Price sensitivity of European road freight transport – towards a better understanding of existing results

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Summary

The opening up of European borders, liberalization of the transport market, as well as the improvement of road infrastructure, have resulted in decreasing transport costs through the years. National road pricing schemes (e.g. in Germany, Austria, Switzerland, the Czech Republic and Slovakia), on the other hand, result in higher costs of road transport. Other policy proposals (e.g. changing the Eurovignette directive, changes in permitted vehicle dimensions) have the potential to modify road transport costs. These changes in the costs of road transport influence total transport volumes (both in terms of vehicle and tonne kilometres), modal shift, total fuel use, and finally environmental effects.

To evaluate these effects of transport policies, a thorough understanding of the price sensitivity of road freight transport is essential. To what extent do hauliers and shippers respond to changes in transport costs? And in which way do they respond (e.g. modal shift, improving loading efficiency, implementing logistical restructuring, etc.)? With the help of the answers to these questions policy makers can be better informed on the effects of the policies they are planning to implement. This can result in a higher effectiveness of European transport policy making.

In this study we investigated the existing knowledge on the price sensitivity, or price elasticity, of road freight transport, using and interpreting results from scientific literature and evaluation studies of existing pricing schemes. We focussed on three types of price changes:

- Changes in fuel prices, which may directly influence total fuel use, the total amount of vehicle kilometres and the total amount of tonne kilometres.
- Changes in vehicle kilometre prices, which directly affect the number of vehicle kilometres and tonne kilometres. Due to the decline in vehicle kilometres also the amount of fuel used is indirectly affected.
- Changes in tonne kilometre prices, which directly influence the number of tonne kilometres. Indirectly also the number of vehicle kilometres and total fuel use will be influenced by this kind of price change.

In this study we focussed on long term elasticities of long distance road transport, which are applicable to international transport.

Elasticities are a means to summarise and compare the outcomes of various studies in a reasonable way (because they are dimensionless). Nevertheless, different definitions of the variables used and response mechanisms included can lead to different elasticities. For a proper impact analysis of proposed policy measures (e.g. as part of a cost-benefit analysis of these measures), we

recommend to use a transport model, estimated on proper data for the study area (e.g. the EU), instead of the use of elasticities. Elasticities should only be used in the absence of appropriate transport models, and to get a first impression ('quick-scan') of the likely effects (which can then be analysed in more detail using detailed and more time-consuming transport models later on).

On the basis of the international literature, road transport price elasticities of tonne-kilometres, vehicle kilometres and fuel demand have been investigated. The literature provides a wide range of elasticity values for these. By analysing differences in the definition of the independent and dependent variables and the response mechanisms included, and differences between countries, (e.g. large differences in the competitiveness of rail transport or inland waterways transport between countries), distance classes and commodity types, a considerable part of the variation can be explained However, the remaining variation in elasticities in some of the categories (e.g. tkm price on tkm for mode choice responses) remains substantial. Here differences in type of data used, modelling methodologies and supporting assumptions may be at stake.

The main conclusions on own-price elasticities are summarized in the table below. In practical studies that use elasticities, it is desirable to carry out sensitivity analyses to cover the elasticity range, instead of solely relying on the mean values.

A consistent set of elasticities

We carried out an exercise to derive our best-guess elasticities from the elasticity ranges presented in this report and ensuring that each is mutually consistent. The table below presents the outcomes of this exercise.

Consistent set of best-guess values of road freight transport price elasticities

Price change	Impact on		
	Fuel use	Vehicle kilometres	Tonne kilometres
Fuel price	-0.3	-0.2	-0.1
Vehicle kilometre price		-0.9	-0.6
Tonne kilometre price			-1.0

- The fuel price elasticity with regard to total fuel demand includes three behavioural responses: changes in fuel efficiency (-0.1), changes in transport efficiency (-0.1) and changes in road freight transport demand (-0.1).
- The vehicle price elasticities also consist of three effects: changes in mode (-0.3), changes in transport demand (-0.3) and changes in transport efficiency (-0.3).
- Finally, for the tonne kilometre price elasticity two effects can be distinguished: change in mode (-0.4) and change in transport demand (-0.6).

The following response mechanisms can be distinguished for the effect of a change in the price of road transport on road transport demand:

Changes in fuel efficiency

1. Using more fuel efficient vehicles
2. Improving fuel efficient driving

Changes in transport efficiency

3. Improving the load factor (the amount of goods measured in tonnes, divided by vehicle capacity) by:
    a. Optimizing the allocation of vehicles to shipments
    b. Consolidating shipments originating from the same company
    c. Consolidating shipments originating from several companies
    d. Changing the number and location of depots, including consolidation and distribution centres
    e. Getting more return loads to reduce empty driving.
4. Changing route and time of day
5. Increasing the shipment size

Changes in transport volumes

6. Changing mode: substitution to and from rail, inland waterways, sea and air transport
7. Changing production technology (affecting the weight of the goods, e.g. trends towards lighter products).
8. Reducing kilometres per tonne:
    a. Changing the choice of supplier or the geographical market size of the supplier
    b. Changing production volumes per location
9. Reducting demand for the product.

Finally, we also assessed the effects of existing road pricing schemes in Germany, Austria and the Czech Republic, as well as the effects of the introduction of a higher weight limit for trucks in the UK. There is evidence that distances driven in road freight transport are influenced by the existing road pricing schemes; for example, after the introduction of the Maut in Germany and Austria, there has been a decrease in the average distance travelled per tonne of goods. However, due to a lack of detailed evaluation studies it is impossible to draw firm (quantitative) conclusions with regard to the impact of these schemes on transport volumes.

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CHAPTER 1 Introduction

1.1 Background of the study

European freight transport policies often have a huge impact on the costs of freight transport. The opening up of European borders, liberalization of the transport market, as well as the improvement of road infrastructure, have resulted in decreasing transport costs through the years. National road pricing schemes (e.g. in Germany, Austria, Switzerland, the Czech Republic and Slovakia), on the other hand, result in higher costs of road transport. Also the recent proposals for amending the existing Eurovignette directive has the potential to increase costs. These changes in the costs of road transport influence total transport volumes (both in terms of vehicle and tonne kilometres), modal shift, total fuel use, and finally environmental effects.

To evaluate these effects of transport policies, a thorough understanding of the price sensitivity of road freight transport is essential. To what extent do hauliers and shippers respond to changes in transport costs? And in which way do they respond (e.g. modal shift, improving loading efficiency, implementing logistical restructuring, etc.)? With the help of the answers to these questions policy makers can be better informed on the effects of the policies they are planning to implement. This can result in a higher effectiveness of European transport policy making.

In this study we will investigate the existing knowledge on the price sensitivity, or price elasticity, of road freight transport. Three types of price changes will be discussed: changes in fuel price, vehicle kilometre price and tonne-kilometre price. Thereby this study provides a complete overview of price sensitivity of road freight transport in Europe.

1.2 Purpose of the study

The purpose of this study is to provide estimates of price elasticities of road freight transport in the European context, based on a thorough review of results from scientific literature and evaluation studies of existing pricing schemes. Thereby we will focus on three types of price changes:

- Changes in fuel prices, which may directly influence total fuel use, the total amount of vehicle kilometres and the total amount of tonne kilometres.

- Changes in vehicle kilometre prices, which directly affect the number of vehicle kilometres and tonne kilometres. Due to the decline in vehicle kilometres also the amount of fuel used is indirectly affected.
- Changes in tonne kilometre prices, which directly influence the number of tonne kilometres. Indirectly also the number of vehicle kilometres and total fuel use will be influenced by this kind of price change.

For these three types of price changes, we will provide bandwidths (and most likely European average values) of price elasticities for all direct end-effects. These six types of price elasticities are summarized in Table 1. The price elasticities of indirect end-effects (e.g. changes in fuel use as a result of higher kilometre prices) will not be provided, since these effects can often simply be derived from direct end-effects.

Table 1. Price elasticities of road freight transport which will be provided in this study

Price change	Impact on		
	Fuel use	Vehicle kilometres	Tonne kilometres
Fuel price	X	X	X
Vehicle kilometre price		X	X
Tonne kilometre price			X

In addition to the six price elasticities mentioned in Table 1 we will also provide an estimate of the average European cross elasticity of road freight transport with regard to rail freight transport.

Starting points

In this study we will use the following starting points:

- we focus on long term elasticities, which means that also adaptations in the logistical chain will be included in the elasticity
- we focus on elasticities of long distance road transport, which are applicable to international transport. The applicability of the elasticities on short distance road transport (e.g. domestic transport) will be discussed.
- we provide European average price elasticities of road transport. The applicability of these average figures in individual countries will be discussed.
- we focus on elasticities for transport of average goods. However, price elasticities of freight transport depend on the type of goods transported. For example, one can expect transport price elasticities of valuable goods, like cars or televisions, to be low since minimizing storage costs of these goods is more important than minimizing transportation costs. The contrary holds for less valuable goods, so that these goods could be expected to be more sensitive to changes in transport prices. We will discuss this dependence of road freight elasticities on type of goods. Additionally, we will provide – next to the elasticities with regard to average goods – a further

segmentation of elasticities. Here we will present elasticities for bulk goods versus general cargo.

1.3 Structure of the report

This report is structured in the following way: in Chapter 2 the methodology used is discussed. The concept 'price elasticity' is explained and reasons why elasticity estimates may differ are discussed. Chapter 3 provides the key results of the literature review. The assessment of individual studies can be found in Appendix B. In Chapter 4 experiences with actual pricing schemes in Europe are discussed. Additionally, the effects of the higher weight limits for trucks in the UK are described. These effects of actual policy instruments will be compared to the price elasticities found in Chapter 3. In Chapter 5 we will discuss in which situations the elasticity estimates can be applied. To show how the estimated elasticities can be used to investigate the effects of transport policies we will also apply them in three case studies. Finally, in Chapter 6 the conclusions of the study will be presented.

CHAPTER 2 Methodology

2.1 Introduction

In this chapter we present the methodological framework for this study. First we will define the concept of elasticities in section 2.2. What are elasticities and which kind of elasticities can be distinguished? In section 2.2 some explanations for variances in transport price elasticities are given. One of these explanations may be that different response mechanisms (ways in which people react on price changes) are taken into account. In section 2.4 these response mechanisms will be further discussed.

2.2 The concept of elasticities

A change in the price of road freight transport can, especially in the long run, have very diverse effects on road freight transport, working through all kinds of behavioural mechanisms. These effects are often expressed in the form of elasticities.

The concept of elasticities was first thought of by the English economist Alfred Marshall. Elasticities give the ratio of a percentage change in demand or supply (e.g. road tonne-kilometres) to a percentage change in one of the factors explaining demand or supply (e.g. price of road freight transport). The advantage of elasticities is that they are dimensionless, i.e. a change in the unit of measurement (for instance from kilometres to miles) does not affect the elasticities. Since the days of Marshall, many demand and supply models have been estimated, either with constant elasticities (double logarithmic specification) or from which implied elasticities at certain points (e.g. at average values) can be calculated.

In this study we shall use the following general **definition** of elasticity:

An elasticity gives the impact of a change in an independent (or stimulus) variable on a dependent (or response) variable, both measured in percentage changes.

If the impact of a 1% increase in the fuel price on road freight tonne kilometres is a decrease in truck tonne kilometres by 0.3%, the fuel price elasticity of the demand for road freight tonne kilometres is -0.3 (=-0.3/1).

Elasticities are defined using the 'ceteris paribus' condition: they are valid under the assumption that all other things (e.g. other independent variables) do not change.

An elasticity can be positive or negative. If an elasticity (in absolute values) exceeds 1, the dependent variable is called 'elastic' (e.g. elastic demand) w.r.t. the independent variable. If the elasticity value (in absolute terms) is between 0 and 1, the dependent variable is 'inelastic'.

Names of elasticities

The convention in economics is that the name of the independent variable comes first (before the word 'elasticity') and the dependent variable follows after the words 'elasticity of'. Examples are the above or the road toll elasticity of road freight vehicle kilometres.

Some basic distinctions

A first distinction is between point elasticities and arc elasticities. A point elasticity measures the proportionate change in the dependent variable resulting from a very small proportionate change in the independent variable. The price (P) elasticity of demand for commodity Q in terms of a point elasticity is:

$$e_p = (dQ/Q) / (dP/P) = (dQ/dP) . (P/Q) \qquad (1)$$

In this formula dQ/dP is the derivative of the (ordinary or Marshallian) demand function w.r.t. P (the slope of the demand function).

An arc elasticity is applicable if the change in the independent variable is not very small, whereas point elasticities are appropriate for small changes. An arc elasticity is defined as:

$$e_p = (\Delta Q/\Delta P). (P_1 + P_2)/(Q_1 + Q_2) \qquad (2)$$

In which the subscripts 1 and 2 represent the situation before and after the change in price. Whether an arc elasticity will be higher or lower than a point elasticity depends on the shape of the demand function (e.g. concave or convex).

Another distinction is between own and cross elasticities. If for instance we are studying mode choice, the own (or direct) elasticity gives the impact of an attribute of some mode on the demand for that same mode, e.g. the road transport cost elasticity of road freight tonne kilometres. A cross elasticity measures the impacts on other modes, e.g. the road transport cost elasticity of rail freight tonne kilometres.

A disaggregate elasticity measures the reaction of an individual (can be an individual firm). Such elasticities can only be derived from disaggregate models, e.g. the (logit) mode choice models discussed below. For policy-making, aggregate elasticities are mostly more interesting. They refer to the responsiveness of a group of individual firms (possibly the entire market). Aggregate elasticities can be derived from aggregate models and from disaggregate models.

Elasticities usually come from models, estimated on empirical data, but in some cases, elasticities can be calculated from direct observations of the impact of a change (e.g. introduction of a toll), from before and after studies. The data used for model estimation can be time series data, cross section data or panel data. If a time-series model contains lagged parameters, the model can distinguish between short and long term effects. Whether the effects from a cross-section are short or long term depends on a judgement on the nature of the behavourial mechanisms included (e. g. location decisions are regarded as long run). Using these distinctions, Goodwin (1992) did not find systematic differences between elasticities in passenger transport from time series and cross section (but in general long run elasticities were larger than short run elasticities).

Cross section (and panel) data can be based on observed choices (revealed preference or RP data) or on choices under experimental (hypothetical) circumstances (stated preference or SP data). Sometimes elasticities are calculated from models purely based on SP data, This is bad practice. Since the experimental circumstances differ from real world conditions, the variation in the unobserved component of the SP model will not reflect reality, which affects all the estimated model coefficients, and thus also the elasticities from the model. SP only models can be used to give the importance of an attribute relative to another attribute (such as the value of travel time savings), but for use as a prediction model it needs to be combined with RP data.

2.3 Variation in elasticity values

Very often considerable heterogeneity in elasticity values has been found. There are two basic explanations for this:

1. Different elasticities seem to be referring to the same thing, but are taking into account different response mechanisms, that may be working at different timescales. This is ‘spurious heterogeneity’. in the long run there are more possibilities to react, so demand will be more elastic. In this study we shall be investigating the existing literature on road freight transport price elasticities to find out which response mechanisms are included in each, to explain observed differences in published elasticities and obtain insight in the most likely values and how these can be decomposed. The response mechanisms for road freight transport are discussed below.
2. Price elasticities can be different because they refer to:
    a. Different market segments (e.g. commodity classes, distance classes, geographic markets), with different substitution possibilities: if two goods are close substitutes, the cross-price elasticity can be expected to be high and the own-price elasticity (in absolute terms) will also be higher if close substitutes exist.

b. Different components of total transport costs (e.g. toll cost, fuel cost or fixed transport costs).

c. Price increases versus decreases; according to prospect theory, decision-makers will react more strongly to losses than to gains, so elasticities for price increases could be larger than for price reductions (however, most models used in practice do not take this into account).

d. Price changes of different magnitude (this refers to the distinction between point and arc elasticities, but also arc elasticities for changes of different magnitude can be different); if the slope of the inverse demand function decreases with increasing price (reflecting satiation), then large price changes will lead to smaller elasticities than small price changes.

e. Different definitions of a transport mode.[1]

Category 2 represents 'true heterogeneity', and will be taken into account in this study by providing different elasticities for different commodity types, in as far as possible with the available material, and by focussing on long distance transport. We will also provide overall average values for the six types of elasticities that need to be provided (see Table 1 in Chapter 1).

Furthermore, especially cross-elasticities (e.g. effect of road transport prices on rail demand) can be very different depending on the market shares of the modes in the base situation. This also means that cross elasticities are not really transferable from one country to the other if these countries have different mode shares. In this project we will not provide estimates for cross-elasticities, except for the road transport cost elasticity of demand for rail transport for the EU as a whole.

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[1] An example of where different definitions of the transport mode can lead to is the following. A transport chain consists of one or more trips; each transhipment from one mode to another leads to a new trip within the transport chain. Transport modes can be seen as single modes (the mode for a trip) or main modes (for a transport chain). In practice, multi-modal transport chains are quite common, certainly in relation to main modes other than road transport.

Assume there are two main modes: road and rail.

Now let there be a cost increase (e.g. toll) for road transport, which does not directly affect rail.

Transport by road falls, transport by rail increases, for example: main mode road – 100 tonnes, main mode rail + 100 tonnes

However, access and egress for rail is by road, so the number of tonnes (lifted) by road increases by 200 tonnes.

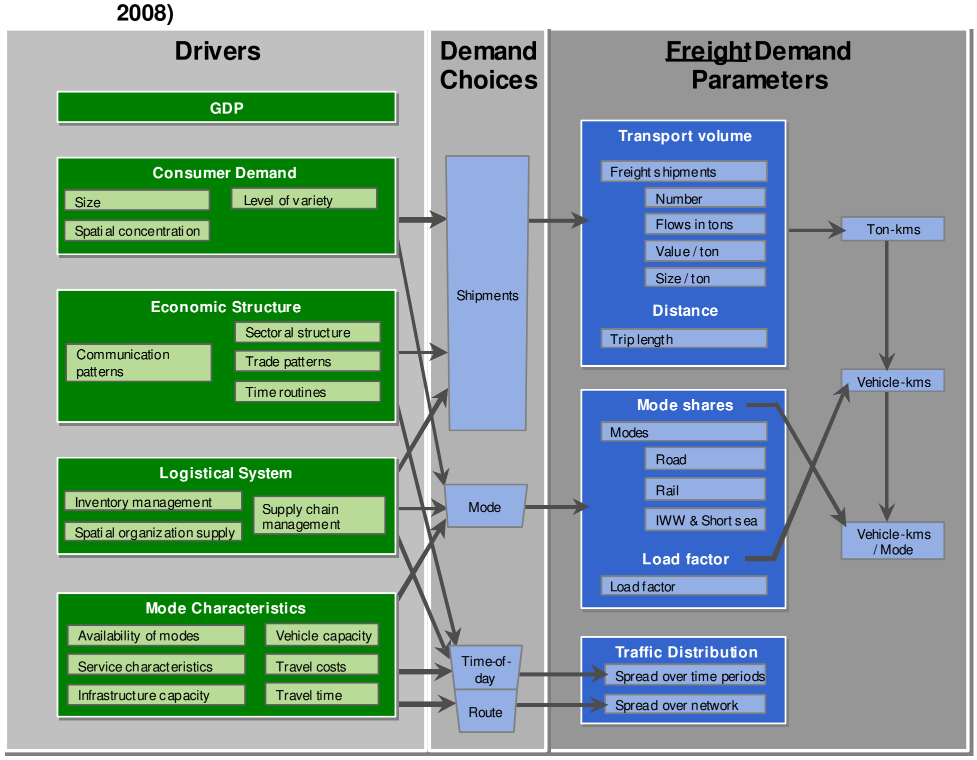
Now the effect of toll is that transport by road increases (in tonnes, not tonne kilometres), and the elasticity would be positive.

