# UK FREIGHT DEMAND: ELASTICITIES AND DECOUPLING

Paolo Agnolucci [(1)] [(*)] and David Bonilla [(2)]

[(*)] = address for correspondence

[(1)] = Visiting Scholar, The Cambridge Centre For Climate Change Mitigation Research, Department of Land Economy, University of Cambridge, 19 Silver Street, Cambridge, CB3 9EP, UK, p.agnolucci@gmail.com

[(2)] = Research Fellow Transport Studies Unit, Centre for Environment, and St. Anne's College, Oxford University, South Parks Road, Oxford OX1 3QY, UK. bonvar@yahoo.com

Acknowledgements: The authors thank the reviewers and the editor for insightful comments on an earlier draft. Research for this paper was funded under the auspices of the UK Energy Research Centre, which is funded by a consortium of UK Research Councils, whose financial support is gratefully acknowledged.
The second author gratefully acknowledges financial support of the European Commission: EU-Marie Curie Fellowships 2005-2007, 6th Framework Programme. The opinions expressed in the article pertain to the author. The author is solely responsible for the information communicated, published or disseminated and it does not represent the opinion of the Community and the Community is not responsible for any use of the data that appears therein.

**Abstract**

The aim of this study is to estimate road freight demand in the UK for the period 1956-2003 and to assess the occurrence of decoupling between economic activity and freight demand as discussed in McKinnon (2006). As models with a deterministic trend cannot accommodate a long-run relationship between the variables in the freight demand, one needs to model a relationship between growth rates rather than between the levels of the variables. Models with a stochastic trend gave better results and confirmed that the pace decoupling during the last years of the sample period increased. Price and income elasticities were estimated to be about 18 percent and 65 percent respectively.

Date of Final Version 27/03/2008

# 1 Introduction

The freight industry is an important part of the British economy with a value of £70 billion per year (FTA, 2007, p.7). Freight demand (all modes), defined as the product of goods lifted times hauled distance and measured in tonne-kilometres moved, has grown on average 2.1percent per year during the period 1957-2003 while road freight demand grew on average by 3.3 percent per year (DfT, 2005). It is worth noting that this does not make the UK a particularly freight-intensive country. In fact, the UK (inland) freight intensity, that is, the ratio between freight demand and economic output, is lower than that observed in Germany, France and Italy (Bennathan et al. 1992 and OECD 2005). This reflects the UK's relatively small manufacturing sector, its land area and its larger service sector.

Over the timespan assessed in this study, road has taken an increasing share of the total freight movements, with the railway share falling significantly since 1954, although it has recently begun to recover. In 2004, 8 percent of freight was moved by rail, 64 percent was taken by road, 24 percent by water and 4 percent by pipelines (DfT 2005). Sustained increases in road freight demand have created a number of externalities related to oil demand, local pollution, accidents and urban congestion. The fuel consumed from road freight in 1970-2005 has almost trebled: from 5.7 MTOE to 15.5 MTOE (DTI 2006). In 2003-04, road freight was responsible for 8 percent of total UK $CO_2$ emissions, 19 percent of $NO_x$, emissions and 11 percent of particular matter ($PM_{10}$) (Defra, 2007).

Considering the externalities arising from road freight, it is not surprising that the issue of decoupling economic activity from road freight has attracted considerable attention in the academic literature and the policy making arena. Decoupling offers the prospect of growing economic prosperity without a corresponding increase in externalities caused by road freight (McKinnon, 2006). Improved efficiency in freight transport can benefit GDP growth by achieving cost savings to businesses, particularly if those improvements are made along congested routes (DfT, 2006). As part of its sustainable distribution policy, the UK Government acknowledges the need to decouple freight traffic from GDP growth (DfT, 1999). Similarly, the 2001 EU White Paper (EU Commission, 2001) on transport policy calls for action "to bring about a significant decoupling of transport growth and GDP growth" (EU Commission, 2001, p.70). Separately from the initiatives aimed at reducing demand, a number of policies have been discussed by the UK Government and the EU Commission in an attempt to reduce the negative externalities of road freight. These include policies to stimulate intermodalism towards rail and sea transport (EU Commission, 2001), the development of the profession of freight integrator and the standardisation of containers. The UK government in its White Paper on sustainable distribution (DfT, 1999), aims to minimise pollution and other externalities such as noise, congestion and accidents.

The main aim of this paper is to estimate the aggregate relationship between road freight demand, economic activity and freight price in the UK. As estimates of road freight demand are scarce in the literature, there is a need for an investigation of the relationship between freight and its determinants. According to DfT (1997), an aggregate approach to the estimation of road freight demand has the advantage of being relatively straightforward to implement but has the drawback of not being able to take into account factors such as changes in the output of different sectors of the economy. These factors can be accommodated in the disaggregate approach, that is estimation implemented at the sectoral or commodity level. Although we agree with the arguments in DfT (1997), our decision to implement the aggregate approach is based on the fact that a disaggregated time series for the price of freight services in the UK is currently not available for the sample used in this study. It should be noted, however, that changes in the importance of the service sector in the economy have been accommodated in this study by using data for two macroeconomic variables, one including and the other excluding the service sector. In addition, the use of models with stochastic trends such as those discussed below allows factors such as structural changes in the manufacturing sector to be accommodated.

In addition to estimating road freight demand, this article tests the robustness of the analysis presented in McKinnon (2006). As discussed below, the author argues that the decoupling between road freight demand and economic growth took place in the UK between 1997 and 2004. In order to provide robust evidence on the magnitude of price and income elasticities, and the extent of decoupling, this paper introduces a number of econometric methodological advances in the transport literature, namely the use of the PSS test for the existence of long-run relationships between the levels of variables, the estimation of econometric models with stochastic trends and the application of the automated specification search incorporated in PcGets, an econometric software.

The paper is structured in the following way: section 2 reviews the issue of decoupling, as discussed in McKinnon (2006) and Tapio (2005), and a number of studies estimating freight demand; section 3 describes the dataset used in this study and assesses the stationarity of the series; section 4 discusses the econometric approach adopted in this study. In section 5 we first assess the existence of a long-run relationship between freight demand and its determinants while assuming only deterministic terms in the model. As the variables were not found to have a long-run equilibrium, only short-run models could be estimated when assuming a linear trend. However, when assuming a stochastic trend, the parameters in long-run models were stable across samples, statistically significant and conformed to economic theory. In addition, the trend in the model confirmed the analysis in McKinnon (2007) on the decoupling between freight demand and economic activity. Section 6 contains the concluding remarks.

## 2 Setting the Background: Elasticities and Decoupling

This section briefly discusses the contribution of McKinnon (2006), which assesses the evidence for decoupling between road freight demand and economic growth in the UK and reviews some of the most important studies, which estimate the price and income elasticities of road freight demand, measured in tonne-kilometres.

## 2.1 Decoupling

In general terms, decoupling takes place when the ratio between the percent growth of a transport-related variable, for example passenger traffic or freight demand as defined in this study, and the percent growth of an economic variable is less than unity (Tapio 2005). In most instances, including McKinnon (2006) and Tapio (2005), the analysis of decoupling is implemented by assessing percentage changes in the variables rather than elasticities from econometric models. Tapio (2005) distinguished between weak, strong and recessive decoupling. In weak decoupling the value of the ratio mentioned above falls to between 0 and 0.8. Strong decoupling occurs when the ratio is smaller than zero while the economy is growing. Finally, recessive decoupling takes place when the ratio is higher than 1.2 and the economy is shrinking. In McKinnon (2007) the terms decoupling refers more precisely to the ratio between percent changes of road freight demand, measured in tonne-kms, and the GDP measured in real terms. The author notes that between 1997 and 2004, GDP in the UK increased by one-fifth, while road freight remained relatively stable. The ratio mentioned above was about 0.38. The author concludes that the long-awaited decoupling of economic and freight transport growth has begun. The U.S. economy has also seen trends towards decoupling in recent years (Gilbert and Nadeau, 2002).

Among the 12 factors discussed in McKinnon (2006, 2007), 67 percent of the observed decoupling can be attributed to: a decline in the share of the freight which is moved by road; increased real prices of road freight; and increased penetration of the

UK market by foreign operators.[1] These three factors are said to explain 22 percent, 12 percent and 33 percent of the observed decoupling. For a thorough discussion of the 12 factors, the reader is referred to McKinnon (2007). A number of factors among those listed in McKinnon (2007) refer to the structure of the logistic chain, for example the falling rate of spatial concentration, the efficiency of vehicle routing and domestic supply chains becoming fully extended. These factors are not taken into account in this study as they are difficult to accommodate in econometric studies unless cross-sectional datasets are available. Readers are referred to Zografos and Giannouli (2003), the EU REDEFINE project (1999) and Black *et al*. (1995) which discuss many of these issues. Among the factors related to the structure of the economy in McKinnon (2006), only the change in the composition of GDP and the erosion of industrial activity to other countries are taken into account in this study. The former was accommodated by estimating models with economic activity for the economy as a whole and economic activity for the production sectors only – defined below. Erosion of industrial activity to other countries is taken into account by incorporating imports into one of the variables of economic activity used in this study. Restructuring within the production and manufacturing sectors is not considered here, as data at the commodity level were not immediately available. McKinnon (2006) concluded that restructuring within the industrial sector is likely to have relatively little impact on decoupling.

