, N) = \frac{\lambda \tilde{b} \epsilon}{1 + \lambda} x_i + c \quad (5.38)$$

$$z_i = \frac{B}{\theta} x_i \quad (5.39)$$

$$\lambda = \frac{1 - e}{2eN} \quad (5.40)$$

$$p(x_i, z_i, N)x_i = F + \frac{1}{2}\theta z_i^2 + cx_i \quad (5.41)$$

Substituting (5.40) into (5.38) and multiplying both sides by x and substituting (5.39) into (5.41) gives:

$$p(x_i, z_i, N)x_i = \frac{\frac{1-e}{2eN}}{1 + \frac{1-e}{2eN}} \tilde{b} \epsilon x_i^2 + cx_i$$

$$p(x_i, z_i, N)x_i = F + \frac{B^2}{2\theta} x_i^2 + cx_i$$

$$\begin{aligned} \frac{\frac{1-e}{2eN}}{1 + \frac{1-e}{2eN}} \tilde{b} \epsilon x_i^2 + cx_i &= F + \frac{B^2}{2\theta} x_i^2 + cx_i \\ \therefore \frac{1 - e + eN}{1 - e + 2eN} \tilde{b} (1 - e) x_i^2 &= F + \frac{B^2}{2\theta} x_i^2 \\ \therefore x &= \left[\frac{F}{\frac{1-e+eN}{1-e+2eN} \tilde{b} (1-e) - \frac{B^2}{2\theta}} \right]^{\frac{1}{2}} \end{aligned}$$

Letting $\eta = \frac{1-e+eN}{1-e+2eN}$, the constrained social planner's outcome is given by:

$$\begin{aligned} x^c &= \left[\frac{2LF}{2\eta b(1-e) - \frac{LB^2}{\theta}} \right]^{\frac{1}{2}} \\ z^c &= \frac{B}{\theta} x_i = \frac{B}{\theta} \left[\frac{2LF}{2\eta b(1-e) - \frac{LB^2}{\theta}} \right]^{\frac{1}{2}} \\ p^c &= \tilde{\eta} \tilde{b} (1-e) x_i + c = \left[\frac{\eta b(1-e)F}{L - \frac{L^2 B^2}{2\eta \theta b(1-e)}} \right]^{\frac{1}{2}} + c. \end{aligned}$$

Substituting these into the break-even condition for firms, we can solve for N :

$$\begin{aligned}
(\alpha + Bz_i - \tilde{b}\epsilon x_i) x_i &= F + \frac{1}{2}\theta z_i^2 + cx_i \\
\alpha x_i + Bz_i x_i - \tilde{b}\epsilon x_i^2 &= F + \frac{1}{2}\theta z_i^2 + cx_i \\
F + \frac{B^2}{2\theta} \frac{2LF}{2\eta b(1-e) - \frac{LB^2}{\theta}} &= (\alpha - c) \left[\frac{2LF}{2\eta b(1-e) - \frac{LB^2}{\theta}} \right]^{\frac{1}{2}} + \frac{B^2}{\theta} \frac{2LF}{2\eta b(1-e) - \frac{LB^2}{\theta}} \\
&\quad - \tilde{b}\epsilon \frac{2LF}{2\eta b(1-e) - \frac{LB^2}{\theta}} \\
F &= (\alpha - c) \frac{\left[2LF \left(2\eta b(1-e) - \frac{LB^2}{\theta} \right) \right]^{\frac{1}{2}}}{2\eta b(1-e) - \frac{LB^2}{\theta}} + \frac{B^2}{\theta} \frac{2LF}{2\eta b(1-e) - \frac{LB^2}{\theta}} \\
&\quad - \tilde{b}\epsilon \frac{2LF}{2\eta b(1-e) - \frac{LB^2}{\theta}} - \frac{B^2}{2\theta} \frac{2LF}{2\eta b(1-e) - \frac{LB^2}{\theta}} \\
\left(2\eta b(1-e) - \frac{LB^2}{\theta} \right) F &= (\alpha - c) \left[2LF \left(2\eta b(1-e) - \frac{LB^2}{\theta} \right) \right]^{\frac{1}{2}} + \frac{LB^2}{\theta} F - 2b\epsilon F \\
\eta(1-e) + \epsilon &= \frac{\alpha - c}{2b} \left[\frac{2L}{F} \left(2\eta b(1-e) - \frac{LB^2}{\theta} \right) \right]^{\frac{1}{2}} + \frac{LB^2}{b\theta} \\
\eta\epsilon &= \left[\frac{2\eta Lb(1-e) - \frac{L^2 B^2}{\theta}}{2F} \right]^{\frac{1}{2}} \frac{(\alpha - c)}{2b} + \frac{LB^2}{2\theta b} \\
N &= \left[\frac{2\eta Lb(1-e) - \frac{L^2 B^2}{\theta}}{2F} \right]^{\frac{1}{2}} \frac{(\alpha - c)}{2\eta b e} + \frac{LB^2}{2\theta \eta b e} - \frac{1-e}{e} \\
N^c &= \frac{\left[\frac{2\eta Lb(1-e) - \frac{L^2 B^2}{\theta}}{2F} \right]^{\frac{1}{2}} (\alpha - c) + \frac{LB^2}{\theta} - 2\eta b(1-e)}{2\eta b e}.
\end{aligned}$$

Chapter 6

Conclusion

In this thesis I have considered the microeconomic mechanisms for gains from trade in the presence of quality investments by firms. Within the framework of a quality-augmented heterogeneous firms model, I have shown that the quality dimension matters for welfare gains. With quality being itself an important channel for gains from trade, I have also investigated how aggregate quality changes as a consequence of globalization. This was done theoretically as well as empirically using firm-level data. Furthermore, I analysed a symmetric firms version of the baseline model in order to isolate the role of firm heterogeneity in driving welfare results. In this context, I also studied the efficiency of the quality-augmented market equilibrium. To the best of my knowledge, this is the first study to provide a comprehensive analysis of the role of endogenous product quality in the determination of gains from trade.