In other words: effects in tonnes with modes defined on a trip basis can lead to confusing results; effects in tonne km or vehicle km are to be preferred, and when in tonnes, should be given for main modes. A cost increase for road (fuel price) will also effect the costs of main modes rail, inland waterway and sea through access/egress.

2.4 Different response mechanisms

Freight transport demand can be measured (also see Figure 1) in terms of tonne-kilometres (tkm), vehicle-kilometres (vkm) and vehicle-kilometres (and tonne-kilometres) by mode (e.g. road vkm). The amounts of tonnes and tkm are determined largely by international and intraregional trade patterns (that depend mostly on consumer demand and economic structure). The amount of vkm is also dependent on logistics decisions, such as on shipment size and the use of consolidation centres. For vkm or tkm by mode, mode choice enters the picture as well. There can be changes in route and time-of-day that do not affect the total number of tkm or vkm (by mode).

Figure 1 Drivers of freight transport demand (source: Van de Riet, de Jong and Walker, 2008)



The following response mechanisms can be distinguished for the effect of a change in the price of road transport on road transport demand (also see Table 2):

Changes in fuel efficiency

1. Fuel efficient vehicles: buy more energy-efficient trucks; in the long run, changes in fuel prices can also influence the fuel efficiency of the vehicles used (at the same transport volume), by accelerating/decelerating technological change in vehicle efficiency.
2. Fuel efficient driving: change in the style of driving (more energy efficient driving).

Changes in transport efficiency

3. Load factor (the amount of goods measured in tonnes, divided by vehicle capacity). The load factor can be changed by:
    a. Optimizing the allocation of vehicles to shipments (e.g. acquire larger vehicles and group shipments, so that the same amount of tonnes an be transported with fewer vehicles).
    b. Consolidating shipments originating from the same company.
    c. Consolidating shipments originating from several companies (e.g. by doing collection rounds stopping at multiple senders, or by using a consolidation centre) and/or destined for several companies (e.g. by distribution rounds or distribution centres).
    d. Changes in the number and location of depots, including consolidation and distribution centres (this can also be done by the shippers, depending on who owns these facilities).
    e. Getting more return loads to reduce empty driving.
4. Change in route and time of day. This is mainly relevant for changes in prices that are differentiated by location and time of day (such as the road pricing scheme proposed for The Netherlands). But there may also be move to a more efficient route planning (e.g. fewer detours) because of the cost increase.
5. Increasing the shipment size (also implying a reduction in the delivery frequency; so this will increase inventory costs). This would be going against the trend towards more just-in-time (JIT) deliveries. Changes in road transport price might change trade-offs between transport costs and other logistics costs such as order costs and inventory costs.

Changes in transport volumes

6. Change of mode: substitution to and from rail, inland waterways, sea and air transport).
7. Changes in production technology (affecting the weight of the goods, e.g. trends towards lighter products).
8. Reduce kilometres per tonne:
    a. Choice of supplier and receiver: changes in the choice of supplier (procurement from more local suppliers, determining the origin given the destination) or in the geographical market size of the supplier (changing the destination given the origin), including changes in the degree of globalisation. This leads to changes in the origin-destination (OD) pattern of goods flows.
    b. Production volumes per location: changes in production volumes per location, including use of raw materials and intermediate products for further processing. A producer can decide to shift its production to plants closer to its customers, to save transport costs.
9. Reduction in demand for the product.

Reactions 1-4 are decisions that are usually taken by the road haulier (carrier). The scope for doing these things depends on the current level of efficiency in logistics (which might be quite high already). Other reactions are possible for the haulier (e.g. hire cheaper foreign drivers or subcontractors; reduce other transport costs, such as fixed costs by postponing replacement of vehicles or economise on maintenance and repairs) that do not lead to a change in transport volumes.

Only when the road haulier passes on some of the cost increase to the shipper, the shipper will respond. The possibilities for passing on cost increases depend on market power, which may be different for different commodity markets (e.g. when specialized equipment is needed for transport, the hauliers might be in a better position). The response mechanisms 5-8 concern decisions that are usually at the discretion of the shipper (some decisions such as on shipment size can be taken by the sender, but are more commonly determined by the receiver).

The manufacturers may pass on some of the cost increase to their clients (retailers, other producers, final consumers). This may then lead to the reduction in demand for the product (response 9).

Table 2 Summary of response mechanisms

Reactions	Decision Maker	Time Scale	Type of Effect			Dimension of Output		
			Fuel Efficiency	Transport Efficiency	Transport Volumes	Tonnes	Vkm	Tkm
1	C	S-M	X					
2	C	S	X					
3 a	C	S-M		X			X	
3 b	C/S	S-M		X			X	
3 c	C	S-M		X			X	
3 d	C/S	S-M		X			X	
3 e	C	S-M		X			X	
4	C/S/R	S		X			X	X
5	S/R	S-M		X			X	
6	S	M-L			X	X	X	X
7	S	L			X	X	X	X
8 a	S	L			X		X	X
8 b	S	L			X		X	X
9	D	S-M			X	X	X	X

Legend: for Decision Maker, S stands for shipper, R stands for receiver, C stands for carrier, D for consumers (Demand);

for Time Scale, S stands for short term, M stands for Medium term and L stands for Long term.

Changes in fuel prices affect fuel efficiency, transport efficiency and transport volumes. Changes in prices per vkm affect transport efficiency and transport volumes. Changes in prices per tkm affect transport volumes.

The mechanisms 6, 7 and 9 will influence the number of tonnes transported by road transport. These mechanisms plus mechanism 3 and 5 will influence the number of vehicles used. Vehicle-kilometres by road are influenced by all of these mechanisms plus the trip lengths (mechanisms 4 and 8). Tonne-kilometres by road are influenced by mechanisms 4 and 6-9.

Many of these reactions (especially 7 and 8 and changes in vehicle technology) will only occur in the long run. Mechanisms 2 and 4 can be relevant in the short run and 1, 3, 5 and 9 in the short to medium run, whereas 6 is most relevant in the medium long run. In the review of the literature, we shall use these distinctions (which of these mechanisms are included?) to characterise the elasticities.

A policy measure such as road pricing also can have an impact on transport time (certainly when it refers to passenger transport as well), which in due course will lead to smaller time-related variable freight transport costs (e.g, wage costs). This is not included in the price and cost elasticities studied, but should be included in a social cost-benefit analysis of road pricing proposals.

CHAPTER 3 Results of the literature review

3.1 Introduction

In this chapter the key results of the review of the scientific literature on road freight transport price elasticities are discussed. The review of the individual studies can be found in Appendix B.

After describing the structure of the literature review in section 3.2, the results with regard to own-price elasticities are presented in section 3.3. In section 3.4 cross elasticities are discussed. Finally, the conclusions of this chapter are presented in 3.5.

3.2 Structure of literature review

For this study we reviewed in total 72 scientific papers with regard to road freight transport price elasticities (a complete overview can be found in appendix A). A first check of the studies made clear that not all of them are useful for this study, since the do not contain any elasticity estimates for road freight transport, only provide a review of other (primary) studies, are too old or were not available. After deletion of these studies from the sample we had 32 studies left, which we have thoroughly reviewed.

In the review of the individual studies the following aspects of the study are analysed:

- *Dependent variable;* does the study consider changes in fuel use, vehicle kilometres or tonne kilometres? Which transport modes are assessed?
- *Independent variable;* which type of price change is assessed (fuel price, kilometre price, tonne kilometre price, other) and is this price change induced by market forces or by government policies?
- *Research method;* are elasticities derived from models or from empirical observations? Which econometric methods are used? Are point elasticities estimated or arc elasticities?
- *Response mechanisms;* which of the following response mechanisms are included in the elasticity estimate:
    1. change in fuel efficiency of the vehicle;
    2. change in fuel efficiency of driving;
    3. optimizing allocation vehicles to shipments;
    4. change in number and location of depots;
    5. change in shipment size;

6. change in consolidated shipments;
7. change in empty driving;
8. change in trip length;
9. change in mode;
10. change in production technology;
11. change in production volumes per location;
12. change in suppliers/customers (change in OD patterns);
13. change in commodity demand.

- *Type of data;* did the study use cross-section, time-series or panel data? Are the data used aggregated or disaggregated? To which years do the data refer? And are the data gathered by revealed or stated preference techniques?
- *Geographical scope;* are the elasticities estimated based on empirical observations from specific transport corridors, regions, countries, or continents?
- *Distance class;* do the elasticities estimates refer to long or short distance road transport?
- *Type of goods;* which types of goods are included in the study?
- *Estimates of own-price elasticities;*
- *Estimates of cross elasticities;*
- *Additional remarks.*

The observations for the individual studies on these aspects can be found in appendix B.

In the literature on freight transport elasticities, we could not find studies that make the detailed distinctions in response mechanisms as we used in our list of 13 mechanisms above. Many studies only include a few of the above response mechanisms, and moreover, most studies only give effects for aggregates of the above 13 mechanisms. When drawing conclusions from the existing body of evidence, we therefore have to use aggregates of response mechanisms as well. The aggregate response mechanisms that we will use in discussing and summarising the literature are:

- Changes in fuel efficiency (mechanisms 1-2)
- Changes in transport efficiency (3-8)
- Changes in mode choice (9)
- Changes in transport demand (10-12)
- Changes in commodity demand (13).

3.3 Own-price elasticities

In this section we present the key results of the literature review after own-price elasticities of road freight transport. Subsequently we will discuss tonne-kilometre price elasticities, vehicle kilometre price elasticities and fuel price elasticities. Finally, we will present a segmentation of the elasticities to various types of goods.

3.3.1 Tonne kilometre price elasticities

Changes in tonne kilometre prices may result in various responses of the shipper (see also Chapter 2):

- *Change in mode;* substitution to and from rail, inland shipping and (short) sea shipping.
- *Changes in transport demand;* due to the changes in tonne-kilometre prices shippers may choose other supplier/receivers or other production locations. These decisions may lead to changes in total transport demand (without changes in tonnes shipped).
- *Changes in commodity demand;* if the shippers cannot 'internalise' the transport price changes by themselves, they have to increase the price of the goods they offer. As a consequence consumer demand will fall and thereby total transport demand.

Based on the results of the literature review (see Table 3 and Table 4) we will first discuss the price sensitivity of these three effects separately. With the help of the results of this discussion we will investigate the tonne-kilometre price elasticity with regard to tonne-kilometres.

Table 3 Overview of road tonne-kilometre price elasticities

Study	**Country**	**Period**	**Dependent variable**	**Response mechanisms**	**Elasticity**
Effect on road tonne-kilometres					
Beuthe et al. (2001)	Belgium		Tkm	9	-1.1 to -1.3
Björner & Jensen (1997)	Denmark		Tkm	9/10/11/12	-0.5 to -2.4
				9	-0.2 tot -0.9
				10/11/12	-0.4 to -1.5
Friedlaender & Spadey (1980)	USA	1972	Tkm	9/10/11/12	-0.96 to -1.58
Friedlaender & Spadey (1981)	USA	1968-1972	Tkm	9/10/11/12	-0.59 tot -1.81
De Jong (2003)	EU	90ties	Tkm	9	-0.62
	Belgium	90ties	Tkm	9	-0.95
	Norway	90ties	Tkm	9	-1.01
	Sweden	90ties	Tkm	9	-0.4
Inabe & Wallace (1989)	USA	1984	Tkm	5/9/12	-0.3 to -0.9
NEI & CE Delft (1999)	Netherlands	1999	Tkm	5/9/11/12/13	-0.43 to -0.63
Oum (1989)	Canada	1979	Tkm	5/9/10/11/12/13	-0.69 (-0.05 to -1.34)
				9	-0.65
				5/10/11/12/13	0.04
Yin et al. (2005)	UK	2001	Tkm	8/9/11/12	-0.2
Effect on road tonnes					
Beuthe el al. (2001)	Belgium		Tonnes	9	-0.6

Chiang, Roberts & Ben-Akiva (1981)	USA	70ties	Tonnes	5/9/12	-0.00 to -9.86 [b]
De Jong (2003	EU	90ties	Tonnes	9	-0.13
	Belgium	90ties	Tonnes	9	-0.4
	Italy	90ties	Tonnes	9	-0.01
Jovicic (1998)	Denmark	1993-1997	Tonnes	9	-0.03 to -0.07
Marzano & Papola (2004)	Italy	90ties	Tonnes	9/11/12	-0.15
Windisch (2009)	Sweden	2003-2004	Tonnes	5	0 to -1.4
				9	0
Effect on mode choice for road					
De Jong & Johnson (2009)	Sweden	2001	Mode choice	5/9	-0.03
García-Mendéndz et al. (2004)	Spain	1998	Mode choice	9	-0.32 to -0.49
McFadden & Boersch-Supan (1985)	USA	1977	Mode choice	5/9/10/11/12/13	-0.75

[a] See section 3.2 for a description of the various response mechanisms

[b] The relatively high values found by Chiang et al. (1981) are the result of changes in shipment sizes in reaction to changes in tonne prices.

Table 4 Overview of road tonne price elasticities

Study	Country	Period	Dependent variable	Response mechanisms	Elasticity
Abdelwahab (1998)	USA		Tonnes	5/9/13	-0.75 to -2.53
Nam (1997)	Korea	1988-1989	Mode choice	9	0.12 to -0.25
Winston (1981)	USA	1975-1977	Tonnes	9	-0.14 to -2.96

[a] See section 3.2 for a description of the various response mechanisms

Mode change

Several studies included in the literature review pay attention to the effect of changes in tonne-kilometre prices on the modal split (measured in tonne-kilometres): Beuthe et al. (2001), Björner and Jensen (1997), De Jong (2003), Oum (1989). These studies find price elasticities that range from -0.2 to -1.3. De Jong (2003) shows an average European value of -0.6, which represents an average of the results found in the literature review too.

The variance in the estimates of tonne-kilometre price elasticities with regard to mode change can largely be explained by differences in geographical regions considered. For example, De Jong (2003) present higher tonne-kilometre price elasticities with regard to mode change for Belgium than for Sweden (-0.95 vs. -

0.4), which is the consequence of better availability of non-road modes in Belgium compared to Sweden (rail transport does have a significant market share in Sweden, but this is mainly due to a few very large shippers, e.g. in the iron ore sector). By the same reasoning the relatively high price elasticities of mode change presented by Beuthe et al. (2001) for Belgium can be explained, as well as the relatively low elasticity with regard to the probability of choosing road transport in Sweden found by De Jong and Johnson (2009) and Windisch (2009) for the mode choice effect.

In Table 3 also tonne-kilometre price elasticties with regard to mode change measured in tonnes are presented: Beuthe et al. (2001), De Jong (2003) and Jovicic (1998). In general these elasticities are significantly lower than the elasticities for mode change measured in tonne-kilometres, which indicates that especially mode shifts of long distance transport take place. On long distance transport rail and inland shipping can be a competitive alternative for road transport; on short distance transport they cannot. The estimates of tonne kilometre prices elasticities on mode change (measured in tonnes) also show a wide variance with regard to geographical region considered. Again, estimates for Belgium are high, while estimates for Italy and Denmark are quite low. These results correspond to the results found for the elasticities of mode change measured in tonne-kilometres.

Finally, in Table 4 the results of some studies of the tonne price elasticities on mode change measured in tonnes are presented. Winston (1981) find a wide range of elasticities, which depends heavily on the type of goods considered. In addition, he considers two types of road transport (private road transport and regulated road transport) which are more substitutable than road and rail transport. Hence, the elasticities presented (separately for private and regulated road transport) will overestimate the actual elasticities for aggregate road freight transport. Nam (1997), on the other hand, finds relatively low values for Korea. However, it is questionable whether these elasticities can be applied on European freight transport.

To conclude, for European long distance road freight transport the tonne-kilometre price elasticity with regard to mode change seems to vary between -0.2 to -1.3.

Changes in transport demand

The effects of changes in tonne kilometre prices on total transport demand are only investigated separately by two studies: Björner and Jensen (1997) and Oum (1989). However, the results of both studies show large differences. Björner and Jensen (1997) find an elasticity of transport demand of -0.4 for manufacturing goods, -0.5 for construction goods, -1.0 for the trade sector and -1.5 for other services (domestic services, restaurants and hotels). Of these elasticities the first two estimates are most connected to ‘traditional’ freight transport and are therefore most usable for this study. For manufacturing goods, Björner and Jensen present both elasticities of transport demand and mode change. From the estimates of Björner and Jensen it becomes clear that transport demand elasticities in Denmark can be twice as high as mode choice elasticities (-0.4 for transport demand and -0.2 for mode choice, both referring to manufacturing goods) .

Oum (1989) provides on the other hand quite low elasticities of transport demand in Canada: -0.04[2]. It is not clear why these estimates differ so much from the estimates of Björner and Jensen. However, for Europe the figures from Björner and Jensen (ca.-0.4) seems more reliable.

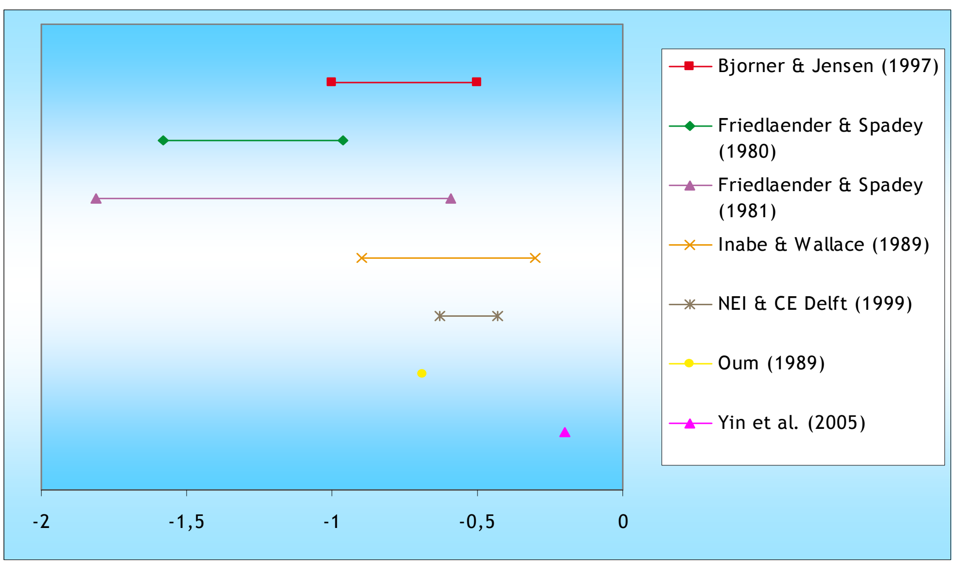
Changes in commodity demand

No studies are found that consider separately the effect of tonne-kilometre price changes on commodity demand. In NEI and CE Delft (1999) it was assumed that the elasticity with regard to this effect would be small (< 0.1). The main reason for this low transport price sensitivity of commodity demand is that transport costs account for only a small part of total commodity prices.