Another factor influencing the existence of decoupling is the displacement of freight from trucks to vans. McKinnon (2006) concluded that the displacement of

[1] Data on foreign vehicles operating in the UK market are not included in the UK official statistics. The estimates in McKinnon (2007, p. 48) were obtained by using information from two small surveys conducted in 2000 and 2003 and by assuming that the number of tonne-km carried by foreign operators directly corresponded to the number of foreign-registered trucks entering the UK.

freight from trucks to vans is likely to have had made little contribution to the observed decoupling. The robustness of this conclusion is assessed in this study as the dataset in this paper uses total road freight, which is the sum of freight carried in heavy goods vehicles (HGVs) together with vans with a weight below 3.5 tonnes. [2]

**2.2 Econometric Studies**

Results from econometric studies of road freight demand differ widely on the basis of the functional form in the model (for example log-linear or linear), the sectors studied (for example  a particular sector or the whole economy), the heterogeneity of economies (for example with a large agricultural or service sector), the sample used (for example cross-section or time series) and the variables employed in the estimation. A number of studies measure freight demand in tonnes lifted while others use tonne-kilometres; some microeconomic studies use the revenue shares of tonne-km (that is money value of tonnes-km moved) as a dependent variable. Agreement on the definition of the price or cost variable is also rare, possibly due to the paucity of the data available. Furthermore, some studies assess only the determinants of road freight demand while others estimate the factors influencing mode choice.

As a result of the factors mentioned above, studies of freight demand tend to produce widely ranging estimates of price and income elasticities. In addition, studies of one freight mode only, for example  road freight, are likely to produce higher price

[2] This refers to freight carried (tonne-km) in goods vehicles 3.5 tonnes (gross vehicle weight) and light goods vehicles weight up to that weight. This includes freight carried by vans for the whole of Great Britain using survey data of several years. The light goods vehicles data is collected in surveys of 1976, 1987, 1992/93, etc. The UK's DfT interpolated data for intervening and subsequent years (Notes and Definitions of TSGB, 2004, 2006, Table 4.3.)

elasticities and lower income elasticities than studies for all freight modes because of the substitution which can occur from, say, road to other modes. In order to facilitate the discussion of the empirical results presented in Section 5 and 6, this section presents a very succinct discussion of the results of studies assessing road freight demand measured in tonnes-kilometres. Studies assessing mode choice, which is an issue discussed by many authors, are not discussed here. The reader is referred to Winston (1981) and to Small and Winston (1999) for further details.

As mentioned above, the composition of the economy is an important factor in determining price and income elasticities of demand for road freight because different commodities have different transportation requirements and might be more suited to a particular mode of transport. Not surprisingly, a number of studies assess road freight at the commodity level. The most disaggregated studies for road freight demand have been conducted in the USA, using a cross section of firms observed in a specific year, (Friedlaender and Spady (1980) and Oum (1989)) or by using time series data as in Lewis and Widup (1982). However, in these three widely cited studies, freight demand is measured by the monetary value of tonnes shipped and for this reason they are not discussed further. In the United Kingdom, three major econometric exercises (Fowkes *et al.* (1993); Black *et al.*(1995), and DfT (1997), also discussed below) have examined road freight at a disaggregated level using equations that include economic activity. Studies at the sectoral or commodity level should be preferred as they are able, to a certain extent, to take into account the changes in the structural composition of the economy. However, according to Graham and Glaister (2004, p: 268-269), it is not by any means clear that disaggregated estimates are any more informative than the aggregate figures.

Using time series data Fowkes *et al.* (1993) estimate the road freight demand for 15 commodity groups where freight demand is measured both in tonnes lifted and tonnes-km moved. Unfortunately, both dependent variables are regressed only against a measure of economic activity, that is, monetary output from the sector producing that commodity group or GDP for the whole economy. No variable for road freight price is incorporated into the regression. We discuss only the result from the specification regressing tonnes-km on the sectoral outputs (both variables in logarithms) as it is the closest functional specification to the one estimated in Section 6. The other two major disaggregated studies of road freight in the UK are not discussed here as they use lifted tonnes to measure freight demand. Interested readers are referred to the National Road Traffic Forecasts in DfT (1997) and Black *et al.* (1995).

As one can see in Table 1, the estimates for income elasticities vary widely. Three commodities, that is agriculture and food stuff, leather textiles and clothing and miscellaneous articles have very high estimates. Considering that the variables are measured in logarithms, a one per cent increase in the monetary output of agriculture causes a 3 percent increase in the freight demand. Values of coefficients much higher than one imply either a change toward much more freight-intensive production as the sector expands or an inefficient use of the production factor. In other words, these results should be taken with caution. Four sectors have coefficients very similar to one, therefore pointing at constant returns in the use of freight service, which is a much more plausible assumption for the sector production function. All the other sectors have lower coefficients. In two cases, manufacturing of metals, coal and coke, the coefficients are lower than zero. In the last row of the table, it can be seen that income elasticity for the whole economy is 1.02 for road freight and a rather similar 1.12 in the case of freight demand for all modes. As discussed above, income elasticity for one mode only is expected to be lower than the elasticity for the total freight demand, that is, all modes. The results from Fowkes *et al.* (1993) confirm this although they also show that the two elasticities are not very different, probably pointing at low intermodal substitution. Similarly, small differences between income elasticity for road and total freight demand have been reported in Bennathan *et al.* (1992).

[INSERT Table 1 HERE ]

At the aggregate level, that is road freight demand for the whole economy, a widely cited study which focused on North America (Oum 1989) reported broad ranging price elasticities, probably caused by the use of different functional forms: linear, log linear, logit and translog. However, as freight demand is in most cases measured in tonnes lifted, this study is not discussed further. An exhaustive review in Great Britain (DfT, 2002) reported a price elasticity of -0.1 for freight demand measured by the length of haul. This estimate is based on the analysis in NRTF (DfT, 1997) mentioned above. Larger elasticity values are reported in Barker and Kohler (2000), about -0.7 for EU freight, although this value was assumed rather than estimated. The elasticity estimates in IEA (2002) are closer to those in DfT (2002), namely, -0.19 for North America and Australia, -0.23 for Europe and -0.12 for Japan. IEA (1994) reported an elasticity of -0.21 for the USA, -0.10 for Europe and -0.19 for Japan. Unfortunately, IEA (2002) does not discuss extensively either how these results were obtained, or the factors used in the definition of the price variables, although it is stated that price data should be intended only as a proxy for actual road freight prices.

Because of the wide differences across studies and of the limited number of studies of freight demand in the literature, Graham and Glaister (2004, p. 268-269) concluded that “it would be imprudent to offer a firm conclusion [even] about the order of magnitude of the price elasticity of demand for road freight movement.” The mean of the elasticities was -1.07 which was obtained from values ranging from -7.92 and 1.72,  although both extremes are rather questionable values for price elasticities. Despite this wide range, we notice that the IEA has given low values for road freight demand at the whole economy level. These estimates are very similar to those obtained in Section 5. However, other authors have obtained higher price elasticities. Bjorner (1999), for example, report price elasticities (based on generalised cost) of -0.47 for the entire Danish road freight sector using aggregate road freight (tonne-km), industrial output and freight price.

The elasticity of freight with respect to economic activity (also called income elasticity) has received more attention in the literature. However, in some instances - see, for example, Fowkes *et al.* (1993), income elasticity has been obtained by regressing freight demand against a measure of economic activity only, that is ignoring the effect of price. Bennathan *et al.* (1992), studied aggregate road freight demand, in a cross-section of 33 developed and developing countries, as a function of economic activity and land area. The income elasticity was approximately unity (1.04) for the 17 developed nations and 1.26 for the larger sample which consisted of developed and developing countries. Similar values for income elasticity are found in IEA (2002). IEA (1994) reported an output elasticity of 0.96 for the USA and 1.12 for Europe. Contrarily, Barker and Kohler (2000) assumed a higher elasticity of 1.5.

From this brief discussion, one can conclude that income elasticity can vary considerably across commodities – see Table 1, even though values much higher than one are somewhat dubious. A number of econometric studies estimating demand for aggregate freight demand, measured in tonnes-km, point at a value of about one for income elasticity. However, a considerable number of commodities assessed in Fowkes *et al.* (1993) point at a lower elasticity. With regard to price elasticity, studies from the International Energy Agency point at a price elasticity not lower than -0.25, although lower values can be found in the literature.