Chapter 2 offered an explanation for observed industry heterogeneity in trade-induced productivity gains and showed that results depend on whether or not firms have the option to invest in quality. Endogenous product quality has the effect of making selection tougher in the initial equilibrium thereby reducing the scope for additional selection-induced productivity gains. This effect is more pronounced the higher the degree of product differentiation and thus the incentive for firms to invest in quality.

Chapter 3 took a broader view of welfare gains from trade and looked beyond just pro-

ductivity improvements. To the best of my knowledge, it represents the first contribution to systematically study how predictions for gains from trade are affected by endogenous product quality. I argued that a convenient short-cut for welfare - the productivity cut-off - which is often used in the trade literature is not a sufficient welfare indicator in a quality-augmented model. Instead of considering just the productivity cut-off, I therefore derived the indirect utility function and used its structure to guide my analysis of the different welfare channels implied by the model. I showed conflicting effects of globalization on welfare when consumers have a strong preference for quality. In particular, I showed that a drop in quality-adjusted prices can be accompanied by a drop in product variety available to consumers. However, combining the different mechanisms using the structure of the indirect utility function revealed that overall gains from trade in this model are always positive. I also discussed the three margins of trade-induced aggregate quality adjustment implied by the model and showed differences in adjustment depending on whether quality incurs additional fixed or variable cost. I argued that the most robust adjustment mechanism is a positive effect on aggregate quality via the intensive margin. Finally, I took first steps in linking the analysis to the current debate on the macroeconomic gains from trade.

In Chapter 4, I took the prediction for quality-adjustment via the intensive margin to data. To the best of my knowledge, this is the first contribution to do so. The analysis suggested that the benefits of globalization are distributed unevenly across firms. The hypothesis was that due to complementarities, the best firms are the best placed to take advantage of a larger market. While the theoretical effect is ultimately driven by productivity, the theory presented in Chapter 3 predicts that it should be observable also in the quality dimension. I used a dataset of firm-level champagne exports matched with firm-level quality ratings to show that it is indeed the highest quality firms which benefit disproportionately from a larger export market size. These results suggest that it is important to account for firm heterogeneity when it comes to the implications of globalization. In particular, if one were to translate results from the cross-section to a time-series

perspective, the data suggest a disproportionate boost to competitiveness in the face of progressing globalization from being a high quality producer. Furthermore, the existence of a market size effect in the data supports the assumption of variable elasticity of demand over CES preferences. This is an important finding given existing insights regarding the sensitivity of welfare results to the exact properties of preference structures (e.g. Dixit and Stiglitz, 1977; Mrazova and Neary, 2013).

Chapter 5 considered the efficiency properties of the quality-augmented market equilibrium in a symmetric firms version of the model presented in Chapter 3. To the best of my knowledge, this has not been done previously. It showed that the decentralized solution is characterized by too little output and quality and that an increase in market size can bring the economy closer to an allocation that would be chosen by a social planner in terms of quality and output levels. However, with endogenous quality the market does not converge to the competitive limit as market size gets large. As in the heterogeneous firms case, the model implied that globalization can be associated with a loss in variety if consumers value quality highly.

Several interesting avenues for future research emerge from the analyses and findings presented in this thesis. The thesis has mainly focused on the microeconomic mechanisms for gains from trade. In a next step, it will be interesting to draw out the implications of the quality dimension at the macro level. I have shown that the baseline model in this thesis fits into the class of models considered by a recent influential study regarding the macroeconomic gains from trade (Arkolakis, Costinot, Donaldson and Rodriguez-Clare, 2012). This represents a useful starting point for further analysis. In particular, the gravity equation derived in Chapter 3 in this context can be used for estimating trade elasticities in the presence of quality, which in turn are a crucial ingredient for calculating the macroeconomic impact of the quality dimension.

Secondly, evidence regarding the dynamics of quality upgrading with respect to market size is still sparse. The theoretical analysis in Chapter 3 suggests that it is necessary to distinguish between two quality cost structures: when quality is achieved via fixed cost

investment only, the optimal level of quality chosen by high quality firms is increasing in market size, i.e. globalization should induce quality upgrading. When quality production incurs only variable cost, on the other hand, a larger market has no effect on firm quality choice. In a next step it will therefore be useful to exploit differences in quality cost functions across industries to test for quality upgrading effects.

Thirdly, this thesis has focused on integration between symmetric countries. This is relevant for example for understanding potential consequences of the EU-US FTA, which is currently under negotiation. However, regional integration often also involves countries of different development levels. In a next step, it will be interesting to study the implications of trade integration between countries of different technological capabilities and with different levels of preference for quality. In particular it will be important from a development perspective to what extent the effects of trade integration on quality upgrading are asymmetric for two integrating countries with different technological capabilities.

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