Total effect: changes in tonne-kilometres

Several studies have estimated tonne-kilometre price elasticities with regard to tonne-kilometres including both mode change, transport demand and/or commodity demand in the analysis. The resulting elasticity estimates are compared in Figure 2.

Figure 2 Overview of road tonne-kilometre price elasticities with regard to road tonne-kilometres from various studies including both mode change and transport demand effects



Note: Björner and Jensen (1997) also present an elasticity of -2.4 with regard to transport related to domestic services, restaurants and hotels. In our opinion this kind of freight transport is not representative for long distance freight transport in Europe. Therefore this elasticity is deleted from the sample.

Figure 2 shows a wide range of tonne-kilometre price elasticities (-0.2 to -1.8). The lower bound (-1,8) of this range is determined by elasticities from

[2] This elasticity includes also shipment size effects and changes in commodity demand. Therefore, the actual elasticity of transport demand will be even smaller.

Friedlaender & Spadey, which refer to road freight transport in the USA. Furthermore, this is a rather old study by now. Compared to the studies with regard to European road freight transport (e.g. Bjorner & Jensen, 1997; NEI & CE Delft, 1999; Yin et al., 2005) these estimates are relatively high in absolute values. Also Abdelwahab (1998) presents elasticities for the USA (tonne price elasticities with regard to tonnes) which are relatively high; for most types of goods he finds elasticities in the range of -1.0 to -1.8 (see also Table 4). These results suggest that tonne-kilometre price elasticities are higher in the North America than in Europe. Inabe & Wallace (1989), however, presents elasticities for the USA which are comparable with the elasticities found for European road freight transport. The same holds for Oum (1989) with regard to Canadian transport. Hence, the literature review do not provide unambiguous evidence that tonne-kilometre price elasticities differ between Europe and North America.

At the higher bound of the range (some of the) elasiticity estimates of Inabe & Wallace (1989), Yin et al. (2005) and NEI & CE Delft (1999) are situated. The elasticity estimates concerned refer to relatively short distance transport, and are therefore an underestimation of the price sensitivity of long distance transport. For long distance transport a higher bound of approximately -0.6 seems more reasonable.

In general, the results presented in Figure 2 correspond to the elasticity estimates found for the separate effects (mode change, transport demand and commodity demand). If the add up the values of the elasticities for mode change, transport demand and commodity demand we find a tonne-kilometre price elasticity of -0.6 to -1.5 (from Björner and Jensen (1997) we only use the values for manufacturing goods) . These values correspond to values presented by Graham and Glaister (2004), who executed a meta-study on price elasticities of road freight transport. As mean of 143 elasticities they found a value of -1.0. About 66% of the elasticities reviewed by Graham and Glaister fall between -0.5 and -1.3. Therefore, we recommend to use -0.6 to -1.5 as values for the tonne-kilometre price elasticities with regard to tonne-kilometres.

3.3.2 Vehicle kilometre price elasticities

Most price elasticities in freight transport refer to changes in the price per tonne-kilometre (see section 3.3.1). Results for changes in the price per vehicle kilometre (vkm) are rather scarce (see Table 5). A change in the vkm price can have an impact on transport efficiency and transport volumes, and can affect the output dimensions tonnes, vkm and tkm).

Table 5 Overview of road vehicle kilometre price elasticities on road vkm, tkm or transport demand

Study	Country	Period	Dependent variable	Response mechanisms	Elasticity
Björner (1999)	Denmark	1980-1993	Vkm	3/4/5/6/7/8/10/11/12/13	-0.81
			Tkm	9/10/11/12/13	-0.47
			Transport demand	10/11/12/13	-0.27
DGITM (2009)	France	2008	Vkm	3/6/7/8/9	-0.01
Holguin-Veras et al. (2006)	USA	2004	Share of deliveries in peak period	3	-0.2
Maurer (2008)	UK	1998	Vkm	4/5/6/9/11/12	-0.14

Holguin-Veras, (2006) provides an estimate for the vkm price elasticity of -0.2. This estimate mainly concerns the effect of shifts between time-of-day periods (from peak to off-peak), the pure transport efficiency(consolidation of trips) effect is likely to be considerably smaller. The estimate of Björner (1999) for transport demand (tkm for all modes together) of -0,27 includes changes in production technology, location of production, OD patterns and commodity demand, so should be seen as a long term effect.

Björner (1999) uses the same cost index for the tkm price and the vkm price, so his results could just as well have been included in Table 3. For the impact of a change in the road transport price (vkm price = tkm price) on tkm for road transport he obtains an elasticity of -0.47. This is due to changes in modal choice (about 40%) and changes in transport demand (60%). When transport efficiency effects are added to give the impact on vkm, the elasticity increases further (in absolute values) to -0.81. The vkm effect can be compared against DGITM (2009) which found a small mode choice effect and a very small effect on transport efficiency (together giving an elasticity of -0.01). Another impact of the price per vkm on vkm was given by Maurer (2008). Although this study included various transport efficiency effects and changes in modal split, production volume and OD patterns, the elasticity was only -0.14.

We thus have to conclude that even when elasticities have the same independent and dependent variable, different studies obtain rather different outcomes. This may have to do with the differences in study area (Denmark, UK, France, USA), but also with methodological differences. The results obtained give an indication that the pure mode choice effect of vkm price changes is probably relatively small: between -0.01 and -0.20. Other transport volume effects influencing trip lengths might be a bit more substantial in the long run (between -0.1 and -0.3). The range for transport efficiency effects is from 0 to -0.34. Added up, the total elasticity for vkm price changes (with respect to vkm) is -0.1 to -0.8. The total elasticity with respect to tkm ranges from -0.1 to -0.5.

If we compare the outcomes for vkm price changes with those of the tkm price changes of section 3.3.1, we see that the vkm price changes lead to smaller mode and transport demand effects. This is plausible, because shippers an especially carriers can avoid changes of mode and in transport demand by changing the load of the vehicles (the number of tonnes per vehicle), until the vehicle capacity will be reached. These are the transport efficiency effects discussed above. Changes in vkm prices will be an incentive to change the transport efficiency. Also there will be an incentive to revise the modal and transport demand choices, but not as much as for changes in the tkm price.

3.3.3 Fuel price elasticities

Changes in fuel prices may lead to various responses of hauliers and/of shippers (see also chapter Chapter 2):

- *Changes in fuel efficiency*; due to changes in fuel prices hauliers may decide to invest in more fuel efficient trucks or they may implement a more fuel efficient way of driving.
- *Changes in transport efficiency*; due to an increase in fuel prices transport prices per vehicle kilometre increases. This will provide an incentive to hauliers to improve the efficiency of their transport such that they can reduce the number of vehicle kilometres needed to transport one tonne of cargo.
- *Changes in transport volumes*; if improvements in fuel and transport efficiency cannot compensate fully for the increase in fuel prices, hauliers will ask higher transport rates from shippers. This will provide an incentive to shippers to reduce the number of tonnes-kilometres shipped, e.g. by reducing the average distance over which goods are transported.

The three responses of hauliers/shippers on changes in fuel prices mentioned above may influence the following variables:

- *Total fuel demand* is influenced by changes in fuel efficiency, transport efficiency and transport volumes.
- *Vehicle kilometres* are influenced by changes in both changes in transport volumes and transport efficiency.
- *Tonnes-kilometres* are only influenced by changes in transport volumes.

For all these three variables we will present elasticities with respect to fuel prices. Unfortunately, the number of studies on fuel price elasticities with regard to road freight transport is limited (see Table 6). Therefore the results on fuel price elasticities should be interpreted carefully.

Table 6 Overview of road transport fuel price elasticities on road tk, vkm or diesel consumption

Study	Country	Period	Dependent variable	Response mechanisms included[ab]	Elasticity
Fiorello et al. (2008)	EU25 + NO + CH	2008	Tkm	1/8/9/10/11/12/13	-0,05 to -0,3
Hemery & Rizet (2007)	France	1998-2006	Tkm	1/2/3/4/5/6/7/8/9/10/11 /12/13	-0,05 to -0,14
			Vkm	1/2/3/4/5/6/7/8/9/10/11 /12/13	-0,3
IEA (1994)	EU	1965-1991	Tons diesel	1(?)/2/3/4/5/6/7/8/9/10 /11/12	-0,4

[a] See section 3.2 for a description of the various response mechanisms

[b] The impact of fuel price changes on fuel efficiency (response mechanism 1 and 2) results in lower cost increases per vkm and tkm since hauliers can 'internalise' part of the fuel price increase by improving the fuel efficiency of his truck or by driving more fuel efficient.

Total fuel demand

The literature review provides only one study that present a fuel price elasticity with regard to total fuel demand. In IEA (1994) a fuel price elasticity of total diesel demand of road transport in Europe (both passenger and freight transport) of -0.4 is estimated by using the World Energy Model (WEM).

In NEI and CE Delft (1999) a study of NEI is mentioned which presents a short term fuel price elasticity on fuel demand of road freight transport of -0.3 (NEI, 1991). The same study also provides a long term elasticity of -0.6. Litman (2009) mention a study of Hagley Bailly (1999), which provides a short term elasticity of -0.1 (-0.05 to -0.15) and a long term elasticity of -0.4 (-0.2 to -0.6). Unfortunately, neither study was available in full for the literature review, so it is therefore unclear which response mechanisms are included. However, the results of both studies correspond to the results of IEA (1994).

Based on the study of IEA and the results of NEI (1991) and Hagler Bailly (1999) we recommend a long term fuel price elasticity on fuel demand of -0.2 to -0.6.

Vehicle kilometres

Only one estimation of a fuel price elasticity with regard to vehicles kilometres was found in the literature review. This estimation was provided by Hemery and Rizet (2007) who studies the effects of changes in fuel prices on road freight transport in France. With regard to vehicle kilometres they found a price elasticity of -0.3.

It is also possible to derive a fuel price elasticity with regard to vehicle kilometres by using the fuel elasticity on total fuel demand (ca. -0.4) and the vehicle kilometre price elasticity on vehicles kilometres (ca. -0.5). Therefore, we need to make to additional assumptions:

- 25% of total vehicle kilometre costs are determined by fuel cost (NEA, 2009);

- about 33% of the fuel price change can be 'internalised' by increasing the fuel efficiency.

Based on these assumptions we can calculate a fuel price elasticity with regard to vehicle kilometres of approximately -0.1.

These results give an indication that fuel price elasticities with regard to vehicle kilometres range from -0.1 to -0.3.

The fuel price is only a part (usually a small part) of the total transport costs (which contains also staff and vehicle costs), as are included in the tkm and the vkm price. Therefore a change in the fuel costs of say 10% will have a much smaller effect on the output dimensions than a 10% change in transport costs. Hence the smaller elasticities for fuel price changes.

Tonnes-kilometres

The literature review provides two studies that present fuel price elasticities with regard to tonnes-kilometres. First, Hemery and Rizet estimated an elasticity for road freight transport in France of -0.05 to -0.14. Fiorello et al. (2008) used the transport model ASTRA to estimate the fuel price elasticity on tonnes-kilometres. They found values of -0.05 to -0.3. So, fuel price elasticities on tonnes-kilometres range from -0.05 to -0,3.

3.3.4 Segmentation of elasticities

Most studies either give elasticities for all commodities together or segment by commodity group (sometimes focussing on one or a few of those). Jovicic (1998) grouped commodities into high value and low value goods. The EXPEDITE study (de Jong, 2003) also distinguished elasticities by distance class. A group of studies find higher road transport price sensitivities for general cargo compared to bulk products (this can be a transport demand effect: in general there are more potential suppliers and receivers in general cargo products than in bulk products, so it's easier to substitute to nearby suppliers and shorten distances for general cargo), but another group finds the reverse (which can be explained by the fact that rail and waterway transport are better substitutes for bulk goods – a mode choice effect).

Table 7 Overview ofroad tonne or tkm price elasticities by commodity type

Study	Country	Effect	Commodity type	Response mechanisms included[ab]	Elasticity
Abdelwahab (1998)	USA	Tonne price on tonnes	Food	5/9/13	-2.2 - -1.1
			Textile		-1.4
			Chemicals, Petroleum, coal		-1.7 - -0.9
			Rubber, plastic, leather		-1.1
			Metal products		-2.2 - -0.8
			Electrical and transportations equipment		-2.5 - -1.2
			Stone, clay, glass, concrete		-0.8
			Wood and paper products		-1.6 - -1.1
Beuthe et al (2001)	Belgium	Tkm price on tkm	Agricultural products and animals	9	-0.96
			Food		-0.69
			Solid fuel		-0.52
			Petroleum		-4.5
			Iron ore and scrpas		-1.67
			Metallurgical products		-2.09
			Minirals and building materials		-0.98
			Fertilisers		-0.72
			Chemical products		-1.1
			Diverse products		-1.18
			Agricultural products and animals		-0.95
			Food		-0.65
			Solid fuel		-0.39
			Petroleum		-3.98
			Iron ore and scrpas		-1.47
			Metallurgical products		-1.98
			Minerals and building materials		-0.77
			Fertilisers		-0.7
			Chemical products		-0.77

Nam (1997)	Korea	Tkm price on mode choice	Textile	9	-0.002
			Paper		-0.253
			Chemicals		-0.107
			Basic metal		-0.212
			Earthenware		0,.21
			Electrical houseware		0.085
Garcia-Mendendz et al. (2004)		Tkm price on mode choice	wood manufacture and furniture	9	-0.38
			Ceramics		-0.49
			Textiles		-0.32
			Agroindustry		-0.36
			Diverse products		-1.18
Jovicic (1998)	Denmark	Tkm price on tonnes	low value goods	9	-0.07
			high value goods		-0.03
De Jong (2003)	EU	Tkm price on tonnes or tkm	Tkm, bulk, 500-100m km	9	-0.5
			Tkm, general cargo, 500-1000 km		-0.7
			Tkm, bulk , >1000 km		-1
			Tkm, general cargo, >1000 km		-0.8
			Tonnes, bulk, all distances		-0.05
			Tonnes, petro, all distances		-0.13
			Tonnes, general cargo, all distances		-0.13
			Tkm, bulk, all distances		-0.18
			Tkm, petro, all distances		-0.35
			Tkm, general cargo, all distances		-0.39

3.4 Cross price elasticities

We have not compared cross elasticities (impact of road transport price changes on the use of other modes) from all studies that reported cross elasticties, since such elasticities heavily depend on the current market shares of the mode, which can be very different between different study areas (e.g. rail is used much more for freight transport in the USA than in Europe). We only look into cross elascities with respect to long distance rail transport at the European scale. The only studies that give such elasticities are EXPEDITE and SCENES (both in de

Jong, 2003). The study area for SCENES was the EU15 (Western Europe), and for EXPEDITE it was the EU15 plus eight Eastern European countries, Switzerland and Norway. SCENES gave a transport cost (per tkm) elasticity of rail tonnage of 1.6 and of rail tkm of 2.4. So the latter is considerably more sensitive than the former, because long distance transports are more sensitive to cost changes than short distance transports. The EXPEDITE tkm price elasticities are between 1.1 and 1.7 for the effect on rail tkm (above 500 km). These are smaller than the 2.4 from SCENES which might be explained from the fact that rail has a higher market share in Eastern Europe so that a similar shift away from road transport will have a smaller relative impact on rail.

3.5 Conclusions

The main conclusions from the literature review on own-price elasticities are summarized in Table 8.

Table 8 Results from the literature review on road own-price elasticities

Price change	Impact on		
	Fuel use	Vehicle kilometres	Tonne kilometres
Fuel price	-0.2 to -0.6	-0.1 to -0.3	-0.05 to -0.3
Vehicle kilometre price		-0.1 to -0.8	-0.1 to -0.5
Tonne kilometre price			-0.6 to -1.5

The above results on elasticity values are supported by almost 80% of the studies reviewed. Just above 20% of the studies yields values that are clearly lower or higher.

Notice that especially the values presented with regard to fuel price change are characterized by rather high uncertainties due to the limited number of studies that reported estimates for these elasticities (to a lesser extent the same notification holds for vehicle kilometre price elasticities).

Finally, we also analyzed the literature on cross elasticities with respect to long distance rail transport at the European scale. Based on this literature review we recommend a transport cost (per tkm) elasticity of rail tonnage of 1.1 to 1.6 and of rail tkm of 1.7 to 2.4.

A consistent set of elasticities

The main results of this study are the elasticity ranges presented above. We also carried out an exercise in which we derived a single set of elasticity values that is internally consistent, gives values in the above ranges, and that can be regarded as our best-guess long distance road price elasticity values over all commodities for the evidence reviewed in this report. These estimates have to be treated with care, because there is a lot of variation around them.

We used the following assumptions:
- 25% of total vehicle kilometre (vkm) costs are determined by fuel costs (NEA, 2009);
- about 33% of the fuel price change can be 'internalised' by increasing the fuel efficiency.
- about 45% of changes in vkm prices can be 'internalised' by increasing transport efficiency.

The studies on observed changes after the introduction of the Maut in Germany and Austria (also see chapter 4) did not lead to clear-cut conclusions on the specific types of effects that the policy measure caused, but indications for limited changes in transport efficiency and in mode choice were found, as well as indications for a change in transport demand.

It turned out that there is no single set of elasticity values which meets all the objectives above. Most of the studies reviewed give information on the tonne kilometre (tkm) price elasticity of the number of tonne kilometres. The centroid value from these studies would be an elasticity of about -1.0. However, this value is not consistent with the range of the vkm price elasticities that we found.

The range of vkm price elastictity values from the literature review was [-0.1 ; -0.8] for the effect on vkm and [-0.1 ; -0.5] for the effect on tkm. The highest tkm price sensitivity of tkm that this range allows is -0.9, below the centroid value of the tkm price elasticity of tkm (-1.0). Given that the tkm price elasticities are based on a much larger body of evidence than the vkm price elasticities, we have selected values that do maximum justice to the outcomes for tkm price elasticites for the centroid values below. The set of best-guess values of road freight transport elasticities is presented in Table 10.

Table 9 Consistent set of best-guess values of road freight transport price elasticities

Price change	Impact on		
	Fuel use	Vehicle kilometres	Tonne kilometres
Fuel price	-0.3	-0.2	-0.1
Vehicle kilometre price		-0.9	-0.6
Tonne kilometre price			-1.0

The fuel price elasticity with regard to total fuel demand includes three behavioural responses: changes in fuel efficiency (-0.1), changes in transport efficiency (-0.1) and changes in road freight transport demand (-0.1).

The vehicle price elasticities also consist of three effects: changes in mode (-0.3), changes in transport demand (-0.3) and changes in transport efficiency (-0.3).

Finally, for the tonne kilometre price elasticity two effects can be distinguished: change in mode (-0.4) and change in transport demand (-0.6).

We have found (limited) evidence from models (e.g. from Denmark) and observed changes after introduction of the Maut that transport demand changes are more important here than modal split changes. On the other hand, a study in Canada (Oum, 1989) found that the modal shift effect dominated the transport demand effect. Transport demand will not be highly elastic, since the main response mechanism (shifting to other suppliers or markets) not only depends on transport costs, but also on factors like production costs and product quality differentials.