## 3 Econometric Methodology

Econometric estimation was carried out using the General-to-Specific (Gets) methodology. In Gets, empirical analysis starts with a general unconstrained model (GUM) that adequately characterizes the empirical evidence. This model is reduced by eliminating non-statistically significant variables until a specific model is obtained (Campos *et al*. 2005). The validity of the reductions is maintained throughout the simplification process by diagnostic checks to ensure congruence of the specific model. Models are designed so that the residuals satisfy a number of criteria which are verified through the application of diagnostic tests in Hendry and Krolzig (2001). Econometric estimation in the Gets approach is firstly undertaken by leaving out a number of observations at the end of the sample so that the forecasting performance of the model can be assessed. When the forecast tests are non-statistically significant the simplification procedure is implemented again over the whole sample. In this study the last five observations are used to compute forecast tests.

Gets has been criticised from a number of perspectives, for example, in relation to the path-dependency of the model delivered by the reduction process (Pagan 1987). However, Hoover and Perez (1999) produced an algorithm which searched for models through multiple paths and compared the specific models through encompassing tests. This algorithm has helped to overcome the problem of path-dependency. The algorithm presented in Hoover and Perez (1999) and later refined by Hendry and his associates has been incorporated in the software PcGets (Hendry and Krolzig, 2001). Applications of PcGets to earlier empirical studies either match or improve the finding of those authors (Hendry and Krolzig, 2001). As the results from GETS are sometimes influenced by the collinearity among regressors (Hoover and Perez, 1999), in this study the reduction was undertaken in the Auto-Regressive Distributed Lag (ARDL) and in Error Correction Models (ECM). The GUM can be written as

$$y_t = \mu + \sum_{i=1}^{p} \boldsymbol{\gamma}_i \mathbf{y}_{t-i} + \sum_{j=0}^{q} \boldsymbol{\beta}_j \mathbf{x}_{t-j} + \rho t + \varepsilon_t \qquad (1)$$

where, in this study, $\mathbf{x}_t$ comprises a measure of economic activity and the price of freight services; $y_t$ is the demand for freight services. This model can be reparametrised into its ECM representation

$$\Delta y_t = \mu + \sum_{i=1}^{p-1} \mathbf{c}'_j \Delta\mathbf{y}_{t-i} + \sum_{j=0}^{q-1} \mathbf{b}'_j \Delta\mathbf{x}_{t-j} - \phi_0 \left( y_{t-1} - \boldsymbol{\theta}' \mathbf{x}_{t-1} \right) + \rho t + \varepsilon_t \qquad (2)$$

where $\boldsymbol{\theta} = \sum_{j=0}^{q} \beta_j \Big/ \left(1 - \sum_{i=1}^{q} \gamma_i \right)$ is the vector of long-run coefficients, which can be computed from the short-run coefficients in (1). The symbol $\Delta$ denotes first differences, e.g. $\Delta y_t = y_t - y_{t-1}$

In the models above, the effect of technological change is modelled by a linear trend, that is the term t in (1)-(2). This specification can be a rather unsophisticated approximation of changes which are likely to occur slowly and in a non-linear fashion. The use of a stochastic trend in the econometric literature was first advocated by Harvey (1989) in the so-called Structural Time Series Model (STSM). Examples of applications of this approach include Agnolucci (2007), Harvey and Marshall (1991) and Hunt *et al.* (2003). The stochastic trend specification substitutes for the trend and intercept in any of the models above. In this approach, model (1) becomes

$$y_t = \mu_t + \sum_{i=1}^{p} \gamma_i y_{t-i} + \sum_{j=0}^{p} \boldsymbol{\beta}_j \mathbf{x}_{t-j} + \varepsilon_t \tag{3}$$

where $\mu_t$ is the trend component. The two equations

$$\mu_t = \mu_{t-1} + \beta_{t-1} + \eta_t \text{ where } \eta_t \sim NID\left(0, \sigma_\eta^2\right) \tag{4}$$

$$\beta_t = \beta_{t-1} + \xi_t \text{ where } \xi_t \sim NID\left(0, \sigma_\xi^2\right) \tag{5}$$

describe the level of the trend and its slope, $\beta_t$. Both terms are random walks driven by the white noise disturbance $\eta_t$ and $\xi_t$ whose variances $\sigma_\eta^2$ and $\sigma_\xi^2$, also known as hyperparameters, determine the shape of the trend. A stochastic representation of the trend is better suited to model change in technology and in the composition of the sectors modelled (Hunt *et al*. 2003). Considering that income and price elasticities of freight services are expected to vary across productive sectors and that the importance of these sectors is expected to have varied in the sample used in this study, STSMs seem an interesting alternative to the more commonly used linear trend specification. Estimation of STSMs was implemented in STAMP (Koopman *et al*. 2006). The general-to-specific search specification was carried out by dropping the regressor with the lowest absolute value of the t-statistic.

## 4 Data and Descriptive Statistics

Annual data on the demand for road freight services for the whole economy, measured in billion tonne-kilometres, was taken from DfT (2004a)[3]. Two distinct measures of economic activity were used in this study: Gross Value Added (GVA) of the all productive sectors and Gross Final Expenditure (GFE), that is, GDP plus imports. GFE was chosen, as both exports and imports require transportation by road freight. The limited importance of freight for the service sector is neglected when using an aggregate indicator of economic activity, such as GFE. Taking into account the expansion of the service sector in the United Kingdom over the last forty years, there was a considerable risk of obtaining biased estimates for the coefficient on economic activity. For this reason, the second measure of economic activity adopted in this study was equal to the GVA from all production sectors (Manufacturing, Mining and Quarrying, Electricity, Gas and Water Supply) together with the

[3] Annual data are available in aggregate terms and split terms according to the commodities being transported. As the relationship between the demand for freight services and its determinants is likely to differ across productive sectors, the use of data at the commodity level would be preferable. However, the timespan of time series, i.e. from 1993 onwards, prevented the use of the more detailed dataset.

construction sector. To summarise, this indicator is equal to GFE minus the GVA from the service sector and imports. Data have been collected from ONS (2006b) and ONS (2006c).

Data on the price of freight services are scarce. DfT (1997) developed a model of unit road freight costs based on data from the magazine Motor Transport and the Continuing Survey of Road Goods Transport (CSRGT) report. Some data on freight cost can also be found in Black *et al.* (1995). In 1996 the British Office of National Statistics (ONS) started to compile the Corporate Price Service Index which includes the freight sector. Although data from this index are likely to be more accurate than those used in this study, the number of observations prevents any time series estimation. For this reason data from MDM, an input-output macroeconometric model (Barker and Peterson 1987), have been employed. This time series was constructed by Cambridge Econometrics Ltd using data from the British ONS. The time series includes the freight services provided by road operators and by pipelines[4].

The time plot of the variables used in this study are shown in Figures 1 and 3. Following the standard practice adopted in econometric studies, discrete data, in this case annual, are graphed with a continuous line. Freight demand has increased more or less linearly, although the growth has sometimes lost momentum, notably in 1979-1985, 1990-1993 and in 1997-2004. The increase has largely been caused by changes in the distances of journeys rather than lifted tonnes, as the average haul length increased in the UK by 33% from 1980 to 2005 (DfT, 2002). The decreased

4 More precisely, the time series refers to the operators in the sectors called Other Land Transport (60.2 in terms of the Standard Industrial Classification (SIC) taxonomy) and Transport via Pipelines (60.3). The price of the freight services charged by operators in Transport via Railways (60.1), Water Transport (61) and Air Transport (62) are not covered in the price time series.

importance of the industrial sector in the British economy is shown in Figure 1b where the gap between the two series is the GVA produced in the service sector plus imports. Freight intensity, that is freight divided by a measure of economic activity, is shown in Figure 2. Freight intensity increased until the mid-sixties and then remained stable or decreased (according to which measure of economic activity is used) until the mid-nineties. In the last part of the sample, a marked decrease in freight intensity can be observed regardless of the time series used to measure economic activity. This confirms the robustness of the discussion in McKinnon (2007), with respect to the role of imports and the service sector, which are included in the GFE but not in the GVA. Finally, the timeplot of the price of freight services can be observed in Figure 3. The change in the trend in the mid-seventies, probably due to the increase in the oil price, is very noticeable. While the price stayed more or less constant in the first half of the nineties, a marked upwards trend can be observed in the last part of the sample.