CHAPTER 4 Learning from existing schemes

4.1 Introduction

In various European countries pricing schemes for heavy duty vehicles are implemented. Based on available evaluation studies we will assess the effects of the HGV road pricing schemes in Germany, Austria and Czech Republic (section 4.2 to 4.4). We did not assess the Swiss HGV road pricing scheme. In Switzerland the road pricing scheme was introduced at the same time as the increase of the weight limit of trucks. None of the available evaluation studies were able to distinguish between the effects of both measures. In addition to the assessment of actual pricing schemes we will also discuss the effects of the introduction of a higher weight limit for trucks in the UK (section 4.5). Finally, we will present the conclusions of this chapter in section 4.6.

4.2 German Maut

4.2.1 Tolling System

Since January 2005, trucks with a maximum laden weight exceeding 12 tonne have to pay the kilometer dependent Lkw-Maut on German motorways. Before, in August 2003, the Eurovignette toll was discarded.

The Maut charge level depends on the pollution class of the vehicle, its weight and the number of axles. Certain vehicles, such as emergency vehicles and buses are exempted from the toll. The toll levels since the introduction in 2005 are in the Table 10. In October 2006 Maut tariffs for Euro 2 and Euro 4 trucks were moved to a more expensive toll class. In September 2007 the toll tariffs were raised. In January 2009, toll tariffs were raised by over 40% and tariffs for Euro 3 trucks were moved to a more expensive toll class.

Table10 LKW-Maut rates since January 2005 (€ct/ km)

Maut category	From Jan 2009 (Jan 2009, new tarrifs and categories)		Sept 2007-Dec 2008 (Sept 2007, new tarrifs)		Oct 2006 – Sept 2007 (Oct 2006, new categories)		Jan 2005-Oct 2006	
	<= 3 axles	>=4 axles	<= 3 axles	>=4 axles	<= 3 axles	>=4 axles	<= 3 axles	>=4 axles
Euro 0, Euro 1	27,4	28,8	14,5	15,5	13	14	13	14
Euro 2	27,4	28,8	14,5	15,5	13	14	11	12
Euro 2 with PMK1-4	19,0	20,4	14,5	15,5	13	14	11	12
Euro 3	19,0	20,4	12	13	11	12	11	12
Euro 3 with PMK 2-4	16,9	18,3	12	13	11	12	11	12
Euro 4	16,9	18,3	12	13	11	12	9	10
Euro 5 and EEV	14,1	15,5	10	11	09	10	9	10

PMK 1-4 are soot filter classes.

4.2.2 Charging System

Automatic tracking and charging is done with a GPS On-Board-Unit (OBU) which sends the travel data through a GSM mobile unit to the (private) company responsible for charging, Toll Collect, which subsequently charges the user for the covered distance. Vehicles without OBU can pay manually before embarking on the trip at any of the *Maut* terminals which are placed at petrol stations and other sites near entries to the German motorway network. Payment is also possible via internet or telephone.

The operating costs of the German HGV toll system are € 620 million per year, while the total revenue from the scheme equals € 3 billion per year (Oehry, 2006). Revenues generated by the toll are spent on infrastructure projects for roads, railways and waterways.

4.2.3 Impact of the German Lkw-Maut

With the introduction of the Lkw Maut in Germany transport costs have increased.[3]

So far no clear effects of the introduction of the Maut on modal shift, transport volumes or truck kilometres have been reported. According to a report of the German federal agency of freight transport, empty trips decreased in 2005 and 2006 after introduction of the Maut, but not a at higher pace than before (BAG, 2006).

German statistics on transport volumes (Statistisches Bundesamt Deutschland (2009) and Eurostat; see also appendix C), do seem to reveal an effect. In Figure 3 the indexed number of tonne-km/tonne are plotted for the domestic road freight transport by German trucks[4] (over 95% of all tonne-km is made by vehicles >12 tonne). The value tonne-km/tonne is an indicator for the average distance travelled to transport one tonne of freight. As can be seen from Figure 3 the average distance travelled (tonne-km/ tonne) show a change around the year 2005. The average distance travelled per tonne freight has increased from 1995 by ca. 3% per year. This increase disappears around 2005 and in 2008 even a decrease of about 0,5% is observed. The decrease in transport distance might be attributed to the introduction of the Maut[5]. Given that the charge is distance dependent, a reaction in terms of distance makes sense. This can be due to better route planning and/or to a change in trade patterns.

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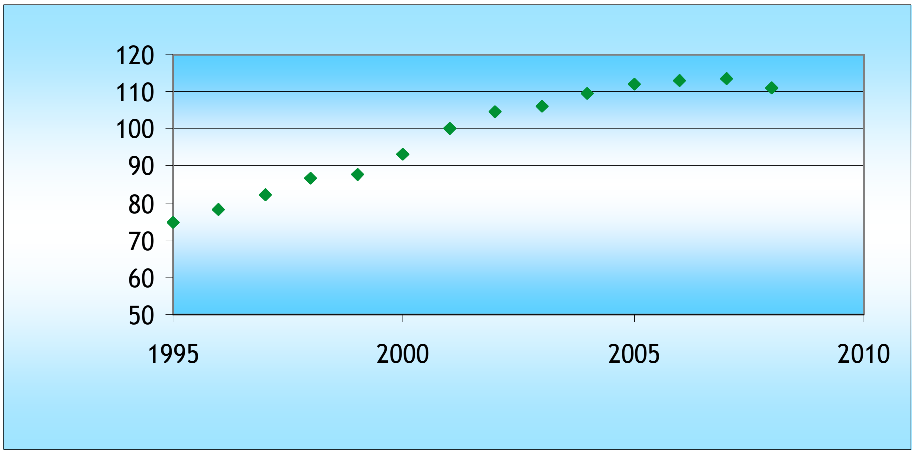
[3] In the first three months after introduction transport prices increased only by 0.5%, whereas an increase of 15% was expected [Runhaar, 2005]. Lower fuel costs and driver salaries (e.g. more Polish drivers) have been mentioned as reasons for this. In addition, the introduction of the Maut was accompanied by huge compensation programs (Innovation program 2007/2008, DeMinimis-Program 2009) to support the purchase of cleaner trucks.

[4] Due to data limitations it was not possible to construct a similar kind of plot taking into account all road freight transport in Germany.

[5] Another (theoretical) explanation may be that part of the long-distance domestic transport in Germany is shifted from German to foreign hauliers (as a consequence of the enlargement of the EU with some Eastern European countries in 2004). However, we see that tkms of German trucks increase at the same rate before and after 2004, while the growth rate of the number of tonnes transported by German trucks even increases after 2005. Hence, it seems unlikely that foreign hauliers transport a larger share of domestic road transport in Germany since 2004/5.

Figure 3 Indices of average distance travelled per tonne transported (tonne-km/tonne) of domestic road freight transport by German trucks (2001=100)



Source data: Tonne-km/ tonne: Statistisches Bundesamt Deutschland (2009)

4.3 Austrian Maut

4.3.1 Toll system

Since January 2004 all vehicles with a gross vehicle weight (GVW) over 3.5 tonne are obliged to pay toll on Austrian motorways (Autobahn) and express highways (Schnellstrasse). With the introduction of the Lkw-Maut, the Vignette duty and road tolls for these vehicles were discarded and the road transport duty was reduced to the level of the year 2000.

The toll levels depend on the number of axles and have been raised two times since the introduction (Table 11).

Table 11 Lkw-Maut levels in Austria since 2004 (€ct/ km)

Period	2 axles	3 axles	>4 axles
May 2008 - Jan 2010	15.8	22.12	33.18
July 2007 - May 2008	15.5	21.7	32.55
Jan 2004 - May 2007	13	18.2	27.3

On some roads a night tariff is valid which is the double of the day tariff (Asfinag, 2009).

In January 2010 the tariffs will be differentiated to emission classes according to the tariffs in Table 12 (Bundesministerium für Verkehr, Innovation und Technologie, 2009).

Table 12 Austrian Maut tariffs valid from January 2010 (€ct/ km)

Emission classes	**2 axles**	**3 axles**	**4 axles**	**Differentiation from present tariff**
C (Euro 1,2,3)	17.40	24.36	36.54	+~10%
B (Euro 4,5)	15.2	21.28	31.92	-~4%
A (Euro 6, EEV)	14.20	19.88	29.82	-~10%
present Tariffs	15.8	22.12	33.18	

4.3.2 Charging system

The Austrian system uses Dedicated Short Range Communication (DSRC) based on 400 road-side beacons distributed across the country's 2000-km autobahn network, mainly at slip roads and intersections. On-board devices called "Go-Boxes" communicate with these beacons, tracking truck movements across the network and calculating the level of toll [McKinnon, 2006]. Operators can either pay the toll retrospectively via a centrally registered account or pre-pay by topping up toll credit in advance through an Internet site or various sales points. All trucks (and coaches) with a gross weight of over 3.5 tonnes travelling on Austrian motorways must be fitted with a Go-Box.

4.3.3 Impact of the Austrian Lkw-Maut

With the introduction of the LKW-Maut transport costs have increased in Austria. Effects of the increase in costs on transport volumes have not been reported.

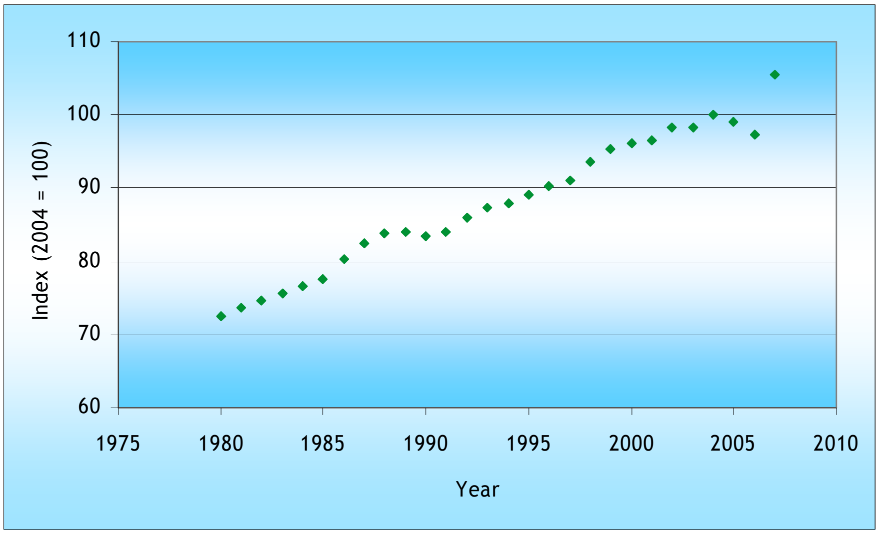
In Figure 4, an index for the average distance travelled per tonne transported (tonne-km/ tonne) is depicted. In contrast to the German case, this figure takes all road freight transport into account, both by domestic and foreign hauliers. In 2004 the graph shows a break in the observed trends. A decrease in the average distance travelled per tonne (about 3% in 2006) is observed for the period 2004 – 2006[6]. This effect may be due to better route planning or a shift of transit transport to abroad. As in the case of the German Maut, the change corresponds well to the year of the introduction of the Maut.

In 2007 a big increase in the average distance travelled per tonne can be observed. According to the Austrian federal agency of transport this can be explained by the introduction of the Czech heavy duty vehicle charge, as a consequence of which some transit transport has been shifted from the Czech Republic to Austria[7].

[6] The decline in the average distance travelled per tonne can be explained by a decline in the growth of tkm, while the growth in tonnes transported is constant.

[7] Since transit traffic is usually long distance traffic, an increase of this kind of transport leads to an increase in the average transport distance.

Figure 4 Indices of average distance travelled per tonne transported (tonne-km/ton) of freight transport by road in Austria (2004=100)



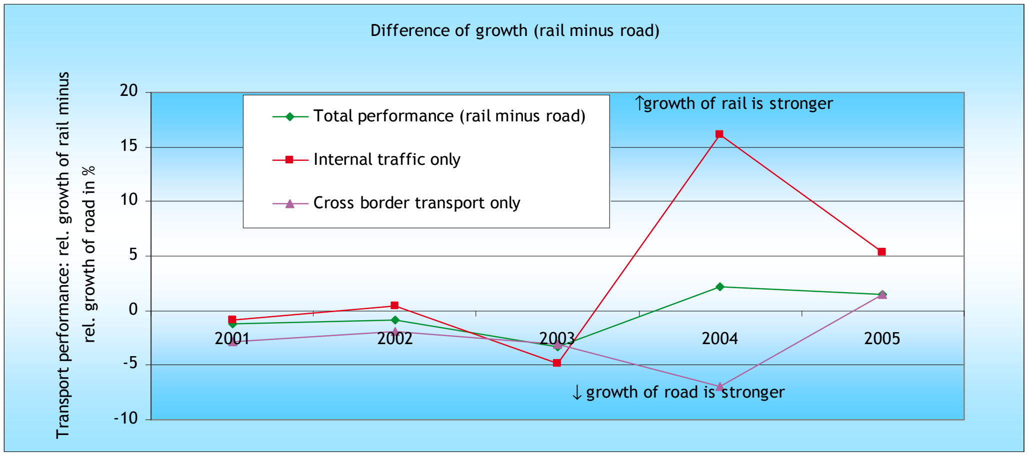
Source data: Austrian federal ministry of transport, innovation and technology (2009) (see Appendix C)

In Figure 5 the growth in rail transport (relative to the year before) minus the growth in road transport is plotted. A positive value in this graph reflects a modal shift from road to train, a negative value a modal shift from train to road. With the introduction of the Maut in 2004, a small modal shift to rail is visible; rail transport is growing 2% faster than road transport. Long distance transport (i.e. cross border), however, remained largely unaffected by the introduction of the Maut, whereas internal transport by rail has got a competitive advantage towards road transport. It seems that internal road transport was more sensitive to the introduction of the Maut. The reason might be that for long distance transport, the price increase due to the Maut was relatively low. In 2005, also advantage for long distance traffic by rail is visible. This effect might come from the introduction of the German Maut in 2005, as a large part of cross border road transport in Austria passes through or comes from Germany.

The latter data are from a short period of time, but also suggests that the introduction of the Maut might have an influence on the modal split of freight transport.[8]

[8] It should be noted, however, that in 2005 total transport volume in Austria decreased both for rail and road which may indicate that economic conditions were changing. These fluctuations in economic conditions may have affected road and rail transport in different ways and hence may be (partly) responsible for the changes in modal split.

Figure 5 Difference in growth (as % of previous year) between rail an road transport (Rail-Road).



Source: Deußner (2005), adapted by Wolfgang Rauh. ÖBB-Holding AG and CE Delft

4.4 Czech kilometer charging

4.4.1 Tolling system

Since January 2007, vehicles or road trains with a permitted total weight equal or greater than 12 tonnes have to pay toll on motorways, expressways and selected roads in Czech Republic. Such vehicles do not have an obligation anymore to fix a vignette (time based charge sticker) on their windshields. The charge level depends on the pollution class of the vehicle, its weight and the number of axles (Premid, 2009). The toll levels are depicted in Table 13 .

Table 13 Toll levels in Czech since 2007-2009 in €ct/km (Kč/ km[9])

	<= Euro 2			>= Euro 3		
	2 axles	3 axles	>4 axles	2 axles	3 axles	>4 axles
Highways	9,0 (2,3)	14,4 (3,7)	21,0 (5,4)	6,6 (1,7)	11,3 (2,9)	16,4 (4,2)
Other roads	4,3 (1,1)	7,0 (1,8)	10,1 (2,6)	3,1 (0,8)	5,5 (1,4)	7,8 (2)

4.4.2 Charging system

The charging system in the Czech Republic is similar to the system in Austria using communication by DSCR with a so called Premid unit in the truck that communicates with the tolling system.

When passing through a toll gate, an acoustic signal from the Premid unit alerts the driver that the toll has been registered properly. The driver can use any lane without having to reduce the vehicle's speed or stop. The tolling process is fully automatic and requires no intervention on the part of the driver.

4.4.3 Impact of the Czech toll

The Czech Transport federation (Brzobohatý, 2009) has studied the intensities on selected motorway segments before (2006) and after (2007) the introduction of the Czech toll. They found that transport intensities of vehicles over 12 tonnes on average had decreased by over 10% on these segments and on base of this estimated an average decrease on the Czech motorways of 10%. Taking into account that without the introduction of the toll the intensities would probably have increased in 2006 compared to 2007 because of economic growth (6% in 2007), the intensity effect is likely even larger than 10%. The study did, however, not cover shifts from motorways to other roads. There are estimations that the intensity increase on regional roads can be in the order of tens of percent. It is clear from the study that the introduction of the Czech toll had a substantial impact on the volume of truck traffic on motorways. It is, however, impossible to draw any conclusions on the overall impact of the toll on the transport volume.

4.5 Permission of heavier lorries in the UK

In 2001 the British government increased the maximum permitted weight for trucks from 41 to 44 tonnes. It was predicted that this measure would lead to a decrease in truck kilometers (100 mln) and therefore in costs for hauliers (ca 6%), because of a better transport efficiency [CfIT, 2000; CfIT 2002]. The studies by CfIT predicted that the lower costs would lead to traffic generation (elasticity 0,1, extra tonnes) and a modal shift (5-19% of tonne-kms) to road.

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9 Exchange rate €/Kč : 1/25.7.

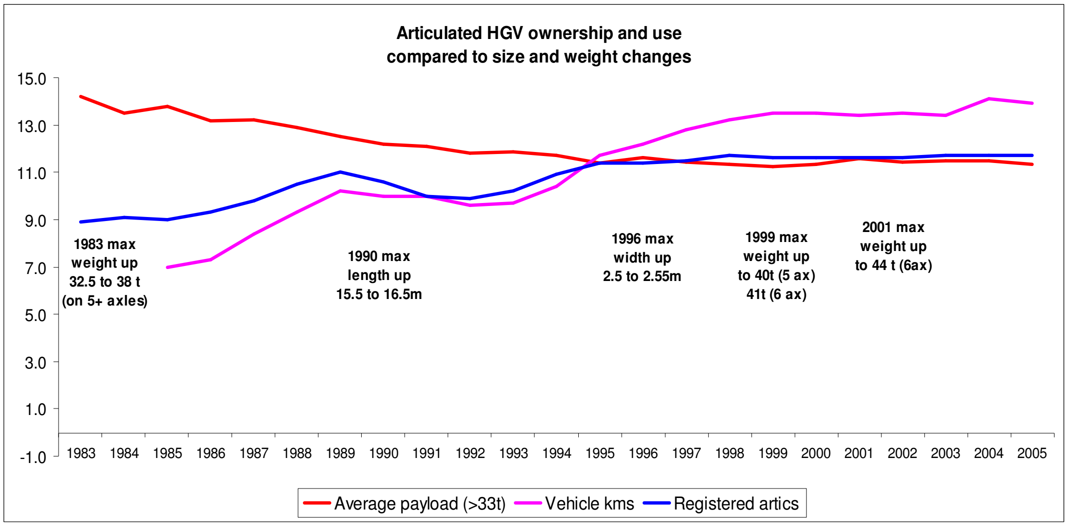
In 2005, Alan McKinnon published a paper on the effects of the maximum weight increase based on actual data from the period 2001-2003 [McKinnon, 2005]. It showed that by the end of 2003 52% of the HGV's of a gross weight of 38 tonne or above were licensed to operate at 44 tonne. The average load factor of the 44 tonne trucks was found to be 62%, which was below the 70% that was assumed in the CFiT study [CFiT, 2000]. Nevertheless, it was concluded that truck kilometers had been reduced by 30% more than predicted and that there was no effect of induced tonne-kms or modal shift from rail to road. The fact that no modal shift had occurred was attributed to the drop in charges for rail-freight operators in 2001, as a consequence of which the permission of heavier lorries did not lead to a decrease in relative road freight prices.