[INSERT Figure 1, Figure 2 and Figure 3 ABOUT HERE]

The stationarity properties of the series were investigated by running ADF tests with the lag in the regression selected by the Modified Akaike Information Criterion (MAIC) (Ng and Perron 2001). From Table 2, economic activity and demand for freight services clearly appear to be integrated of order one, that is, they are stationary if differenced once. The evidence for the price for freight service is less straightforward. According to the ADF test, the series is not stationary even after being differenced. However, the implementation of a number of other unit root tests, namely the PP test of Phillips and Perron (1988), the $MZ_{\alpha}$ , $MZ_t$, MSB and the $MP_T$ of Ng and Perron (2001) , the $DF^{GLS}$ of Elliott, Rothenberg and Stock (1996) and the stationary test of Kwiatkowski, Phillips, Schmidt and Shin (KPSS) (1992), points at the series being stationary after being differenced when the lag is selected by the Schwarz information criterion[5]. Overall, the evidence in favour of the freight price series being integrated of order one seems to be stronger than the evidence against it.[6]

[INSERT Table 2 ABOUT HERE]

## 5 Results

Econometric estimation was implemented using the logarithms of the data described in section 3. ARDLs with linear and stochastic trend and unconstrained ECMs were estimated over the 1956-1998 sample, as the last five observations were initially left out in order to perform the forecasting diagnostic tests. If the tests were not statistically significant, estimation was carried out again over the whole sample. The decoupling discussed in McKinnon (2006) was introduced in the model by using dummy variables, that is variables taking only the value one or zero. In particular, the dummy took value one from 1997 onwards. Two dummies were used in the modelling: a dummy on the intercept and a dummy multiplied by the data of the economic activity. The existence of decoupling was ultimately based on the parameter on economic activity - according to the definition in Tapio (2005). However, the introduction of the dummies allowed us to evaluate if decoupling had increased from

[5] A discussion of the tests can be found, among others, in Maddala and Kim (2002). A concise description and an application of the tests can be found in Agnolucci (2006). Detailed results from the application of these tests are available upon request.

[6] Econometric estimation has also been carried out by assuming that the freight service price is integrated of order two. Results, which are available upon request, are not discussed as they were very similar to those discussed below.

1997 onwards. This required the coefficient on the dummy to be negative and statistically significant. A negative coefficient for the dummy on the intercept implied that decoupling had increased exogenously, while a negative coefficient for the dummy on economic activity implied that a rise in decoupling occurred due to decreasing income elasticity.

The first finding of this study is related to the long-run relationship among the variables, which was tested by following Pesaran, Shin and Smith (PSS) (2001). The PSS test consists of an F- or Wald-test on the variables in levels in the unconstrained version of (2). PSS (2001) tabulated critical values for the models containing no deterministic terms, intercept only and intercept and trend. For each model two sets of critical values were given, one assuming that all variables were integrated of order one, the other assuming that all the variables were stationary. The drawback is that a conclusive decision cannot be drawn when the statistic falls between the two critical values. As one can see in Table 3, the existence of a long-run relationship is firmly rejected. This conclusion is not influenced either by the deterministic terms in the regression or the indicator of economic activity.

[INSERT Table 3 HERE]

As no long-run relationship seems to be present among the integrated variables, one should be estimating models with variables in their first differences. It is, however, interesting to discuss results from the Gets procedure carried out when the result from the PSS test was ignored and the existence of a long-run relationship was assumed. In the 1956-1998 sample the price variable was non-statistically significant in all of the estimated GUMs. Both information criteria select the model without trend and with the GVA-based indicator of economic activity. As the price dropped during the reduction process, the presence of the variables in levels was imposed in specific models obtained from ECMs. The long-run price and income elasticity in the specific model are -0.04 and 0.79. All variables in levels are strongly not statistically significant, therefore confirming the results from the PSS tests. When the estimation is carried out over the whole sample, that is 1956-2003, the long-run coefficient on price becomes positive although not statistically significant[7]. Introduction of dummy variables in order to model a decoupling effect independent of the variables in the model, i.e. a shift in the intercept, can overcome this problem. Long-run price elasticity is now negative but, as in the shorter sample, long-run coefficients are non-statistically significant and their presence needs to be imposed in the specific model as has the dummy variable. These were considerable limitations which lead us to discard this model, therefore confirming the results of the PSS tests.

More promising results were obtained when estimating models with variables in first differences, as suggested by the PSS test. The reduction process was started from (3) with two lags, after dropping the variables in levels. As was the case with the models discussed above, both information criteria selected the model using GVA with a linear trend. Therefore, only models with this variable were estimated. In the GUM, price and income elasticities were 0.94 and -0.17. The simplification procedure produced the model on the second column of Table 3. The model passed all diagnostic and forecast tests and, as can be seen in Figure 4, it appeared stable. The

[7] Also the GUMs with the other indicator of economic activity or the linear trend have parameters conforming to economic theory.

long-run effect of economic activity[8] was 0.57; that of price was -0.18. A reduction process carried out over the whole sample gave the same specific models – see the third column in Table 4. One can also notice the similarity of the values of the coefficients when the model estimated over the two samples. Both dummies used to model an increase in the decoupling effect after 1996 had to be dropped during the reduction process. When the dummy on the intercept was imposed, the specific model in the last column of Table 4 was obtained. The sign on the dummy was negative but the long-run effect of economic activity increased. The long-term effect of a percentage increase in the growth rate of economic activity on the freight growth rate was now 0.78, that is fairly close to the 0.80 threshold. Considering the effect of the coefficient on economic activity and that the presence of the dummy needs to be imposed, it seems sensible to conclude that no change in the decoupling of the relationship between economic activity of productive sectors and freight demand could be observed in the 1997-2004 sample. However, over the whole sample, 1956-2004, weak decoupling can be observed, as the long-run effect of GVA is 0.56. It should be stressed that in this case decoupling refers to the growth rates rather than the levels of variables.

[INSERT Table 4 and Figure 4 HERE]

In GUMs with a stochastic trend, long-run price and income elasticities were -0.12 and 0.79. The reduction process delivers the model in Table 5. One can notice the similarity with the model in Table 4, in terms of the long-run effect of price and

[8] Long-run effect of the independent variables in First Differenced models are computed as discussed in section 4. However, in these models the long-run coefficient is not the long-run elasticity of the levels of the variables, as there is no long-run relation between the levels. The long-run coefficient measures the long-run effect of a one percentage point increase in the growth rate of the independent variable on the growth rate of dependent variable, measured in percentage points.

economic activity. In Table 5 all lagged terms in the GUMs were dropped making the relationship between the variable instantaneous. The same specification was obtained when the same GUM was reduced over the whole sample. Price and income elasticities were –0.19 and 0.65, that is very close to the values shown in Table 5. The value of the slope in the trend becomes negative in the last 5 years of the sample, i.e. the trend changed direction (see Figure 5). The coefficients of either dummy introduced to model the decoupling effect were non-statistically significant and the variables were dropped in the search specification. Keeping the dummies in the model and dropping all other not statistically significant variables produces a model with coefficient on either dummy which is not statistically significant and rather small, although negative.

[INSERT Table 5 and Figure 5 HERE]

As our approach to model an increase in the decoupling between economic activity of the productive sectors and the demand for freight has never produced statistically significant coefficients on the dummies, it is interesting to discuss the reason behind the decrease in freight intensity observed at the end of the sample (Figure 2). In the case of the model in the last column in Table 4, this is mostly due to the increase in price observed in the same period (see Figure 3). Coefficients on economic activity estimated over the 1956-1998 and 1956-2003 subsamples were very stable. If there was a change in the relation between economic activity and freight demand, this would be picked up by a change in the coefficients. If the decrease in the freight intensity was due to factors outside the model, one would observe abnormal residuals at the end of the sample. While a certain correlation at the end of the sample was noticed, that is the model tends to over-predict, with the exception of the observation in 2003, the fit of the model is not any worse than in the other parts of the sample. In the case of the model with a stochastic trend, the decrease in freight intensity observed in Figure 2 is brought about by the increase of the price and by a change in the stochastic trend in the last years of the sample (Figure 5). In other words, the decoupling process discussed in McKinnon (2006), occurring after 1997, has found its way back into the model despite the coefficient of the dummies not being statistically significant. This is a clear advantage of adopting a flexible specification such as that in the STSMs. The change in the direction of the trend observed in Figure 5 could also be the factor leading to the rejection of a long-run relationship among the levels of the variables.

## 6 Sectoral Road Freight Demand

As suggested by a referee, the estimation of an STSM is implemented for the road freight generated by three commodities in order to evaluate the robustness of the analysis discussed above. Data on road freight at the commodity level have been sourced from DfT (2006) and DfT (1996). The time series goes back to 1982 only. The commodities for which the estimation was performed were chosen on the basis of the tonne-kms generated road freight and on the basis of the readily availabile data for the GVA of the sectors matching the taxonomy of the commodities in DfT (2006) and DfT (1996). It is worth mentioning that the freight generated by the three sectors was about 37.5 percent of the whole road freight. Following the advice of a referee, the data for the freight price discussed in section 4 was used. A time series for the price of road freight services for different types of commodities is not available.