In the work of McKinnon the reduction of truck kilometers was calculated by a bottom-up approach using data from Continuing Survey of Road Goods Transport (CSRGT). The total distance travelled annually by 44 tonne trucks with a weight-constrained load was estimated by using data on the proportions of road freight movements subject to a weight and/or volume constraint. It was assumed that if the weight limit had not been raised to 44 tonnes, weight-constrained freight movement in 44tonne vehicles would have been handled by fully-laden 41tonne trucks, thereby causing extra vehicle kilometers (both laden and empty).

In a report by MTRU effects of the weight increase were evaluated by three indicators, using national statistical data on trucks with a gross permitted of 33 tonnes or more: (1) Average load, (2) Vehicle kms, (3) number of registered trucks (MTRU, 2007). Before the introduction of the higher weight limits it was predicted by CfIT that this policy would result in (1) an increase in the average load, and a decrease in the number of vehicle kms and trucks. However, MTRU found that all three indicator kept following the same trend as before and no changes can be observed (see Figure 6). It was reasoned (as in [McKinnon, 2005]) that most hauliers buy 44 tonnes trucks for only a few occasions in which they need the maximum load. In most instances, however, they will travel with the same load as before, thereby hardly reducing vehicle kms. The author further mentioned that the price elasticity with regard to traffic generation of 0.1 as mentioned in the CfIT report is rather low and that a value of 1 is more likely. As mentioned in the CfIT report [CfIT, 2002], a price elasticity of ca. 1 would generate enough traffic to undo the benefits of a better transport efficiency by 44 tonne trucks.

It can also be reasoned that if there is no change in average load per trip it means that there is also no change in costs. The few lower cost trips with higher loads will be balanced by the trips with the same loads, which will be more expensive in a 44 tonne truck.

Figure 6 Average load, vehicle kms and number of vehicles per year for trucks > 33tonnes



Source: [MTRU, 2007]

4.6 Conclusions

The evaluation studies on HGV road pricing schemes in Germany, Austria and Czech Republic provide some indications that road freight transport is sensitive to changes in transport prices. Statistics on freight transport in Germany and Austria show that the introduction of the Maut coincides with a decrease in the average distance travelled by trucks. Although decisive evidence is absent, this may indicate that the Maut encourages decision-makers in freight transport to re-evaluate their choice of suppliers or customers and/or their route planning. Also in the literature review in Chapter 3 we found evidence that price changes may induce shippers to look for other suppliers or customers and or/more route planning. In Austria there are also indications that rail transport increased due to the the Maut, both in Austria and in Germany. A study on the effect of the toll system in the Czech Republic clearly revealed the transport volumes on motorways decreased after the introduction of the toll. It is, however unclear what the overall effect on transport volumes is, when the complete road network is taken into account. The lack of detailed evaluation studies on the various pricing schemes made it impossible to draw some more conclusions on the effects of vkm price changes.

On the permission of heavier trucks in the UK different effects have been reported. Data based on national statistics, however do not reveal any change in truck kms or average loads. It can even be questioned whether the transport costs have decreased with the introduction of the 44 tonne trucks.

CHAPTER 5 Application of elasticities

5.1 Introduction

To show how the estimated road freight transport elasticities can be used to investigate the effects of transport policies we will apply them in three modeling exercises:

1. An increase of the diesel tax of €0.10 per liter on fuel used, CO_2 emitted and kilometers driven.
2. A kilometer charge of € 0.15/km on fuel used, CO2 emitted and kilometers driven.
3. A 20% cost decrease per tonne kilometer due to lower loading costs on tonne kilometers and vehicle kilometers performed by heavy lories.

In these exercises we will make use of the consistent set of values of the elasticities as presented in section 3.5 (see Table 9). In addition, we will use the following European average cost figures: a diesel price of € 1.05 per litre, a vehicle kilometre price of € 0.88 per kilometre and a tonne-kilometre price of € 0.07 per tonne-kilometre (NEA, 2009).

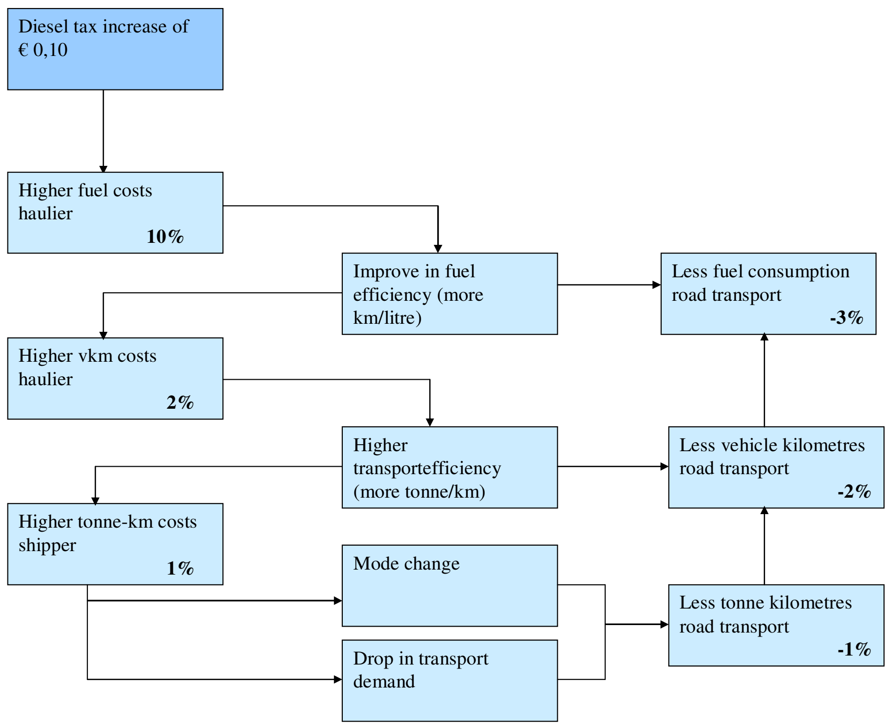
5.2 Increase of diesel tax

With an average fuel price of € 1.05 per litre an diesel tax increase of € 0.10 results in approximately 10% higher fuel costs. On the longer term the price increase will cause an increased fuel efficiency which will absorb approximately 1% (-0.1 x 10%) of the fuel price increase and leave a 9% fuel cost increase end up in the vehicle kilometre price. If we assume that the fuel costs are 25% of total vehicle kilometre costs, the resulting fuel cost increase will lead to approximately 2% higher kilometre costs. With the help of an elasticity of -0.9 this results in a reduction of vehicle kilometres of 2%. Together with the increase in the fuel efficiency of ca. 1% this will result in a fuel demand reduction of approximately 3%.

The reduction in vehicle kilometres due to the higher fuel prices can be partly explained by an increase in transport efficiency. About 45% of the increased vehicle kilometre costs are absorbed due to this improvement of efficiency. As a result the tonne-kilometre costs will only increase by approximately 1% (55% x 2%). This increase results in a drop in transported tonne-km by road of approximately 1% (-1 x 1%). This is caused on the one hand by a drop in demand (0.6%) and on the other hand due to modal shift to inland ships and rail (0.4%).

In total, the improved transport and fuel efficiencies, the drop in demand and modal shift result in approximately 1% decrease in tonne-km per road, 2% less vkms and 3% less fuel consumption (and CO_2 emissions). A summary of the calculation of these effects can be found in Figure 7.

Figure 7 Overview of the effects of a diesel tax increase by € 0.10



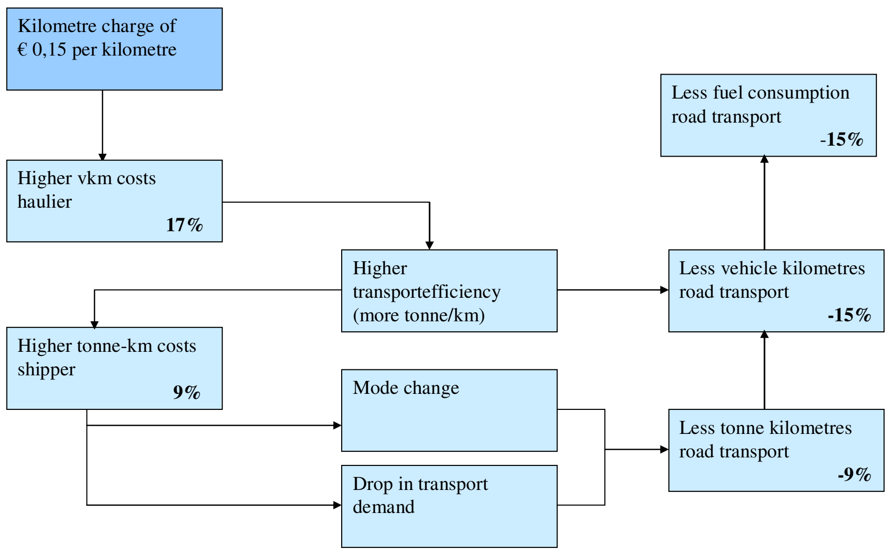
5.3 Introduction of a kilometre charge

The introduction of a kilometre charge of € 0.15 results in an increase of the transport cost per vehicle kilometre of 17%, based on an average European vkm price of €0.88/km. . This will lead to a decrease of the number of vehicle kilometres by approximately 15% (-0.9 x 17%). Also the total amount of fuel demanded (and CO_2-emissions of road freight transport) decrease with ca. 15%.

In addition, the increase in costs will cause improved transport efficiency. About 45% of the increased vehicle kilometre costs are absorbed due to this improvement of efficiency. As a result the tonne-kilometre costs will only increase by approximately 9% (55% x 17%). Tonne-kilometres of road freight transport will drop by 9%. This is caused on the one hand by a drop in demand (ca. 5.6%) and on the other hand due to modal shift to inland ships and rail (3.8%).

An overview of the effects of the introduction of a kilometre charge of € 0.15 is presented in Figure 8.

Figure 8 Overview of effects of the introduction of a kilometre charge of € 0.15 per kilometre

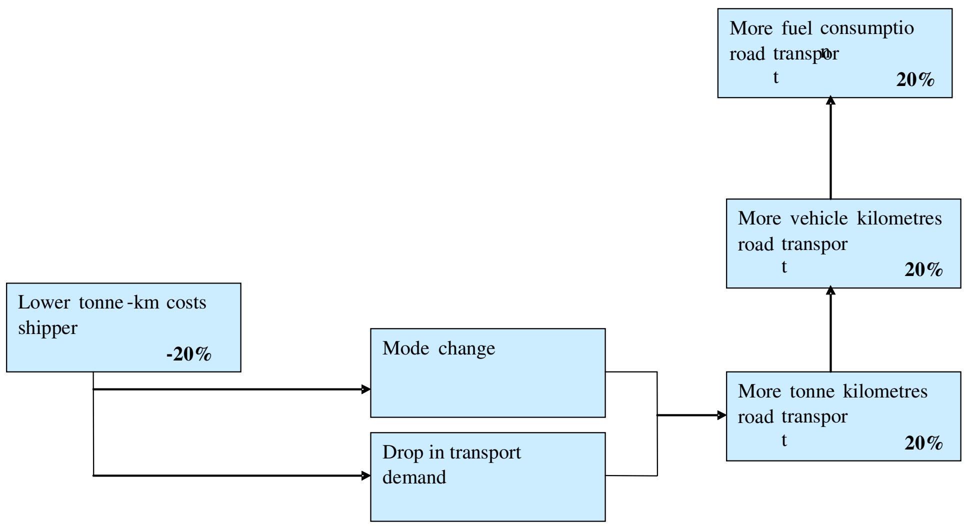


5.4 Decreased tonne-kilometre costs

With a current price of 7 €ct/tonne-km a decrease with 20% (due to lower loading costs) will be equal to 1.4 €ct/tonne-km. The decreased tonne-km costs results in 20% more tonne-kms (-1 x -20%). This will be the result of an increase in transport demand (ca. 12%) and an modal shift from rail and inland shipping to road transport (ca. 8%). Since the load factor of the trucks do not change, also the number of vehicle kilometres (and consequently total fuel demand and CO_2-emissions) increase by 20%.

In Figure 9 an overview of the effects of a 20% decrease of the tonne-kilometre costs due to lower loading costs is presented.

Figure 9 Overview of the effects of a 20% decrease of the tonne-kilometre costs



CHAPTER 6 Conclusions and recommendations

Elasticities are a means to summarise and compare the outcomes of various studies in a reasonable way (because they are dimensionless). Nevertheless , different definitions of the variables used and response mechanisms included can lead to different elasticities. For a proper impact analysis of proposed policy measures (e.g. as part of a cost-benefit analysis of these measures), we recommend to use a transport model, estimated on proper data for the study area (e.g. the EU), instead of the use of elasticities. Proper models can accommodate the different reactions of many different segments (including feedback effects) and can use other functional forms than the constant elasticity formulation. Elasticities should only be used in the absence of appropriate transport models, and to get a first impression ('quick-scan') of the likely effects (which can then be analysed in more detail using detailed and more time-consuming transport models later on). Importantly also, the elasticities chosen should be appropriate for the situation studied.

On the basis of the international literature, road transport price elasticities of tonne-kilometres, vehicle kilometres and fuel demand have been investigated. The literature provides a wide range of elasticity values for these. By analysing differences in the definition of the independent and dependent variables and the response mechanisms included, and differences between countries, (e.g. large differences in the competitiveness of rail transport or inland waterways transport between countries), distance classes and commodity types, a considerable part of the variation can be explained However, the remaining variation in elasticities in some of the categories (e.g. tkm price on tkm for mode choice responses) remains substantial. Here differences in type of data used, modelling methodologies and supporting assumptions may be at stake.

The elasticities presented in this report focus on the effect on long distance road freight. In Europe this will often mean international transport, but for the larger countries long distance transport (and its elasticities) can also be relevant within domestic transport. The road transport price elasticities should however not be applied to short distance trips, such as urban freight transport, where road transport price elasticities will be considerably lower due to the absence of viable alternatives for road transport..

The main conclusions from the literature review on own-price elasticities are summarized in Table 14. Notice that especially the values presented with regard to fuel price change are characterized by rather high uncertainties due to the limited number of studies that reported estimates for these elasticities (to a lesser extent the same notification holds for vehicle kilometre price elasticities).

In this study we investigated the existing knowledge on the price sensitivity, or price elasticity, of road freight transport, using and interpreting results from scientific literature and evaluation studies of existing pricing schemes. We focussed on three types of price changes:

- Changes in fuel prices, which may directly influence total fuel use, the total amount of vehicle kilometres and the total amount of tonne kilometres.
- Changes in vehicle kilometre prices, which directly affect the number of vehicle kilometres and tonne kilometres. Due to the decline in vehicle kilometres also the amount of fuel used is indirectly affected.
- Changes in tonne kilometre prices, which directly influence the number of tonne kilometres. Indirectly also the number of vehicle kilometres and total fuel use will be influenced by this kind of price change.

On the basis of the international literature, road transport price elasticities of tonne-kilometres, vehicle kilometres and fuel demand have been investigated. The literature provides a wide range of elasticity values for these. By analysing differences in the definition of the independent and dependent variables and the response mechanisms included, and differences between countries, (e.g. large differences in the competitiveness of rail transport or inland waterways transport between countries), distance classes and commodity types, a considerable part of the variation can be explained However, the remaining variation in elasticities in some of the categories (e.g. tkm price on tkm for mode choice responses) remains substantial. Here differences in type of data used, modelling methodologies and supporting assumptions may be at stake.

A consistent set of elasticities

We carried out an exercise to derive our best-guess elasticities from the elasticity ranges presented in this report and ensuring that each is mutually consistent. The table below presents the outcomes of this exercise.

Table 14: Consistent set of best-guess values of road freight transport price elasticities

Price change	Impact on		
	Fuel use	Vehicle kilometres	Tonne kilometres
Fuel price	-0.3	-0.2	-0.1
Vehicle kilometre price		-0.9	-0.6
Tonne kilometre price			-1.0

- The fuel price elasticity with regard to total fuel demand includes three behavioural responses: changes in fuel efficiency (-0.1), changes in transport efficiency (-0.1) and changes in road freight transport demand (-0.1).
- The vehicle price elasticities also consist of three effects: changes in mode (-0.3), changes in transport demand (-0.3) and changes in transport efficiency (-0.3).
- Finally, for the tonne kilometre price elasticity two effects can be distinguished: change in mode (-0.4) and change in transport demand (-0.6).

The following response mechanisms can be distinguished for the effect of a change in the price of road transport on road transport demand:

Changes in fuel efficiency

1. Using more fuel efficient vehicles
2. Improving fuel efficient driving

Changes in transport efficiency

3. Improving the load factor (the amount of goods measured in tonnes, divided by vehicle capacity) by:
    a. Optimizing the allocation of vehicles to shipments
    b. Consolidating shipments originating from the same company
    c. Consolidating shipments originating from several companies
    d. Changing the number and location of depots, including consolidation and distribution centres
    e. Getting more return loads to reduce empty driving.
4. Changing route and time of day
5. Increasing the shipment size

Changes in transport volumes

6. Changing mode: substitution to and from rail, inland waterways, sea and air transport
7. Changing production technology (affecting the weight of the goods, e.g. trends towards lighter products).
8. Reducing kilometres per tonne:
    a. Changing the choice of supplier or the geographical market size of the supplier
    b. Changing production volumes per location
9. Reducting demand for the product.

Finally, we also assessed the effects of existing road pricing schemes in Germany, Austria and the Czech Republic, as well as the effects of the introduction of a higher weight limit for trucks in the UK. There is evidence that distances driven in road freight transport are influenced by the existing road pricing schemes; for example, after the introduction of the Maut in Germany and Austria, there has been a decrease in the average distance travelled per tonne of goods. However, due to a lack of detailed evaluation studies it is impossible to draw firm (quantitative) conclusions with regard to the impact of these schemes on transport volumes.

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APPENDICES

Appendix A: Overview of studies

In this appendix we present an overview of all studies gathered for this study (see Table 15). As was mentioned in section 3.2 not all of these studies are reviewed. In general there are four reasons for studies to be deleted from the sample to be reviewed:

- The study doesn't provide estimates of road freight transport price elastiticities;
- It involves an overview study of other (primary) studies on the field of road freight price elasticities;
- Other reasons: study is too old, results are already presented in another paper, etc.
- The study is not available anymore.

Further bibliographic data of the studies not reviewed can be found at the end of this appendix.

Table 15 Overview of studies

	Reviewed	Not reviewed, because:			
		No elasticity estimates	overview study	other	not available
Abdelwahab, W. M. and M. A. Sargious (1992)		x			
Abdelwahab, W. (1998)	x				
Arunotayanun, K. and J. Polak (2007a)					x
Arunotayanun, K. and J. Polak (2007b)					x
Baum, H. et al., (1988)	x				
Beuthe, M. et al. (2001)	x				
Beuthe, M. (2002)				x	
Bjørner, T.B. (1997)	x				
Bjørner, T.B. (1999)	x				
Blauwens, G. and E. van de Voorde (1988)		x			
Blauwens, G., et al. (2001)					x
Ecorys (2005)	x				

Brons, M.R.E. (2006)		x			
Catalani, M. (2001)					x
Chiang, Y., Roberts, P. and Ben-Avika, M. (1981),	x				
Commission for Integrated Transport (2000)	x				
Cranfield School of Management, Cranfield University (1995)					x
Direction Générale des Infrastrucure des Transport et de la Mer, SAGS/Mission Tarification (2009)	x				
Fehmarn Belt Traffic Consortium (1999)					x
Fosgerau, M. (1996)	x				
Friedlaender, A. and R. Spady (1980)	x				
Friedlaender, A.F., Spady, R.H. (1981)	x				
García-Mendéndz, L., et al. (2004)	x				
Golias, J. and G. Yannis (1998)		x			
Goodwin, P.B. (1992)		x			
Goodwin, P., J. Dargay and M. Hanly (2004)		x			
Graham, D.J. and S. Glaister (2002)		x			
Graham, D.J. and S. Glaister (2004),			x		
Fiorello, D., Martino, A., Schade, W., Schade, B., Wiesenthal, T. (2008)	x				
Fowkes, A.S., C.A. Nash and G. Tweddle (1991)		x			
Hague Consulting Group (1992b)		x			
Hanly, M., J. Dargay and P. Goodwin (2002)		x			
Hemery, C., Rizet, C. (2007)	x				
Holguín-Veras, J. (2002)	x				
Holguín-Veras, J., et al. (2006a)		x			
Holguín-Veras, J., et al. (2006b)	x				
Holguín-Veras, J., et al. (2006c)	x				
IEA (1994)	x				
Inaba, F. S. and N. E. Wallace (1989)	x				
Jiang, F., Johnson, P. and Calzada, C. (1999)	x				
Jong, G.C. de and H.F. Gunn (2001)		x			
Jong,G.C. de, et al. (2002)	x				
Jong, G.C. de (2003)	x				

Jong, G.C. de, H.F. Gunn and W. Walker (2004)		x			
Jong, G.C. de, H.F. Gunn and M.E. Ben-Akiva (2004)	x				
Jong, G.C. de (2007)		x			
Jourquin, B., et al. (1999)				x	
Jovicic G. (1998)	x				
Kim, B. (1987)					x
Kim, M. (1984),					x
Lewis, K. and Widup, D. (1982)				x	
Liedtke, G. (2005)		x			
Marzano, V. and A. Papola (2004)	x				
Maurer, H. H. (2008)	x				
McFadden, D.L., C. Winston and A. Boersch-Supan (1985)	x				
McKinnon, A. (1998)	x				
Michaelis, L. (1996)				x	
Nam, K. C. (1997)	x				
NEI (1991)					x
NEI en CE Delft (1999)	x				
NVI (Nederlands Vervoerswetenschappelijk Instituut) (1986)					x
Oum, T.H., (1989)	x				
Oum, T.H., W.G. Waters II and J.S. Yong (1992)			x		
Oum, T.H. (1990)			x		
Puckett, S.M. and D.A. Hensher (2006)		x			
Rutten, B.J.C.M. (1995)		x			
Small, K. and Winston, C. (1999)	x				
Wilson, W., Wilson, W. and Koo, W. (1988)				x	
Windisch, E. (2009)	x				
Winston, C. (1981)	x				
Yin, Y, I. Williams and M. Shahkarami (2005)	x				
Zlatoper, T.J. and Z. Austrian (1989)		x			

Studies not be reviewed

Abdelwahab, W.M., Sargious, M.A. (1992) Modelling the Demand for Freight Transport, *Journal of Transport Economics and Policy* 26 (1), 49-70

Arunotayanun, K., Polak, J. (2007a), *Taste Heterogeneity in Freight Shippers' Mode Choice Behaviour*, Annual Meeting of the Transportation Research Board, Washington, DC, Transportation Research Board.

Arunotayanun, K., Polak, J. (2007b), U*nobserved Heterogeneity in Freight Shippers' Mode Choice Behaviour*, World Conference on Transport Research, Berkeley, CA.

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Brzobohatý, T., Analysis of impact of toll on road freight traffic intensities in the Czech Republic**,** The Czech Transport Federation 2009

Catalani, M. (2001), *A Model of Shipper Behaviour Choice in a Domestic Freight Transport System*, 9th World Conference on Transport Research, Seoul, Korea.

Cranfield School of Management, Cranfield University (1995), Modelling the links between economic activity and vehicle kilometers, Cranfield Centre for Logistics and Transportation, Black, I., *CCLT research report No.2*, March 1995.

Deußner, R. Novak, S. (2005) *Aktuelle Verkehrsentwicklung im grenzüberschreitenden Güterverkehr; Analyse Verkehrsmarkt 2005* Verkehr und Infrastruktur Nr32

Fehmarn Belt Traffic Consortium (1999), *Fehmarn Belt Traffic Demand Study. Final Report for the Danish and German Ministries of Transport*, FTC, Copenhagen.

Golias, J., Yannis, G. (1998), Determinants of combined transport's market share, *Transport Logistics* 1(4): 251-264.

Goodwin, P.B. (1992), A review of new demand elasticities with special reference to short and long run effects of price changes, *Journal of Transport Economics and Policy*, 26, 15-163.

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Graham, D.J., Glaister, S. (2002), *Review of income and price elasticities of demand for road traffic*, Centre for Transportation Studies, Imperial College, London.

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Fowkes, A.S., Nash, C.A., Tweddle, G. (1991), Investigating the market for intermodal freight technologies, *Transportation Research A*, 25A-4, 161-172.

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Hanly, M., Dargay, J., Goodwin, P. (2002), *Review of income and price elasticities in the demand for road traffi*c, ESRC-TSU publication 2002/13, ESRC-TSU, University College London.

Holguín-Veras, J., Silas, M., Polimeni, J., Cruz, B. (2006a), An Investigation on the Effectiveness of Joint Receiver-Carrier Policies to Increase Truck Traffic in the Off-Peak Hours. Part I: The Behavior of Receivers, *Networks and Spatial Economics*.

Jong, G.C. de, Gunn, H.F. (2001), Recent evidence on car cost and time elasticities of travel demand in Europe, *Journal of Transport Economics and Policy*, 35-2, 137-160, May 2001

Jong, G.C. de, Gunn, H.F., Walker, W. (2004), National and international freight transport models: overview and ideas for further development, *Transport Reviews*, 24-1, pp. 103-124, 2004.

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Kim, B. (1987), The optimal demand for freight transportation in strategic logistics and intermodal substitution in the United States. PhD dissertation, Department of Economics, Northwestern University, Evanston, IL.

Kim, M. (1984), A disaggregate demand model for freight transportation: a theory of the firm approach.PhD dissertation, Department of Civil Engineering, Stanford University, CA.

Lewis, K., Widup, D. (1982), Deregulation and rail truck competition: evidence from a translog transport demand model, *Journal of Transport Economics and Policy*, 16, pp. 139–149.

Liedtke, G. (2005), *An actor-based approach to commodity transport modeling*, PhD thesis, University of Karlsruhe.

Michaelis, L. (1996), Sustainable transport policies: CO_2 emissions from road vehicles, Annex 1 Expert Group on the UN FCCC, *'Policies and measures for common action', Working paper 1*, OECD, Paris, July 1996.

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Puckett, S.M. and D.A. Hensher (2006), *The role of attribute processing strategies in estimating the preferences of road freight stakeholders under variable road user charges*, UGM Paper #10, Institute of Transport and Logistics, The University of Sydney.

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Zlatoper, T.J. and Z. Austrian (1989), Freight transportation demand: A survey of recent econometric studies, *Transportation*, 16, 27-46.

Appendix B: Literature review

<table>
<tr><td colspan="5">Abdelwahab, W.M. (1998), Elasticities of mode choice probabilities and market elasticities of demand: evidence from a simultaneous mode choice/shipment-size freight transport model, Transportation Research E 34, p. 257-266</td></tr>
<tr><td colspan="5">Description of the study</td></tr>
<tr><td>Dependent variable</td><td colspan="4">Market demand for both rail and road freight transport (probably measured in tonnes).</td></tr>
<tr><td>Independent variable</td><td colspan="4">Rail and road freight rates (probably per tonne)</td></tr>
<tr><td>Research method</td><td colspan="4">A system of simultaneous equations was estimated to simulate the joint choice of mode and shipment size in freight transport. Equation 1 (mode choice model) was specified as a binary probit model, and equations 2 and 3 (shipment size model) were specified as linear regression equations.

Disaggregate elasticities of mode choice probabilities were derived from this set of demand equations. Next, aggregate elasticities of market demand for rail and road transport are derived by taking the weighted average from the disaggregate elasticities at the individual shipper level.</td></tr>
<tr><td colspan="5">Response mechanisms included</td></tr>
<tr><td>Fuel efficiency</td><td>Change fuel efficiency vehicle</td><td>No</td><td>Change fuel efficiency driving</td><td>No</td></tr>
<tr><td rowspan="3">Transport efficiency</td><td>Optimizing allocation of vehicles to shipments</td><td>No</td><td>Change in consolidated shipments</td><td>No</td></tr>
<tr><td>Change in number and locations of depots</td><td>No</td><td>Change empty driving</td><td>No</td></tr>
<tr><td>Change in shipment size</td><td>yes</td><td>Change in trip length (route planning)</td><td>no</td></tr>
<tr><td rowspan="2">Changes in transport volumes</td><td>Change in mode</td><td>yes</td><td>Change in production volumes per location</td><td>no</td></tr>
<tr><td>Change in production technology</td><td>no</td><td>Change in suppliers/customers</td><td>no</td></tr>
</table>

			(change in OD patterns)	
	Change in commodity demand	yes		
Additional remarks	Since the shipper is the decisionmaker, most response mechanisms with regard to transport efficiency are not included in the elasticities estimates. The only exception is change in shipment size, which is defined as an endogenous variable in the road and rail demand functions. The authors also mention that total market demand is not fixed, which means that changes in commodity demand are included in the elasticities estimates. The same holds for change in transport modes. It becomes not clear from the article whether changes in production volumes per location, changes in production technology and changes in OD patterns are included in the elasticities estimates. The description of the empirical data used to estimate the elasticities is too limited to find out.			
Description of empirical data				
Type of data	To estimate elasticities data from the Commodity Transportation Survey obtained form the US Bureau of Census are used. Disaggregated data was provided at individual commodity level.			
Geographical scope + distance class	Elasticities for intercity freight transport are estimated. Five different geographical regions in de USA are distinguished: official, southern, western, southwestern and mountain-Pacific territory.			
Type of goods	Elasticities for 7 groups of commodities are estimated: - Food and kindred products, tobacco products - Textile products - Chemicals and allied products, petroleum and coal - Rubber and miscellaneous plastic products, leather and leather products - Primary and fabricated metal products - Electrical machinery, equipment and supplies, transportation equipment - Stone, clay, glass and concrete products - Lumber and wood products, furniture, fixtures, pulp, paper and allied products			

Own price elasticities

The own-price elasticities of road freight transport demand are presented in Table 16a.

Table 16a Own-price elasticities of road freight transport demand

	Official	Southern	Western	Southwestern	Mountain-Pacific
Food	-1,20	-1,63	-1,34	-2,19	-1,13
Textile	-1,40	n/a[a]	n/a	n/a	n/a
Chemicals, Petroleum, coal	-0,93	-1,61	-1,71	-1,48	-1,01
Rubber, plastic, leather	-1,14	n/a	n/a	n/a	n/a
Metal products	-0,80	-1,33	-1,12	-2,18	-1,62
Electrical and transportation equipment	-1,19	-2,53	-2,05	n/a	n/a
Stone, clay, glass, concrete	-0,75	n/a	n/a	n/a	n/a
Wood and paper products	-1,06	-1,62	-1,28	n/a	-1,80

[a] n/a, sample size too small

Cross elasticities

Cross-elasticities of rail freight transport demand with regard to changes in road freight transport prices are presented in Table 16b.

Table 16b Cross-price elasticities of rail freight transport demand with regard to changes in road freight transport prices

	Official	Southern	Western	Southwestern	Mountain-Pacific
Food	1,26	1,73	1,42	2,33	1,20
Textile	1,47	n/a[a]	n/a	n/a	n/a
Chemicals, Petroleum, coal	1,08	1,57	2,01	1,41	1,43
Rubber, plastic, leather	1,28	n/a	n/a	n/a	n/a
Metal products	0,93	1,36	1,40	2,53	1,96
Electrical and transportation equipment	1,20	2,20	2,03	n/a	n/a
Stone, clay, glass, concrete	0,98	n/a	n/a	n/a	n/a
Wood and paper products	1,11	1,71	1,43	n/a	2,14

[a] n/a, sample size too small

Additional remarks

Baum, H. (1988), Preiselastizitäten der Nachfrage im Güterverkehr, Empirische Untersuchung über das zu erwartende Verhalten der Verlader, in: Massmann (1993), Preiselastizitäten für den Güterverkehr und ihre Anwendung in Verkehrsprognosen.

Description of the study

Dependent	The demand of transport, probably measured in tonnes kilometres.

variable	Road, rail and inland shipping freight transport are considered.			
Independent variable	Change (20% reduction) in market prices for shippers (probably tonnes kilometres prices) due to deregulation of the freight transport market are considered.			
Research method	Based on data from questionnaire surveys cross elasticities are estimated. The study considers arc elasticities.			
Response mechanisms included				
Fuel efficiency	Change fuel efficiency vehicle	No	Change fuel efficiency driving	No
Transport efficiency	Optimizing allocation of vehicles to shipments	No	Change in consolidated shipments	No
	Change in number and locations of depots	No	Change empty driving	No
	Change in shipment size	No	Change in trip length (route planning)	No
Changes in transport volumes	Change in mode	Yes	Change in production volumes per location	No
	Change in production technology	No	Change in suppliers/customers (change in OD patterns)	No
	Change in commodity demand	no		
Additional remarks	The only response mechanism considered is substitution to other transport modes.			
Description of empirical data				
Type of data	The data is gathered from 1500 firms by questionnaire surveys. Firms were asked whether they would consider switching to another mode when the rate of the mode the firm is currently using increases by 20%.			
Geographical scope + distance class	The geographical scope of the study is Germany.			
Type of goods	Nine groups of commodities are considered: - agricultural goods - Food - Coal - Petroleum and minerals - Metals - Surface minerals - Fertilizers - Chemical products - Semi manufactured products			
Estimates of elasticities				

Own price elasticities	
Cross elasticities	The cross elasticities of tonnes kilometres rail transport due to a change in road transport prices are presented in Table 17.

Table 17 Cross elasticities of tonnes kilometers rail transport due to a change in road transport prices

Type of good	Cross elasticity
Agricultural products	0,52
Food	0,72
Coal	0,25
Petroleum and minerals	0,47
Metals	1,73
Surface minerals	0,16
Fertilizers	0,48
Chemical products	0,18
Semi manufactured products.	0,73

Additional remarks

Beuthe, M., Jourquin, B., Geerts, J.F., Koul à Ndjang'Ha, C. (2001), Transportation demand elasticities, a geographic multimodal transportation network analysis, *Transportation Research E* 37, 4, p. 253-266.

Description of the study

Dependent variable	Two dependent variables are distinguished - tonnage - tonnes- kilometres For both variables own and cross elasticities are estimated with respect to road, rail and waterway transports.
Independent variable	Two types of price changes are considered: - changes in total transportation costs (vehicle operations, handling costs, commodities inventory costs) by 2%, 5% and 10% of the reference level for each mode separately. - Reductions in travel costs by 5% for each mode separately. In both cases, not only monetary costs are included, but also the value of

	time for the shippers (generalised transport costs).			
Research method	Elasticities are estimated by using a detailed multimodal geographic information system (GIS) network model of freight transport in Belgium. Given the matrices of origins and destinations for ten different categories of goods, it minimises the generalised cost of the corresponding transportation tasks by an optimal assignment of the flows between modes, type of vehicles, or their combination, and routes. Direct and cross arc-elasticities are derived by simulations with different cost parameters. Notice that generalised cost elasticities rather than price elasticities are estimated.			
Response mechanisms included				
Fuel efficiency	Change fuel efficiency vehicle	No	Change fuel efficiency driving	No
Transport efficiency	Optimizing allocation of vehicles to shipments	No	Change in consolidated shipments	No
	Change in number and locations of depots	No	Change empty driving	No
	Change in shipment size	No	Change in trip length (route planning)	No
Changes in transport volumes	Change in mode	Yes	Change in production volumes per location	No
	Change in production technology	No	Change in suppliers/customers (change in OD patterns)	No
	Change in commodity demand	No		
Additional remarks	The only response mechanism taken into account in this study is the substitution between modes. The model used to estimate the elasticities assume fixed O-D matrices and constant transport volumes. Additionally, it is assumed that transportation costs are proportional to total transport volumes, which implies that efficiency effects are not included.			
Description of empirical data				
Type of data	Since elasticities are estimated by using a model, they are not directly based on empirical observations. However, the model is calibrated on empirical data, which implies that the elasticities are indirectly based on this empirical observations.			
Geographical scope + distance class	Only transport in Belgium is analysed. Elasticities are estimated for both short (< 300 km) and long distances (> 300 km).			

Type of goods

Both aggregate elasticities and elasticities per group of commodities are presented. The following 10 groups of commodities are distinguished:

- agricultural products and animals
- food
- solid fuel
- Petroleum products
- Iron ore and scraps
- Metallurgical products
- Minerals and building materials
- Fertilisers
- Chemical products
- Diverse products

Estimates of elasticities

Own price elasticities

The short-run price elasticities of road transport (tonnes and tonnes-km) are presented in Table 18 and Table 19.

Table 18 Aggregate elasticities when costs are reduced by 5%

	Total cost reduction	Travel cost reduction	Total cost reduction	
			Short distance	Long distance
Tonnes	-0,59	-0,48	-0,58	-0,63
Tonnes-km	-1,21	-1,10	-1,06	-1,31

Table 19 Tonne km elasticities per group of commodities when costs are reduced by 5%

	Total cost reduction	Travel cost reduction	Total cost reduction	
			Short distance	Long distance
Agricultural products and animals	-0,96	-0,95	-0,52	-1,11
Food	-0,69	-0,65	-0,14	-1,11
Solid fuel	-0,52	-0,39	-0,91	0,00
Petroleum products	-4,50	-3,98	-7,92	-0,10
Iron ore and scraps	-1,67	-1,47	-2,06	0,00
Metallurgical products	-2,09	-1,98	-2,38	-1,78
Minerals and building materials	-0,98	-0,77	-0,91	-1,14
Fertilisers	-0,72	-0,70	-0,89	-0,50
Chemical products	-1,10	-0,77	-0,21	-1,54
Diverse products	-1,18	-1,18	-0,24	-1,54

Some observations:

- as expected, elasticities with respect to total cost are larger (in absolute value) than those with respect to travel cost only
- aggregate elasticities are bigger for long distance transports than short distance transports. This is because competition by other means of transport is more fierce for long distance transport.
- Commodity elasticities exhibit more dispersion than aggregate

	elasticities, which is the result of differences in competitiveness on the transport market of various commodities.
Cross elasticities	Beute et al. (2001) present a full set of cross elasticities for rail, road and waterway transports. Below, we present the cross elasticities of rail transport with respect to reductions in road costs by 5%.