The results from the estimation for the three commodities shown in Table 6 confirm overall the results from the previous section. However in two instances, that is Food and Tobacco and Chemical, the coefficients fail to be significant at the ordinary confidence levels, probably due to the time series comprising only 20 observations. The analysis implemented at the commodity level shows the peculiarity of the freight demands for different goods, probably reflecting the intermodal substitution possibilities of the commodities. The values of the coefficients in Table 6 fall around the values of the coefficients in Table 5, as would be expected. One can notice the similarity between the coefficients for Food and Tobacco, which is responsible for about a quarter of the whole road freight and those in Table 5. On the other hand, the income and price elasticity for the Iron and Steel sector is much higher that the value presented in the previous section. Despite the differences in the income and price elasticities, one can notice the similarity between the trends for Food and Tobacco and Iron and Steel. Similar to the trend displayed in Figure 5, the plateau in the trend is caused by a decrease in the slope of the trend, also shown in the figure. In the case of chemicals, the slope can be dropped from the model. The decreasing trend displayed in Figure 6 is modelled only by a change in the level of the trend, probably caused by a shift in the composition of the sector, for example from raw Chemicals to Pharmaceuticals.

## 7 Conclusions

A number of conclusions can be drawn from the estimation presented in this paper. The first is related to the relationship between the variables in the freight demand in linear models. The results from the PSS test, which rejects a long-run relationship among the variables when assuming a deterministic trend, are confirmed by the search specification conducted when using variables in levels. When we take the result from the PSS into account and estimate first difference models, long-run effects of price and economic activity were about 0.18 and 0.56 respectively.[9] The use of a stochastic specification for the trend allowed us to estimate a relationship between the levels of freight demand, economic activity and price which shows stable parameters over the sample used in this study. In particular, the price elasticity was about 0.18 while income elasticity was about 0.65. The value of the price elasticity agrees with those of DfT (2002) and IEA (1994, 2002) but it is about half the value estimated by Bjorner (1999) for Denmark. This difference can be explained by the fact that Bjorner (1999) uses a generalized cost approach that include fuel costs, salaries, change in vehicle capital cost and overheads. However, it is unclear whether the short time-span of the sample in Bjorner (1999), that is 1980-1993 is the cause of a bias in the estimates obtained from the asymptotic Johansson procedure used in the study. The value for income elasticity estimated in this study, that is 0.65, is smaller than those normally seen in the literature. As mentioned above, work from IEA point at an income elasticity of about unity. However, the value reported in this study is not at odds with the values presented for a number of commodity groups in Fowkes *et al.* (1993).

Estimation of models for three commodities, Food and Tobacco, Chemicals, and Iron and Steel products, shows some variability in the parameters which is thought to be caused by the peculiarities of the commodity being transported. On the other hand,

[9] It is important to stress that these specifications model the relationship between the growth rates of the variables rather than their levels.

the parameters for Food and Tobacco products, which are responsible for about a quarter of the road freight, are very similar to the aggregate estimate for income elasticity, therefore supporting the lower value of income elasticity estimated by this study. The value obtained for income elasticity in the case of Iron and Steel products is virtually identical to the one reported in Fowkes *et al.* (1993), whereas estimated income elasticity is about 25 percent lower in the case of Chemicals, compared to Fowkes *et al.* (1993). A marked difference can be observed in the case of the Food and Tobacco products, that is 3.14 in Fowkes *et al.* (1993) versus 0.67 in this study. As mentioned above, income elasticities much higher than one should be considered dubious as they imply a structural change towards more freight intensive production function or a considerably inefficient utilisation of the freight services.

On the basis of the definition in Tapio (2002) a weak decoupling effect, that is, income elasticity smaller than 0.8, can be observed between economic activity in all productive sectors and freight demand. Our attempts to use dummy variables to model an increase in the pace of decoupling over the last 6 years of the sample, as argued in McKinnon (2006), did not produce any positive results. It can be concluded that in the case of the first difference model the decrease in the freight intensity observed in the last years of the sample is entirely explained by the increase in the freight price. In the case of the model with a stochastic trend, the increased pace of decoupling was picked up by the shape of the trend which was positive until 1995 and negative afterwards. The change in the trend and the increase in the price observed in the last years of the sample are the factors responsible for the decrease in freight intensity observed in the data. The trend for the Food and Tobacco and Iron and Steel products displays a similar shape. It also seems likely that the change in the direction of the stochastic trend is responsible for the lack of a long-term relationship between freight demand and its determinants, discovered by the PSS tests in models with deterministic trend.

Econometric road freight studies differ widely on the basis of the functional form of the model (whether log-linear or linear), the sectors studied (a particular sector or the whole economy), the sample used (cross-section or time series) and the variables employed in the estimation. Agreement on the definition of income, price or cost variable or commodity definition is needed.

## 8 References


Agnolucci, P. (2006): *The Persistence of Oil and Energy Intensities in Industrialised Countries* London: Policy Studies Institute: mimeo

Agnolucci, (2007): *Non-Transport Energy Consumption in the UK a Comparison of Alternative Approaches* London; Policy Studies Institute: mimeo

Atkinson, J., and N. Manning (1995): A survey of international energy elasticities in barker T., Ekins P., and N. Johnstone (eds) *Global Warming and Energy Demand* London: Routledge

Barker, T. S., and W. Peterson (eds) (1987): *The Cambridge Multisectoral Dynamic Model of the British Economy*, Cambridge University Press, Cambridge.

Barker, T. S., and J. Kohler (2000): Charging for road freight in the EU: economic implications of a weigh-in-motion tax, *Journal of Transport Economics and Policy*, 34, 311-331

Bennathan, E., Fraser J., and L. S. Thompson (1992): What Determines Demand for Freight Transport? Washington, D.C.: Working Paper No. WPS 998, Infrastructure and Urban Development Department (Washington, D.C: The World Bank)

Bjorner, T. (1999): Environmental benefits from better freight transport management: Freight traffic in a var model, *Transportation Research Part D*, 4, 45-64

Black, I. G., Clark, J., Peters, M., Richards, R. (1995): Modelling the Links between Economic Activity and Goods Vehicle Movements. CCLT, Research report No. 2, Cranfield University, Cranfield

Campos, J., Ericsson N. R. and D. Hendry (2005): *General-to-Specific Modelling* Cheltenham: Edward Elgar

Department for Environment and Rural Affairs (DEFRA) (2007): Table 6 Estimated emissions of nitrogen oxides (NOx) by UNECE source category, type of fuel and end user: 1970-2004. Available in internet at: http://www.defra.gov.uk/environment/statistics/airqual/alltables.html

Department for Environment and Rural Affairs (DEFRA) (2007): Table 11 Estimated emissions of PM101 by UNECE source category, type of fuel and end user: 1970-2004. Available in internet at: http://www.defra.gov.uk/environment/statistics/airqual/alltables.html

Department of Trade and Industry (DTI) (2006): (Energy Statistics) Table: 2.1 Transport energy consumption by type of transport and fuel, 1970 to 2005. Available in internet at: http://www.dti.gov.uk/energy/statistics/publications/ecuk/page17658.html (Tables 2.1 and 1.5)

Department of Trade and Industry (DTI) (2006): (Energy Statistics) Table 1.5 Final energy consumption by fuel 1970: 2006. Available in internet at: http://www.dti.gov.uk/energy/statistics/publications/ecuk/page17658.html.

Department for Transport (DfT) (1996): *Transport Statistics Great Britain* 1996 Edition London: DfT

Department for Transport (DfT) (1997): *National Road Traffic Forecast (Great Britain) 1997,* Working paper 3, non-car traffic: Modelling and Forecasting. London: DfT. pp. 1-69

Department for Transport (DfT) (1999): *Sustainable distribution: A strategy,* London: DfT. pp. 1-82

Department for Transport (DfT) (2002): *Integrated Transport and Economic Appraisal. Review of freight modelling,* Report B1. Review of GB freight models. June 2002. pp. 1-110

Department of Transport (DfT) (2004): *The Future of Transport: A network for 2030*. Vol 1: July, pp. 1-138;

Department for Transport (DfT) (2004a, 2005): *Transport Statistics for Great Britain* (TSGB) London: DfT (1.2, 4.1, 9.1 and 5.1)

Department for Transport (DfT) (2005): *Transport Statistics for Great Britain* (TSGB): Table 3.8 Carbon dioxide emissions in the United Kingdom: 1993-2003. available on the internet at: www.dft.gov.uk/pgr/statistics/datatablesppublications/energyenvironment/tsgbchapter3energyandenvir1863

Department for Transport (DfT) (2006): *Transport Statistics Great Britain* 2006 Edition London: DfT

Elliott, G., Rothenberg, T. J., and J. H. Stock (ERS) (1996): Efficient tests for an autoregressive unit root, *Econometrica*, 64 (4), 813-836

European Commission (2001): White paper, "European Transport Policy for 2010: time to decide," http:/europa.eu.int/comm./energy_transport/en/lb_en.html

Fowkes, A. S., Nash, C. A., Toner, J.P., G. Tweddle (1993): Disaggregated Approaches to Freight Analysis: A Fesasibility Study; report for the Department of Transport, Working Paper 399, Institute of Transport Studies, University of Leeds.

Freight Transport Association (2007): *Delivering the Economy* 2007. pp 1-24. Kent, United Kingdom.

Friedlaender, A. N., and R. H. Spady (1980): A derived demand function for freight transportation, *Review of Economics and Statistics*, vol. 62 (3), 432-441

Gilbert, R., and K. Nadeau (2002): decoupling economic growth and transport demand: A requirement for sustainability. Paper presented at the Conference o Transportation and economic development, Transportation Research Board, Portland Oregon, May.

Graham, D., and S. Glaister (2004): Road Traffic Demand Elasticity Estimates : A review, *Transport Reviews*, 24 (3), 261-274

Granger, C. W. J., and P. Newbold (1974): Spurious Regression in Econometrics, *Journal of Econometrics*, 2, 111-120 24

Harvey, A.C. (1989): Forecasting, Structural Time Series Models and the Kalman Filter Cambridge University Press, Cambridge

Harvey, A.C., and P. Marshall (1991): Inter-fuel Substitution, Technical Change and the demand for Energy in the UK Economy, *Applied Economics*, 23, 1077-1086

Hendry, D. F., and H. M. Krolzig (2001): Automatic Econometric Model Selection using PcGets London: Timberlake Consultants Press

Hendry, D. F., and H. M. Krolzig (2005): The Properties of Automatic Gets Modelling *The Economic Journal*, 115, 32-61

Hoover, K. D., and S. J. Perez (1999): Data Mining Reconsidered: Encompassing and the General-to-specific Approach to Specification Search, *Econometrics Journal*, 2, 167-191

Hunt, L. C., Judge G., and Y. Ninomiya (2003a): Underlying Trends and Seasonality in UK Energy Demand: a Sectoral Analysis, *Energy Economics*, 25, 93-118

International Energy Agency (IEA) (1994): *World Energy Outlook* Paris: IEA

International Energy Agency (IEA) (2002): Transportation Projections in OECD Regions Paris: IEA.

Johnson, D.H., Whiteing, A. E., Fowkes, A. S. (2005): LEF2- A strategic freight transport model for great Britain. AET European Transport Conference, 3-5 October 2005, Strasbourg.

Koopman, S. J., Harvey A. C., Doornik J. A. and N. Shephard (2006): Structural Time Series Analyser, Modeller and Predictor - STAMP London: Timberlake Consultants

Kwiatkowski, D., Phillips P. C. B., Schmidt P., and Y. Shin (1992): Testing the Null Hypothesis of Stationarity against the Alternative of a Unit-Root - How Sure Are We that Economic Time-Series Have a Unit-Root, *Journal of Econometrics*, 54(1-3), 159-178

Lewis, A.K., and D. P. Widup (1982): Deregulation and Rail Truck Competition: Evidence from a Translog Transport Demand Model for Assembled Automobiles, *Journal of Transport Economics and Policy*, XVI, 139-149

Maddala, G. S., and I. Kim (2002): Unit Roots, Cointegration, and Structural Change Cambridge: Cambridge University Press

McKinnon, A. (2006): The Decoupling of road freight transport and economic growth trends in the UK: An exploratory analysis. Logistics Research Center, p. 2-35, Heriot Watt University, Edinburgh, UK. October, 2006.

McKinnon, A. (2007): Decoupling of freight transport and economic growth trends in the UK: An exploratory analysis, *Transport Reviews*, 27, 37-64

Ng, S., and P. Perron (2001): Lag length selection and the construction of unit root tests with good size and power, *Econometrica*, 69(6), 1519-1554

Office for National Statistics (ONS) (2006a): *Economics Trends* London: ONS

Office for National Statistics (ONS) (2006b): *United Kingdom Balance of Payments*. The Pink Book 2006 London: ONS

Office for National Statistics (ONS) (2006c): *Input-Output - United Kingdom National Accounts* London: ONS

Organisation for Economic Co-operation and Development (OECD) (2005): Total Trade in values 1991-2004, OECD International Trade by Commodity Statistics Data, OECD statistical database (www.oecd.org)

Oum, T. H. (1989): Alternative demand models and their elasticity estimates, *Journal of Transport Economics and Policy*, 23, 163-187

Pagan, A. (1987): Three Econometric Methodologies: A Critical Appraisal, *Journal of Economic Surveys*, 1, 3-24

Pesaran, M. H., Shin Y., and R. J. Smith (2001): Bounds Testing Approaches to the Analysis of Level Relationships, *Journal of Applied Econometrics*, 16, 289-326

Phillips, P. C. B., and P. Perron (1988): Testing for a Unit Root in Time Series Regression, *Biometrika*, 75(2), 335-346

REDEFINE Project. Final Report. European Commission, DG TREN, 1999. http://cordis.europa.eu/transport/src/redefinerep.html

Small, K., Winston C. (1999): The demand for transportation: Models and applications', in Winston, C., Gomez-Ibanez, W.B., Tye (eds.), *In Essays in Transport Economics and Policy in Honour of J. R. Meyer.* Brookings Institution Press, Washington D.C

Tapio, P. (2005): Towards a theory of decoupling: degrees of decoupling in the EU and the case of road traffic in Finland between 1970 and 2001, *Transport Policy,* 12, 137–151

Tight, M., Delle Site, P. and O. Meyer-Ruhle (2004): Decoupling transport from economic growth: Towards sustainability in Europe, *European Journal of Transport Infrastructure Research*, 4 (4), 381-404

Winston, C. (1981): Disaggregate model for intercity freight transportation, *Econometrica*, 49 (4), 981-1006

Wooldridge, J. M. (1990): An Encompassing Approach to Conditional Mean Tests with Applications to Testing Nonnested Hypotheses, *Journal of Econometrics*, 45, 331-350

Zografos, K G., and M. Giannouli (2002): Emerging trends in logistics and their impact on freight transportation systems. *Transportation Research Record*, 1790, Paper No. 02-4177. 36-44, Washington D.C.

Zografos, K.G., and M. Giannouli (2003): Emerging supply chain management trends and their impact on spatial organization of logistical networks, *Transportation Research Record*, Paper No. 03 3582, 1833, 30-38, Washington D.C.

| **Sector or Area** | **Income Elasticity** | **Sector or Area** | **Income Elasticity** |
|---|---|---|---|
| Agriculture and food stuffs | 3.14 | Cement | 1.16 |
| Crude materials | 0.43 | Fertilisers | 0.72 |
| Wood timber and cork | 0.16 | Chemicals | 1.05 |
| Coal and coke | -0.39 | Transport equipment Machinery | 1.03 |
| Petroleum products | 0.76 | Metal manufacturing | -0.38 |
| Ores | 0.40 | Leather textiles and clothing | 2.14 |
| Iron and steel products | 1.08 | Miscellaneous articles | 3.70 |
| Crude minerals | 1.53 | | |
| Whole economy (road freight) | 1.02 | Whole economy (all modes) | 1.12 |

***Table 1** Results for the commodity-based freight demands in Fowkes et al. (1993), which regress road freight demand (measured in tonnes-km) against economic output from the industrial subsectors which produce the commodities in the table. The sample used in the study covers the 1974-1990 timespan.*

| | Level | Lags | | First Differences | Lags | |
|---|---|---|---|---|---|---|
| Freight Demand | -1.96 | 1 | I | - 4.82 $^{(**)}$ | 0 | I |
| GVA | -1.76 | 2 | IT | - 5.26 $^{(**)}$ | 0 | I |
| GFE | -1.90 | 0 | IT | - 5.24 $^{(**)}$ | 0 | I |
| Price | -0.67 | 1 | I | -1.83 | 0 | I |

***Table 2*** *Results from the ADF tests. I indicates the presence of an intercept only in the ADF regression; IT indicates the presence of intercept and trend. The specification of the testing regression was chosen on the basis of the Akaike Information Criterion (AIC) and Schwarz Criterion (SC). The 1%, 5% and 10% critical values for the ADF test are -3.43, -2.86 and -2.57 for the regression with an intercept and -3.96, -3.41, and -3.13 for the regression with intercept and trend. (**) indicates a value for the ADF statistics higher than the 1% critical value.*

| | **Intercept** | **Intercept and Trend** |
|---|---|---|
| $W(n_{t-1} \mid gva_{t-1}; p_{t-1})$ | 4.87 | 1.93 |
| $W(n_{t-1} \mid gfe_{t-1}; p_{t-1})$ | 5.16 | 2.29 |