Table 20 Aggregate cross-elasticities of train tonnes and tonnes-kilometres when road costs are reduced by 5%

	Total cost reduction	Travel cost reduction	Total cost reduction	
			Short distance	Long distance
Tonnes	2,19	1,95	2,26	2,13
Tonnes-km	2,03	1,94	2,99	1,92

Table 21 Cross-elasticies of train tonnes-kilometres per group of commodities with respect to reductions in road costs by 5%

	Total cost reduction	Travel cost reduction	Total cost reduction	
			Short distance	Long distance
Agricultural products and animals	13,79	13,72	12,87	13,86
Food	3,51	3,42	9,78	3,37
Solid fuel	0,36	0,27	0,59	0,00
Petroleum products	1,02	0,72	2,99	0,16
Iron ore and scraps	0,54	0,47	0,68	0,00
Metallurgical products	1,71	1,61	10,87	0,90
Minerals and building materials	3,66	2,63	8,08	2,96
Fertilisers	0,43	0,43	0,01	0,46
Chemical prodoucts	2,22	2,18	0,55	2,23
Diverse products	1,76	1,75	0,52	1,76

Additional remarks

Bjørner, T.B., Jensen, T.C. (1997), Freight by road or rail?, *Nationaløkonomisk Tidsskrift* 135

Description of the study

Dependent variable	Demand for freight transport (measured in tonnes kilometres), both for road and rail.
Independent variable	Rail and road freight transport rates (market prices) measured in tonnes kilometres).

Research method	Two demand equations are estimated: - First total transport demand is estimated by using a log linear model. Among others, output and relative prices are included in this function - Next a translog equitation is used to determine by which transport mode the shipments will be performed. From the first demand equitation an elasticity of total road freight demand can be derived. An elasticity with regard to the substitution to rail transport can be derived from the second equitation.			
Response mechanisms included				
Fuel efficiency	Change fuel efficiency vehicle	No	Change fuel efficiency driving	No
Transport efficiency	Optimizing allocation of vehicles to shipments	No	Change in consolidated shipments	No
	Change in number and locations of depots	No	Change empty driving	No
	Change in shipment size	No	Change in trip length (route planning)	No
Changes in transport volumes	Change in mode	Yes	Change in production volumes per location	yes
	Change in production technology	yes	Change in suppliers/customers (change in OD patterns)	yes
	Change in commodity demand	No		
Additional remarks	The authors do not explicitly mention which changes in transport volumes are included in their models. However, it seems likely that change in production volumes per location, change in production technology and change in OD patterns are considered. Change in commodity demand is not considered as a response mechanism, since this variable is included as exogenous variable in the total freight demand function.			
Description of empirical data				
Type of data	The elasticities were estimated from aggregate time series, which are extracted from input-output tables for Denmark.			
Geographical scope + distance class	The geographical scope of the study is Denmark. Various lengths of hauls are considered.			
Type of goods	Five different types of industries are considered: - Manufacturing - Construction - Trade (wholesale and retail) - Other services (domestic services, restaurants and hotels) - Public sector			

	In this factsheet we will not take the elasticities estimates for the public sector into account, since the data used for this sector also considers public transport (bus and taxi).
Estimates of elasticities	
Own price elasticities	Own price elasticities of road freight transport with respect to changes in transport demand and mode choice are presented in Table 22. In addition, a total elasticity of the demand for road freight transport is presented. Table 22 Own-price elasticities of road freight transport (see table below) [a] Not significant at 5%
Cross elasticities	
Additional remarks	

Table 22 Own-price elasticities of road freight transport

	Transport demand	Mode choice	Total elasticity
Manufacturing	-0,4	-0,2	-0,6
Construction	-0,5[a]	-	-0,5
Trade	-1,0	-	-1,0
Other services	-1,5[a]	-0,9	-2,4

[a] Not significant at 5%

Bjørner, T.B. (1999), Environmental benefits form better freight transport management: freight traffic in a VAR model, *Transportations Research Part D* 4, p. 45-64	
Description of the study	
Dependent variable	Two dependent variables: - Freight transport by trucks (measures in tonnes km) - Freight traffic by trucks (measured in driven km).
Independent variable	The independent variable in this study is price per kilometre. Theoretically it would be preferred to use transport price as the independent variable to estimate freight transport. However, it is assumed that the price per kilometre and the price of transport develop in the same way, so that the same measure can be used for both independent variables.
Research	The elasticities are estimated from empirical observations by using a

method	Vector Auto Regressive (VAR) model.			
Response mechanisms included				
Fuel efficiency	Change fuel efficiency vehicle	no	Change fuel efficiency driving	no
Transport efficiency	Optimizing allocation of vehicles to shipments	yes	Change in consolidated shipments	yes
	Change in number and locations of depots	yes	Change empty driving	yes
	Change in shipment size	yes	Change in trip length (route planning)	yes
Changes in transport volumes	Change in mode	yes	Change in production volumes per location	yes
	Change in production technology	yes	Change in suppliers/customers (change in OD patterns)	yes
	Change in commodity demand	yes		
Additional remarks	A production function of transport services is assumed, which depend on driven kilometres and other inputs like management resources and capital. This implies that shippers may substitute between driven kilometres and other inputs, for example by increasing management and capital resources devoted to transport planning. So, all response mechanisms with respect to transport efficiency are included in this study. Also all response mechanism with regard to transport volumes are included. A cross-elasticity from Bjørner and Jensen (1997) is used to make a distinction between the substitution effect and the transport demand effect.			
Description of empirical data				
Type of data	The data used are aggregate quarterly time series from 1980:1 to 1993:4 (source: Statistics Denmark). Transport variables are based on questionnaires concerning the transport activity in one truck-week to users of large trucks (> 6 tonnes without load). Transport prices are calculated form suggested prices originally calculated by the Danish Road Haulage Association.			
Geographical scope + distance class	The empirical data only includes transport activities taking place in Denmark by Danish registered truck.			
Type of goods	No distinction to different types of goods.			
Estimates of elasticities				
Own price elasticities	The following long-run elasticities with respect to the price per kilometre are presented: - Freight traffic (vehicle km): -0,81 - Freight transport (tonnes km): -0,47			

	The elasticity of freight transport consists of: - substitution by another mode: -0,20 - drop in transport demand: - 0,27 The substitution elasticity is coming from Bjørner and Jensen (1997).
Cross elasticities	No cross-elasticities are estimated in this study.
Additional remarks	

Chiang, Y., Roberts, P. and Ben-Avika, M. (1981), Development of a Policy Sensitive Model for Forecasting Freight Demand: Final Report. Report No. DOT-P-30–81–04 (Washington, DC: US Department of Transportation).				
Description of the study				
Dependent variable	A short-run disaggregated model of mode, shipment size and origin choice at the level of the individual firm was developed. The model provides the output in tonnes.			
Independent variable	Changes are made in the transport charges (which are given per shipment and depend on the shipmen size in tonnes and on the transport distance) for each of the groups considered and for each mode of transportation. The own elasticities are calculated for Rail, truck, private truck and air with respect to shipment size for specific groups (commodity, geographical area and size of the firm). No cross elasticities have been computed.			
Research method	A short-run disaggregated (logistic choice) model of mode, shipment size and origin choice at the level of individual firm was developed. The annual demand for an input is treated as fixed and only transportation-related choices (origin of the supplier, mode of transport and shipment size) can be open to choice. Therefore, substitution is allowed only within the transportation and logistics cost elements.			
Response mechanisms included				
Fuel efficiency	Change fuel efficiency vehicle	No	Change fuel efficiency driving	No
Transport efficiency	Optimizing allocation of vehicles to shipments	No	Change in consolidated shipments	No
	Change in number and	No	Change empty driving	No

	locations of depots			
	Change in shipment size	Yes	Change in trip length (route planning)	No
Changes in transport volumes	Change in mode	Yes[10]	Change in production volumes per location	No
	Change in production technology	No	Change in suppliers/customers (change in OD patterns)	yes
	Change in commodity demand	No		
Additional remarks				
Description of empirical data				
Type of data	The model has been estimated on the basis of database (early 1970s) from the Census of Transportation, such as the Commodity Transportation Survey, the National Travel Survey and the Truck Inventory and Use Survey.			
Geographical scope + distance class	USA			
Type of goods	Different market segments are reported (see 'own price elasticities' section)			
Estimates of elasticities				
Own price elasticities	Elasticities (not clear if they are point or arc elasticities) have been calculated for a transport charges (transport rate and special charges) change for the following cases (commodity, geographical area and annual size, respectively): Case 1: Agricultural Fertilizer, Houston to Chicago, Use = 5,000 tons/yr Case 2: Rubber Hoses, New York to Pittsburgh, Use = 500 tons/yr Case 3: Human Drugs, Los Angeles to Boston, Use = 1 ton/yr Case 4: Textiles, Boston to Hartford, Use = 100 tons/yr			

Table 23 . Elasticities for Common Carrier Truck

	Case 1	Case 2	Case 3	***Case 4***
Min. Shipment	-9.858	-0.858	-0.002	-0.130
Less than a	-1.741	-0.148	-0.002	-0.016

[10] The model can produce mode choice elasticities but the elasticities presented seem to be largely driven by changes between shipment size.

Vehicle				
Full Vehicle	-1.143	-1.050	-0.001	-0.006
Carload (as in railcar)	-0.862	-0.046	-	-0.005
Multiple Vehicle	-0.784	-0.042		-0.005

Table 24. Elasticities for Private Truck

	Case 1	Case 2	Case 3	***Case 4***
Min. Shipment	-	-0.844	-0.010	-0.071
Less than a Vehicle	-1.502	-0.175	-0.003	-0.016
Full Vehicle	-0.590	-0.026	-	-0.002
Carload (as in railcar)	-0.574	-0.026	-	-0.002
Multiple Vehicle	-	-	-	-

Cross elasticities	

Additional remarks

Transport costs are the cost incurred during and as the result of transport. The components are: packaging cost, freight charges, including special charges, handling costs, loss and damage during transport, capital carrying cost and loss of value. These components can be function of mode, shipment size, length of the trip, type of commodity.

Jong, G.C. de (2003) Elasticities and policy impacts in freight transport in Europe, paper presented at the European Transport Conference 2003, Strasbourg

Description of the study

Dependent variable	Modes, as mode of a trip, considered are: road, conventional rail, combined (road-rail), inland waterways and sea. Changes on operating costs to number of tonnes transported and tonne-kilometres.

<table>
<tr><td>Independent variable</td><td colspan="4">SCENES and the four national models:
- +10% road transport operating cost elasticities of the number of tonnes transported;
- +10% road transport operating cost elasticities of the number of tonnes-kilometres

EXPEDITE: policy are tested regarding fuel price change (+ 10% and + 25% road transport cost) and road pricing (+ 25% road transport cost).</td></tr>
<tr><td>Research method</td><td colspan="4">National models:
- Swedish, Norwegian and Belgian are called network models as they search for the modes and routes that minimise transport cost on the network;
- Italian model is based on discrete choice theory and explains choices between alternatives such as modes on the basis of utility maximization.

Long run arc elasticities are calculated as mode choice responses to the changes. No assumption about effects of changes in fuel efficiency or load factors on elasticities are made, here are constant.

EXPEDITE is meta-model for freight transport is the results of merging national and international models. This model can look at the type of commodity and length of haul of the road freight consignments.

This model gives only mode choice changes. With this model different policies have been tested with different % change in the stimulus variables, including increases and decreases.</td></tr>
<tr><td colspan="5">Response mechanisms included</td></tr>
<tr><td>Fuel efficiency</td><td>Change fuel efficiency vehicle</td><td>No</td><td>Change fuel efficiency driving</td><td>No</td></tr>
<tr><td rowspan="3">Transport efficiency</td><td>Optimizing allocation of vehicles to shipments</td><td>No</td><td>Change in consolidated shipments</td><td>No</td></tr>
<tr><td>Change in number and locations of depots</td><td>No</td><td>Change empty driving</td><td>No</td></tr>
<tr><td>Change in shipment size</td><td>No</td><td>Change in trip length (route planning)</td><td>No</td></tr>
<tr><td rowspan="3">Changes in transport volumes</td><td>Change in mode</td><td>Yes</td><td>Change in production volumes per location</td><td>No</td></tr>
<tr><td>Change in production technology</td><td>No</td><td>Change in suppliers/customers (change in OD patterns)</td><td>No</td></tr>
<tr><td>Change in commodity demand</td><td>No</td><td></td><td></td></tr>
<tr><td>Additional remarks</td><td colspan="4"></td></tr>
<tr><td colspan="5">Description of empirical data</td></tr>
</table>

<table>
<tr><td>Type of data</td><td></td></tr>
<tr><td>Geographical scope + distance class</td><td>Europe.

Different distance classes are considered, but the elasticities are calculated as average distance or divided into:
- 500 to 1000km;
- More than 1000km.</td></tr>
<tr><td>Type of goods</td><td></td></tr>
<tr><td colspan="2">Estimates of elasticities</td></tr>
<tr><td>Own price elasticities</td><td>

Table 25. Averaged elasticities (+10% Road transport operating costs) over commodity classes and distance classes.

Model	*Tonnes transported*	*Tonnes-kilometers*
Belgium	-0.4	-0.95
Italy	-0.01	n.a.
Norway	n.a.	-1.01
Sweden	n.a.	-0.4
SCENES	-0.13	-0.62

Table 26. Road transport cost direct for bulk and general cargo at different transport distances for the EU

	Distance range			
Mode	*500 to 1,000 km*		*More than 1,000 km*	
	Bulk	*General cargo*	*Bulk*	*General cargo*
Road transport	*-0.5*	*-0.7*	*-1*	*-0.8*

Table 27. Road transport cost direct at all transport distances for the EU

	Bulk	Petroleum (products)	General cargo
Tonnes	-0.05	-0.13	-0.13
Tkm	-0.18	-0.35	-0.39

</td></tr>
</table>

<table>
<tr><td>Cross elasticities</td><td>

Table 28 Road transport cost (+ 10%) cross elasticities for bulk and general cargo at different transport distances for the EU

	Distance range			
Mode	*500 to 1,000 km*		*More than 1,000 km*	
	Bulk	*General cargo*	*Bulk*	*General cargo*
Train	*1.5*	*1.1*	*1.7*	*1.2*
Combined transport	*0*	*1.1*	*0*	*1.2*

</td></tr>
<tr><td colspan="2">Additional remarks</td></tr>
<tr><td colspan="2">

This study summarises the most relevant findings for freight provided in the following two studies:

1) Jong,G.C. de, et al. (2002) EXPEDITE, Main outcomes of the national model runs for freight transport, Deliverable 7, RAND Europe, Leiden.

In this study there are a relevant number of runs, testing different changes in costs (increase and decrease, different commodity type and different distance segmentations) and other variables. The elasticities values (averaged and for different distance) concerning road cost changes are presented here in Table 1, Table 2 and Table 4.

2) Jong, G.C. de, H.F. Gunn and M.E. Ben-Akiva (2004) A meta-model for passenger and freight transport in Europe, **Transport Policy**, 11 (2004), 329-344.

This study focuses more in the policy scenarios, which are summarised here in Table 3.

</td></tr>
</table>

<table>
<tr><td colspan="2">Jong, G.C. de and D. Johnson (2009) Discrete mode and discrete or continuous shipment size choice in Sweden, Paper to be presented at ETC 2009.</td></tr>
<tr><td colspan="2">Description of the study</td></tr>
<tr><td>Dependent variable</td><td>Multinomial Logit and regression analysis are used to model the choice of mode and shipment size simultaneously.

Mode of transportation is here the main mode of a transport chain. The modes taken into account are: lorry, vessel, rail, air.</td></tr>
<tr><td>Independent variable</td><td>Elasticities are calculated by increasing the total cost for the shipment for a mode alternative by 10%.</td></tr>
<tr><td>Research method</td><td>Decision makers of the modelled choices are sending firms or their commissioned shippers.</td></tr>
</table>

	The model comprises a logistics perspective by modelling the shipment size (decisions relating to inventory strategies are endogenous); Arc elasticities are calculated, based on the model, in terms of number of shipments			
Response mechanisms included				
Fuel efficiency	Change fuel efficiency vehicle	No	Change fuel efficiency driving	No
Transport efficiency	Optimizing allocation of vehicles to shipments	No	Change in consolidated shipments	No
	Change in number and locations of depots	No	Change empty driving	No
	Change in shipment size	Yes	Change in trip length (route planning)	No
Changes in transport volumes	Change in mode	Yes	Change in production volumes per location	No
	Change in production technology	No	Change in suppliers/customers (change in OD patterns)	No
	Change in commodity demand	No		
Additional remarks				
Description of empirical data				
Type of data	Disaggregate data. Revealed preference. Data set describing shipments (1 millions entries) on a disaggregate and individual level of the Swedish Commodity Flow Survey 2001.			
Geographical scope + distance class	Sweden			
Type of goods	No separate results presented			
Estimates of elasticities				

Own price elasticities	Road transport costs elasticity of road shipments: -0.03 (mode choice only) Road transport costs elasticity of road shipments by size: -0.5 (mode and shipment size choice)
Cross elasticities	
Additional remarks	

Direction Générale des Infrastructures des Transports et de la Mer (2009) Eco-redevance Poids Lourde, Synthèse économique. Ministère de l'Écologie, de l'Énergie, du Développement durable et de l'Aménagement du territoire. Paris.				
Description of the study				
Dependent variable	vehicle kilometres			
Independent variable	The policy tested here is an eco-tax for road freight vehicles on national roads and some regional/local roads in France that are presently not taxed, implemented as a kilometre charge for road freight transport			
Research method	Carried out runs with existing transport models			
Response mechanisms included				
Fuel efficiency	Change fuel efficiency vehicle	No	Change fuel efficiency driving	No
Transport efficiency	Optimizing allocation of vehicles to shipments	No	Change in consolidated shipments	Yes
	Change in number and location of depots	No	Change empty driving	Yes
	Change in shipment size	No	Change in trip length (route planning)	No
Changes in transport volumes	Change in mode	Ye s	Change in production volumes per location	No
	Change in production technology	No	Change in suppliers/customers (change in OD patterns)	No
	Change in commodity demand	No		
Additional remarks	The mode choice reaction was quantified using a transport model (MODEV) and also the changes in route choice (to Germany and to			

	French roads that are currently tolled)are produced by a transport model. The additional reduction in empty driving and increase in the load factor is not model-based, but is an expert estimate.
Description of empirical data	
Type of data	Transport model using zone-to zone transport flow data and networks.
Geographical scope + distance class	All freight transport in France (incl. domestic, import, export and transit).
Type of goods	All included, but no distinctions reported.
Estimates of elasticities	
Own price elasticities	From the reported outcomes, we calculated that the fuel costs elasticity of road vkm is -.012, 77% of which is due to mode shift (to rail and water transport) and 23% is due to changes in the load factor and a reduction of empty driving.
Cross elasticities	
Additional remarks	

Ecorys (2005), *Effecten gebruiksvergoeding in het goederenvervoer,* 2005	
Description of the study	
Dependent variable	This study presents both elasticies with regard to vehicle kilometres and tonne kilometres. The latter are all coming from other studies and will not be discussed here. Road, rail and shipping freight transport are considered.
Independent variable	Change in price per vehicle kilometre due to the introduction of a kilometre charge for freight transport on the main infrastructural networks (infrastructure governed by national government).
Research	A model is developed to estimate the effects of the introduction of a kilometre charge for freight transport. This model is based on