***Table 3.*** *Results from the PSS test. The 90 percent inconclusive regions for k =2 are 9.55–12.38 in the case of intercept and no trend and 12.62-15.33 in the case of intercept and trend. Values of the statistic below the inconclusive region imply that the null hypothesis of no long-run relationship cannot be rejected.*

| | 1957 – 1998 sample | 1957 – 2003 sample | |
|---|---|---|---|
| constant | 0.061 (0.01) | 0.065 (0.00) | 0.056 (0.00) |
| $\Delta y_{t-2}$ | -0.147 (0.24) | -0.145 (0.22) | -0.273 (0.06) |
| $\Delta gva_{t}$ | 0.649 (0.00) | 0.637 (0.00) | 0.721 (0.00) |
| $\Delta gva_{t-2}$ | | | 0.268 (0.17) |
| $\Delta p_{t}$ | -0.209 (0.03) | -0.201 (0.03) | -0.223 (0.01) |
| trend | -0.001 (0.01) | -0.001 (0.00) | -0.001 (0.03) |
| Intercept Dummy | | | -0.033 (0.07) |
| **Long-run effect** | | | |
| $\theta p$ | -0.182 | -0.176 | -0.175 |
| $\theta y$ | 0.566 | 0.556 | 0.777 |
| **Fit of the model** | | | |
| Sigma | 0.033 | 0.032 | 0.031 |
| AIC | -6.682 | -6.761 | -6.781 |
| SC | -6.475 | -6.564 | -6.505 |
| **Diagnostics Statistics** | | | |
| Chow 1 | 1.007 (0.50) | 0.625 (0.859) | 0.444 (0.96) |
| Chow 2 | 0.240 (0.91) | 0.105 (0.980) | 0.165 (0.96) |
| Normality | 3.936 (0.14) | 5.692 (0.058) | 3.728 (0.16) |
| AR (1-4) | 1.016 (0.41) | 0.786 (0.542) | 1.015 (0.41) |
| ARCH (1-4) | 0.460 (0.77) | 0.449 (0.772) | 0.226 (0.92) |
| Heterogeneity | 2.494 (0.04) | 2.435 (0.034) | 2.042 (0.06) |
| **Forecast tests** | | | |
| Forecast $\chi^2_{(5)}$ | 2.942 (0.71) | n/a | n/a |
| Chow $F_{(5)}$ | 0.450 (0.81) | n/a | n/a |
| CUSUM t(4) | -0.999 (0.37) | n/a | n/a |

***Table 4*** *Coefficients, fit of the model, diagnostic and forecast tests for the specific model estimated over the 1956-1998 sample. The Chow 1 and Chow 2 tests assessed the instability of the model assuming breaks at 50 percent and 90 percent of the sample. In the case of the diagnostics and forecast tests, the p-value of the statistics was reported. The values indicate the level at which the test becomes statistically significant. Following Hendry and Krolzig (2001), diagnostic tests are considered statistically significant only if p-values are smaller than 0.01.*

| | | | |
|---|---|---|---|
| **Coefficient (p-value)** | | | |
| $p_t$ | - 0.18 (0.08) | | |
| $y_t$ | 0.66 (0.00) | | |
| **Estimated hyper-parameters** | | | |
| $\sigma_\eta$ x $10^{-2}$ | 3.37 | $\sigma_\xi$ x $10^{-2}$ | 0.40 |
| **Diagnostics** | | | |
| *Equation Residuals* | | *Auxiliary Residuals* | |
| Standard error | 0.03 | Irregular | |
| Normality | 5.98 | Normality | 2.99 |
| Kurtosis | 0.99 | Kurtosis | 0.14 |
| Skewness | 4.99 | Skewness | 2.85 |
| Hetero test | 0.95 | | |
| r(1) | 0.17 | Level | |
| r(8) | -0.27 | Normality | 2.80 |
| DW | 1.44 | Kurtosis | 1.13 |
| Q | 12.34 | Skewness | 1.67 |
| | | | |
| | | Slope | |
| *Predictive tests* | | Normality | 41.47 (**) |
| $\chi^2$ | 3.08 | Kurtosis | 25.88 (**) |
| Cusum t | -1.29 | Skewness | 15.60 (**) |
| | | | |

***Table 5*** *Parameters, diagnostic and forecast tests for the Structural Time Series Model estimated on the 1956-1998 sample. (**) indicates statistics significant at the 99 percent confidence level. A description of the tests used in the tables can be found in Koopman et al (2006).*

| | Food and Tobacco | Chemicals | Iron and Steel |
|---|---|---|---|
| **Coefficients (p-value)** | | | |
| $p_t$ | - 0.25 (0.21) | -0.17 (0.70) | -0.64 (0.12) |
| $y_t$ | 0.60 (0.33) | 0.82 (0.18) | 1.03 (0.00) |
| **Estimated hyper-parameters** | | | |
| $\sigma_\eta$ x $10^{-2}$ | 3.20 x $10^{-3}$ | 7.31 | n/a |
| $\sigma_\xi$ x $10^{-2}$ | 0.85 | n/a | 1.23 |
| **Diagnostics** | | | |
| *Equation Residuals* | | | |
| Standard error | 0.033 | 0.07 | |
| Normality | 0.75 | 2.35 | 0.13 |
| Kurtosis | 0.73 | 1.35 | 0.09 |
| Skewness | 0.03 | 0.99 | 0.04 |
| Hetero test | 2.14 | 2.41 | 0.57 |
| r(1) | -0.19 | 0.08 | -0.19 |
| r(8) | -0.19 | 0.07 | 0.12 |
| DW | 1.88 | 1.74 | 1.93 |
| Q | 6.45 | 3.07 | 7.87 |
| *Auxiliary Residuals* | | | |
| Irregular | | | |
| Normality | 1.55 | 0.11 | 0.95 |
| Kurtosis | 0.15 | 0.09 | 0.34 |
| Skewness | 1.40 | 0.02 | 0.61 |
| Level | | | |
| Normality | 0.83 | 2.19 | 0.60 |
| Kurtosis | 0.67 | 0.93 | 0.60 |
| Skewness | 0.15 | 1.25 | 0.01 |
| Slope | | | |
| Normality | 0.85 | n/a | 1.81 |
| Kurtosis | 0.49 | n/a | 1.56 |
| Skewness | 0.36 | n/a | 0.25 |

***Table 6*** *Parameters and diagnostics for the Structural Time Series Model estimated on the 1982-2003 sample for the three commodities mentioned in the table. A description of the tests used in the tables can be found in Koopman et al (2006).*

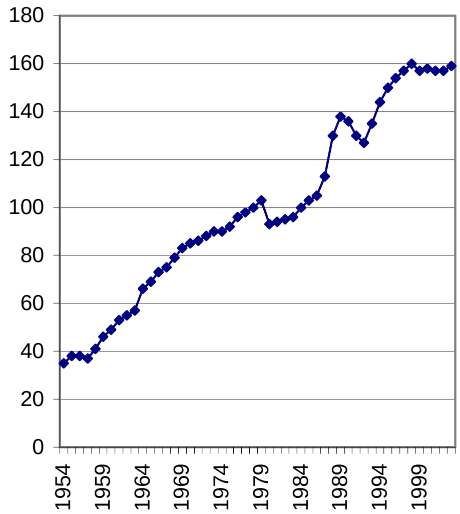


*__Figure 1a__ Demand for road freight services in billion tonne kilometres. Source: DfT (2004a)*

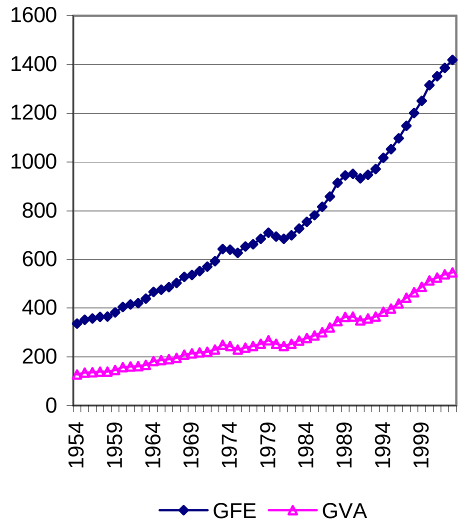


*__Figure 1b__ Economic activity in 2002 in billion pounds. Source: ONS (2006a) and ONS (2006b)*

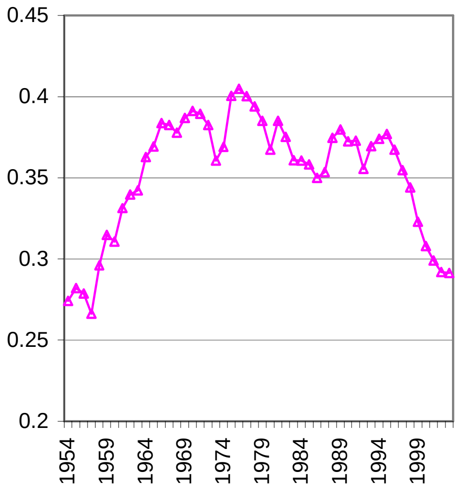


*__Figure 2a__ Freight intensity when using the GVA-based measure of economic activity.*

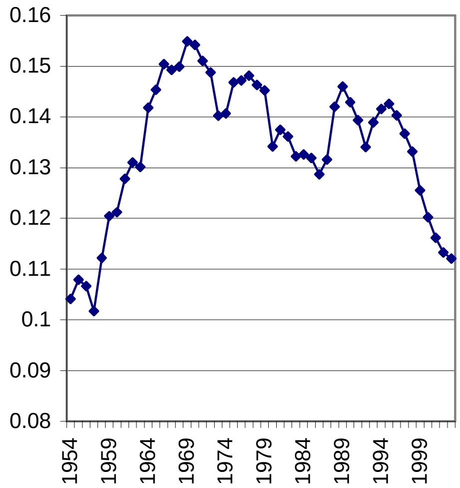


*__Figure 2b__ Freight intensity when using the GFE-based measure of economic activity*

.

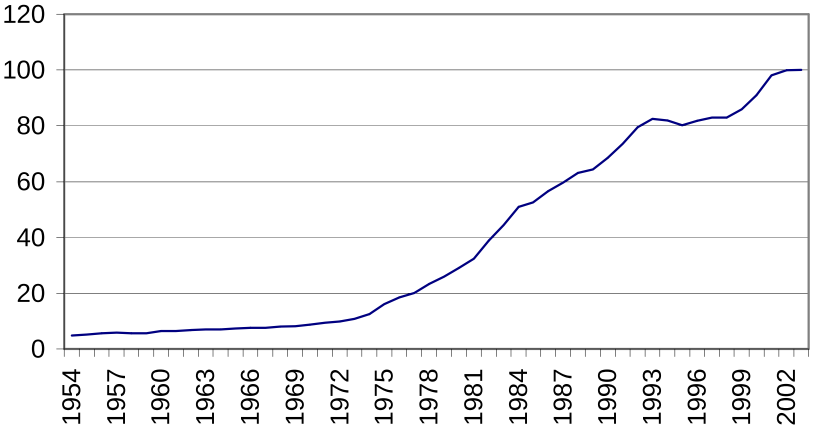


***Figure 3*** *Price Index of freight services.*

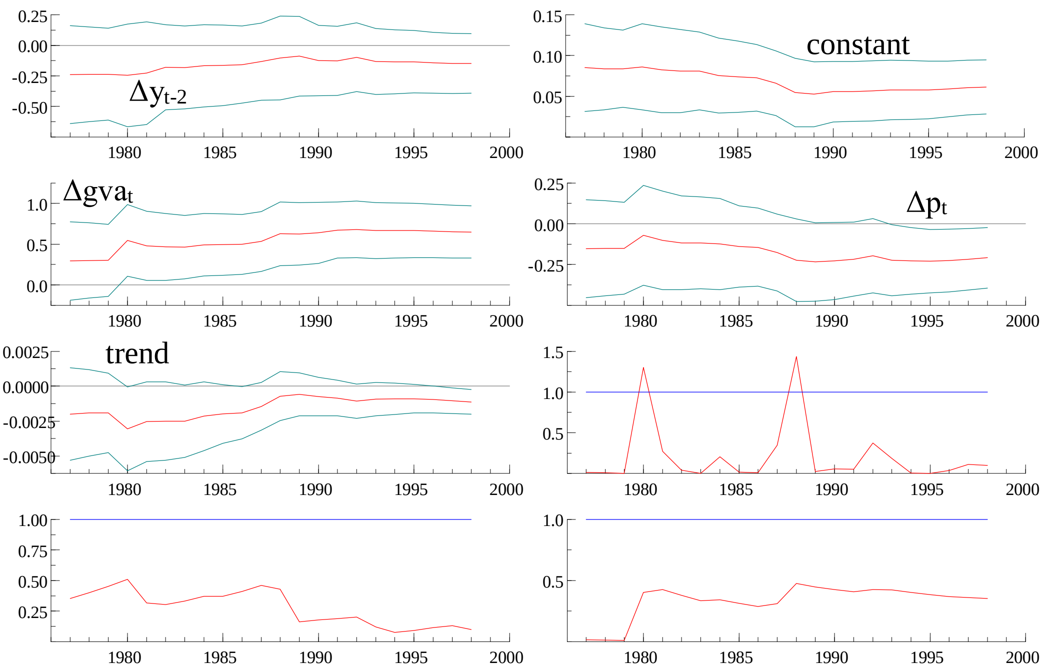


***Figure 4*** *Recursive coefficient estimation and stability tests. The straight line in the last row of the figure indicates the 5 percent confidence interval level for the 1-step, Forecast and Breakpoint Chow tests.*

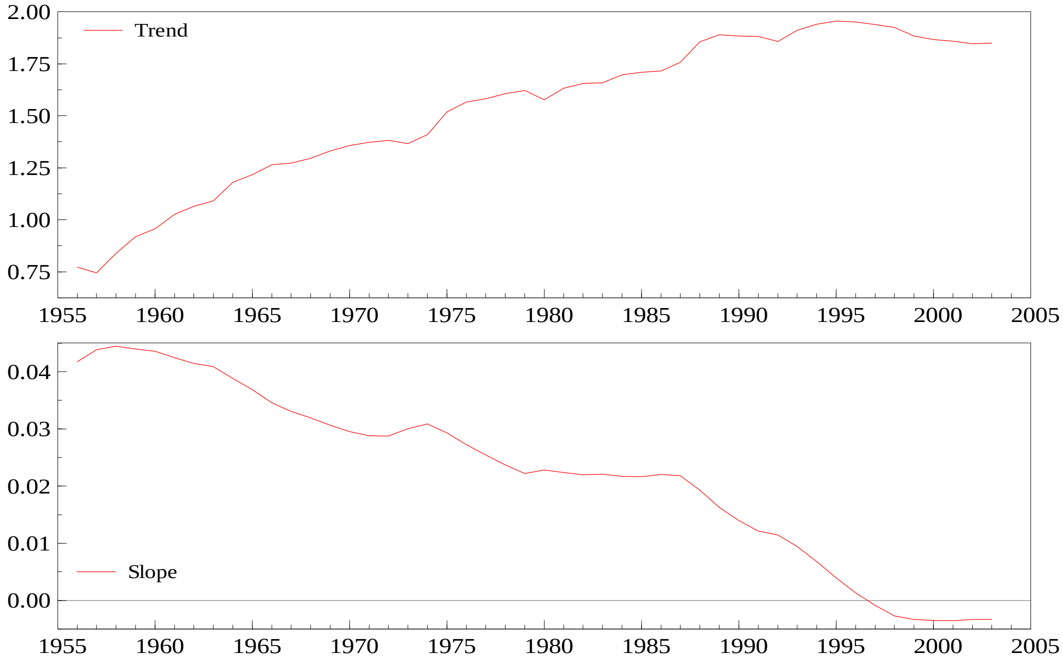


***Figure 5*** *Stochastic trend and slope of the specific model estimated using the 1956-2003 sample.*

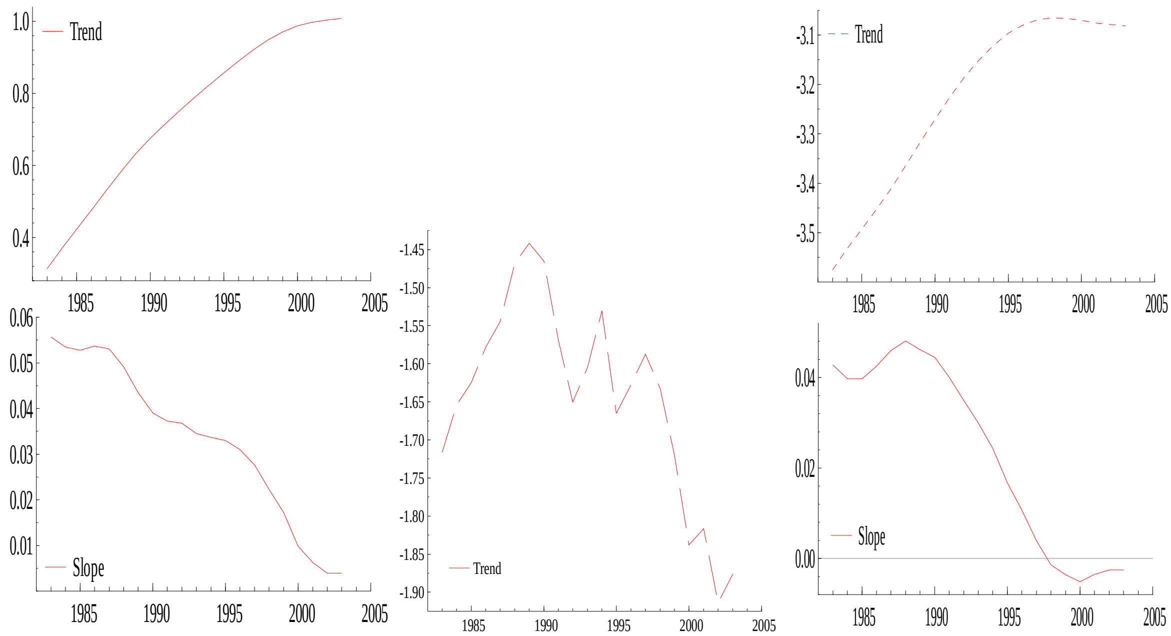


***Figure 6*** *Trend and slope (when applicable) in the Food and Tobacco sector (solid line), Chemical sector (dashed line) and Iron and Steel sector (dotted line)*