<table>
<tr><td>method</td><td colspan="4">elasticities, among which also the elasticities with regard to changes in vehicle kilometres due to transport efficiency measures. Three types of transport efficiency measures are increased:
- increased utilisation rates of trucks
- acquire larger vehicles
- shift of road freight traffic from highways to local roads

The elasticities with regard to the first two measures are derived from an elasticity of vehicle kilometres (due to transport efficiency measures) presented by Bjørner (1999). According to Ecorys (expert guess) 50% of this elasticity can be allocated to increased utilisation rates of trucks and 50% to the acquirement of larger vehicles. The elasticity with respect to the shift to local roads was based on an expert guess by Ecorys.</td></tr>
<tr><td colspan="5">Response mechanisms included</td></tr>
<tr><td>Fuel efficiency</td><td>Change fuel efficiency vehicle</td><td>no</td><td>Change fuel efficiency driving</td><td>no</td></tr>
<tr><td rowspan="3">Transport efficiency</td><td>Optimizing allocation of vehicles to shipments</td><td>yes</td><td>Change in consolidated shipments</td><td>yes</td></tr>
<tr><td>Change in number and locations of depots</td><td>yes</td><td>Change empty driving</td><td>yes</td></tr>
<tr><td>Change in shipment size</td><td>no</td><td>Change in trip length (route planning)</td><td>yes</td></tr>
<tr><td rowspan="3">Changes in transport volumes</td><td>Change in mode</td><td>No</td><td>Change in production volumes per location</td><td>No</td></tr>
<tr><td>Change in production technology</td><td>No</td><td>Change in suppliers/customers (change in OD patterns)</td><td>no</td></tr>
<tr><td>Change in commodity demand</td><td>no</td><td></td><td></td></tr>
<tr><td>Additional remarks</td><td colspan="4">All transport efficiency measures which can be implemented by shippers are included.</td></tr>
<tr><td colspan="5">Description of empirical data</td></tr>
<tr><td>Type of data</td><td colspan="4">No empirical data is used to estimate the elasticities, since these are based on other studies or expert guesses.</td></tr>
<tr><td>Geographical scope + distance class</td><td colspan="4">The Netherlands, both domestic and international (kilometres on Dutch infrastructure) transport</td></tr>
<tr><td>Type of goods</td><td colspan="4">The elasticities presented refer to aggregate goods</td></tr>
<tr><td colspan="5">Estimates of elasticities</td></tr>
</table>

Own price elasticities	The following long-run vehicle kilometre price elasticities with regard to changes in vehicle kilometres due to transport efficiency measures are presented: - Increase of utilisation rates: 0,15. Additionally, it is assumed that the reduction of vehicle kilometres due to the increased utilisation rates will not be more than 3%. The reason for this upper bound for the decrease in vehicle kilometres is that shippers already try to perform as efficiently as possible and hence they don't have many opportunities to increase the utilisation rates of their trucks. - Acquire larger vehicles: 0,15 - Shift from highways to local roads: 0,05 (domestic transport) and 0,025 (international transport).
Cross elasticities	
Additional remarks	

Fiorello, D., Martino, A., Schade, W., Schade, B., Wiesenthal, T. (2008), *High oil price, the transport system and the European economy: some results from a model based analysis*, TRT (Milan), ISI Fraunhofer (Karlsruhe), JRC-IPTS (Sevilla)				
Description of the study				
Dependent variable	Tonnes-kilometres of road freight transport			
Independent variable	Diesel prices			
Research method	The elasticities are estimated using the ASTRA (Assessment of Transport Strategies) model. The model consists of nine modules, among which a regional economics module, a transport module and a vehicle fleet module. These modules are linked in manifold ways, including feedback loops.			
Response mechanisms included				
Fuel efficiency	Change fuel efficiency vehicle	yes	Change fuel efficiency driving	no
Transport efficiency	Optimizing allocation of vehicles to shipments	no	Change in consolidated shipments	no
	Change in number and locations of depots	no	Change empty driving	no
	Change in shipment size	no	Change in trip length (route planning)	ye s
Changes in transport	Change in mode	yes	Change in production volumes per location	ye s

volumes	Change in production technology	yes	Change in suppliers/customers (change in OD patterns)	yes
	Change in commodity demand	Yes		
Additional remarks				
Description of empirical data				
Type of data	Since the elasticities are estimated using a model, no specific data is used.			
Geographical scope + distance class	EU25 + Norway and Switzerland			
Type of goods	No distinction between goods is made			
Own price elasticities	The study present a bandwidth for the fuel price elasticity with respect of tonnes-kilometres of road transport: -0,05 to -0,3.			
Cross elasticities				
Additional remarks				

Fosgerau, M. (1996), Freight traffic on the Storebaelt fixed link. PTRC, London	
Description of the study	
Dependent variable	Mode and route choice model. The demand is measured in tonnes. Six different modes: trucks (solo, road train and articulated vehicle), trailer and rail (2).
Independent variable	Own and cross price arc elasticities are calculated by mode and by applying the model with fare (price paid for transport services per tkm) increased by 10%.
Research method	The model structure contains mode choice and two different route choices, one for loaded trucks and one for empty returning trucks. The two route choices affect mode choice proportionally to the number of loaded and empty trucks, while being independent of each other. Elasticities are calculated by applying a validated model.

	Six modes: Three types of trucks, a trailer mode (where trailers are unaccompanied on ferries) and two rail modes (ordinary rail and road/rail combined transport or train and combi for short). The six modes have different routes available. One route was the planned Storebaelt Fixed Link (20km combined bridge and tunnel for rail and road).			
Response mechanisms included				
Fuel efficiency	Change fuel efficiency vehicle	No	Change fuel efficiency driving	No
Transport efficiency	Optimizing allocation of vehicles to shipments	No	Change in consolidated shipments	No
	Change in number and locations of depots	No	Change empty driving	yes
	Change in shipment size	No	Change in trip length (route planning)	yes
Changes in transport volumes	Change in mode	Yes	Change in production volumes per location	No
	Change in production technology	No	Change in suppliers/customers (change in OD patterns)	No
	Change in commodity demand	No		
Additional remarks				
Description of empirical data				
Type of data	Disaggregate data collected for the model in 1988/89: - RP interviews (13,130) with truck drivers combined with data from the Danish State Railway on rail and combi transport. - SP survey 53 transport operators (route choice responsible) RP and SP are combined here. The data on number of trucks by route and mode, used for the model calibration, were collected from available statistics for 1993.			
Geographical scope + distance class	275 zones in Denmark and three external/international zones for prediction for the model.			
Type of goods	Eight different types of good (not specified by the authors), but results are shown only for one. It is unclear which one.			
Estimates of elasticities				

Own price elasticities

Own and cross price elasticities by mode, tonnes:

Price change on	Solo	Art. veh.	Road train	Trailer	Rail
Solo	-1.10	0.05	0.05	0.05	0.04
Art. veh.	0.44	-0.64	0.45	0.40	0.42
Road train	0.16	0.17	-0.66	0.15	0.17
Trailer	0.50	0.47	0.45	-1.53	0.37

Route choice elasticities (for substitution between routes), fare increase on route 5.

Route	Elasticity
Route 1	0.35
Route 2	0.42
Route 3	0.36
Route 4	1.67
Route 5	-1.61
Route 6	2.49
Route 7	0.81
Rail	0.32

Cross elasticities

Additional remarks

Friedlaender, A.F., Spady, R.H. (1981), *Freight transport regulation: Equity, Efficiency and Competition*, Cambridge, Massachusetts and London

Description of the study

Dependent variable	Transport demand, measured in ton-miles, both for road and rail freight transport
Independent variable	Changes in market prices per ton-mile of rail and road freight transport.

Research method	In this study a model was developed which estimated the share of road/rail traffic in total freight demand (total freight demand is assumed to be equal to the sum of road and rail transport demand). The independent variables in this model are: truck/rail revenue per ton-mile, some shipment characteristics (truck-tons per vehicle, truck average length of haul, value of commodity, rail tons per car, rail average length of haul), output and some dummy variables for region and type of commodity. From the road/rail share model price elasticities of road and rail transport demand (measured in ton-miles) are derived. These elasticities are compensated elasticities, since output is included as exogenous variable in the model.			
Response mechanisms included				
Fuel efficiency	Change fuel efficiency vehicle	no	Change fuel efficiency driving	no
Transport efficiency	Optimizing allocation of vehicles to shipments	no	Change in consolidated shipments	no
	Change in number and locations of depots	no	Change empty driving	no
	Change in shipment size	no	Change in trip length (route planning)	no
Changes in transport volumes	Change in mode	yes	Change in production volumes per location	yes
	Change in production technology	yes	Change in suppliers/customers (change in OD patterns)	yes
	Change in commodity demand	no		
Additional remarks	Since shipment characteristics are included as exogenous variables in the model the elasticities are estimated for given shipment characteristics. This means that response mechanisms with respect to transport efficiency are not included. Changes in commodity demand are also not included in the estimates, since compensated elasticities are estimated.			
Description of empirical data				
Type of data	To estimate the elasticities a combination of cross-sectional and time –series data for four broad commodity types and three regions for the five-year period 1968-1972 was used. Thus the sample contained sixty observations.			
Geographical scope + distance class	Elasticities for intercity freight transport are estimated. Three different geographical regions in de USA are distinguished: The Official Territory, the Southern region and the Western Region.			

Type of goods	Four groups of commodities are distinguished: - Durable manufactures - Nondurable manufactures - Petroleum & related - Mineral, chemical and other bulk commodities
Estimates of elasticities	
Own price elasticities	The long-term own-price elasticities of ton-miles by road transport are presented in Table 29.

Table 29 Ton-miles price elasticities of ton-miles by road transport

	Official Territory	Southern region	Western region
Durable manufactures	-0,8262	-0,9906	-1,2385
Nondurable manufactures	-0,9863	-1,0701	-1,3823
Petroleum & related	-0,5867	-0,6620	-0,8318
Mineral, chemical & other	-1,1592	-1,3780	-1,8183

Own-price elasticities of demand for trucking is close to unity for both types of manufactured goods, substantially less than unity for petroleum products and greater than unity for minerals, chemicals and other bulk commodities.

Cross elasticities	The cross elasticities of train ton-miles with respect to changes in road ton-mile prices are shown in Table 30.

Table 30 Cross elasticities of train ton-miles with respect to changes in road ton-mile prices

	Official Territory	Southern region	Western region
Durable manufactures	0,1638	0,1820	0,1480
Nondurable manufactures	0,1820	0,1791	0,0972
Petroleum & related	0,0836	0,1150	0,1650
Mineral, chemical & other	0,1667	0,0989	0,1569

Cross price elasticities of train ton-miles with respect to changes in road ton-mile prices range from 0,084 to 0,182.

Additional remarks	

Friedlaender, A.F., Spady, R.H. (1980), A derived demand function for freight transportation, *The review of economics and statistics*, 62, p. 432-441

Description of the study				
Dependent variable	Transport demand, measured in ton-miles, both for road and rail freight transport			
Independent variable	Changes in market prices per ton-mile of rail and road freight transport.			
Research method	A translog firm's cost function, in which rail and road transport are included, is estimated. From this cost function a freight demand equation and subsequently price elasticities are derived.			
Response mechanisms included				
Fuel efficiency	Change fuel efficiency vehicle	no	Change fuel efficiency driving	no
Transport efficiency	Optimizing allocation of vehicles to shipments	no	Change in consolidated shipments	no
	Change in number and locations of depots	no	Change empty driving	no
	Change in shipment size	no	Change in trip length (route planning)	no
Changes in transport volumes	Change in mode	yes	Change in production volumes per location	ye s
	Change in production technology	yes	Change in suppliers/customers (change in OD patterns)	ye s
	Change in commodity demand	no		
Additional remarks	Since shipment characteristics are included as exogenous variables in the model the elasticities are estimated for given shipment characteristics. This means that response mechanisms with respect to transport efficiency are not included. Changes in commodity demand are also not included in the estimates, since compensated elasticities are estimated.			
Description of empirical data				
Type of data	The researchers used disaggregated cross-section data on road and rail freight transport of 96 manufacturing industries in 1972. The data is coming from the Census of Transportation and no distinctions is made between the LTL (less-than-truckload) trucking market and the full truckload trucking market.			
Geographical scope + distance class	Elasticities for intercity freight transport are estimated. Five different geographical regions in de USA are distinguished: official, southern, western, southwestern and mountain-Pacific territory.			

Type of goods	Elasticities for 8 groups of commodities are estimated: - Food products - Wood & wood products - Paper, plastic & rubber products - Stone, clay and glass products - Iron & Steel products - Fabr. Metal products - Nonelectrical machinery - Electrical machinery

Estimates of elasticities

Own price elasticities

The own price elasticities of road ton-miles are presented in Table 31.

Table 31 Own price elasticities of road ton-miles by commodity group and region

	All regions	Official	Southern	Western	South-western	Mountain-Pacific
Food products	-1,001	-1,010	-1,037	-0,963	-0,987	-0,956
Wood & Wood products	-1,547	-1,719	-0,1455	-1,546	-1,277	-1,323
Paper, plastic, rubber products	-1,054	-1,083	-1,066	-1,047	-1,016	-0,970
Stone, clay, glass products	-1,031	-1,061	-1,000	n/a[a]	-1,026	-1,022
Iron and steel products	-1,083	-1,091	-1,059	n/a	n/a	n/a
Fabr. metal products	-1,364	-1,581	-1,194	-1,342	-1,282	-1,168
Nonelectrical machinery	-1,085	-1,066	-1,017	-1,140	-1,175	-1,097
Electrical machinery	-1,230	-1,312	-1,177	-1,196	n/a	-1,073

[a] n/a, sample size too small

Most own price elasticities are clos to unity, being highest for fabricated metal products, electrical machinery and wood & wood products. However, the range of estimated elasticities is relatively narrow. The same holds with respect to the various regions.

<table>
<tr><td>Cross elasticities</td><td>The cross elasticities of train ton-miles with respect to changes in road ton-mile prices are shown in Table 32

Table 32 Cross elasticities of train ton-miles with respect to changes in road tonnes-km miles

	All regions	Official	Southern	Western	South-western	Mountain-Pacific
Food products	0,004	-0,002	-0,015	0,033	0,013	0,019
Wood & Wood products	-0,129	-0,186	-0,098	-0,101	-0,050	-0,075
Paper, plastic, rubber products	0,003	-0,004	0,000	0,012	0,026	0,010
Stone, clay, glass products	0,016	0,005	0,013	n/a[a]	0,023	0,020
Iron and steel products	-0,013	-0,018	0,002	n/a	n/a	n/a
Fabr. metal products	-0,099	-0,164	-0,051	-0,080	-0,074	-0,053
Nonelectrical machinery	-0,010	0,0002	0,007	-0,025	-0,043	-0,026
Electrical machinery	-0,061	-0,089	-0,056	-0,044	n/a	0,008

[a] n/a, sample size too small

The signs of the cross elasticities are generally negative, indicating that rail and road transport act as complements rather than substitutes. The authors explain these counterintuitive results by the specific composition of the transport market in the sample. LTL trucking accounts for a large share of the transport activities on the market. Since there is virtually no competition among railroads and LTL trucking carriers, these activities are largely independent. Moreover, there is a complementary relationship between rail and LTL trucking; an increase in trucking rates causes firms to switch to private carriage, and increased utilization of private carriage generally leads to a reduction of usage of all for-hire common carriage.</td></tr>
<tr><td colspan="2">Additional remarks</td></tr>
<tr><td colspan="2"></td></tr>
</table>

<table>
<tr><td colspan="2">García-Menéndez, L., I. Martínez-Zarzoso, and D. Pínero De Miguel (2004) Determinants of Mode Choice between Road and Shipping for Freight Transport. Evidence for Four Spanish Exporting Sectors, Journal of Transport Economics and Policy, 38 - 3, 447-466</td></tr>
<tr><td colspan="2">Description of the study</td></tr>
<tr><td>Dependent variable</td><td>Mode Choice (per shipment)</td></tr>
<tr><td>Independent</td><td>Change in road (and sea) cost are applied, where the road cost is the</td></tr>
</table>

variable	price (in pesetas) of a transport service to a specific destination (point to point) for a TIR lorry. For the shipping mode, the price is for a twenty feet container. It is unclear whether they calculated point or arc elasticities.			
Research method	The authors used a Conditional Logit model in their research. The influence of the attributes of the mode of transport on the choice probabilities of a specific option is measured by elasticities (and not by coefficients). It is the attribute's coefficients we are referring to, not the decision maker characteristics or the attributes of variables that do not change no matter which mode is chosen.			
Response mechanisms included				
Fuel efficiency	Change fuel efficiency vehicle	No	Change fuel efficiency driving	No
Transport efficiency	Optimizing allocation of vehicles to shipments	No	Change in consolidated shipments	No
	Change in number and locations of depots	No	Change empty driving	No
	Change in shipment size	No	Change in trip length (route planning)	No
Changes in transport volumes	Change in mode	Yes	Change in production volumes per location	No
	Change in production technology	No	Change in suppliers/customers (change in OD patterns)	No
	Change in commodity demand	No		
Additional remarks				
Description of empirical data				
Type of data	Disaggregate data/Revealed Preference. Personal interviews with export managers and logistic agents of exporting firms and logistic operators were conducted from October to December 1998. A total of 157 exporting firms (to the EU and East European countries) were interviewed. Data about transport costs, transit time, percentage of damaged good percentage of cargo loss for each mode were obtained			
Geographical scope + distance class	Valencian community.			
Type of goods	Four type of good, which are considered to be highly representative of the Spanish domestic industry:			

<table>
<tr><td></td><td>1) Wood Manufacture and Furniture
2) Ceramics
3)Textiles
4)Agroindustry</td></tr>
<tr><td colspan="2">Estimates of elasticities</td></tr>
<tr><td>Own price elasticities</td><td>Cost Road Elasticity (impact on probability of choosing road transport for a shipment)
<table><tr><th>Elasticities</th><th>Mode</th><th>Wd & Furniture</th><th>Ceramics</th><th>Texitiles</th><th>AgroIndustry</th></tr><tr><td>Cost - Road</td><td>Road</td><td>-0.384</td><td>-0.491</td><td>-0.324</td><td>-0.360</td></tr></table></td></tr>
<tr><td>Cross elasticities</td><td></td></tr>
<tr><td colspan="2">Additional remarks</td></tr>
<tr><td colspan="2">Elasticities are calculated also for change in cost for shipping, and then for change in transit time, damage and delay both for sea and road transport.

The elasticities for choosing sea transport are always larger than the elasticities of choosing road because road has by far (about 94% in a weighted average for considered market) the largest market share, therefore the possibility of improving it is rather limited.</td></tr>
</table>

<table>
<tr><td colspan="5">Hemery, C., Rizet, C. (2007), Fuel price elasticity of road freight transport demand in France, presentation hold at Cost 355 – WATCH “Changing behaviour towards a more sustainable transport system, Torino, January 2008</td></tr>
<tr><td colspan="5">Description of the study</td></tr>
<tr><td>Dependent variable</td><td colspan="4">Tonnes-kilometres and vehicle kilometres of road freight transport</td></tr>
<tr><td>Independent variable</td><td colspan="4">Changes in market prices (tax changes included) of diesel prices</td></tr>
<tr><td>Research method</td><td colspan="4">Simple empirical models are estimated. Next to diesel prices only a transport price index is included as independent variable. The empirical models are estimated separately for both transport on own account and hire and reward transport.</td></tr>
<tr><td colspan="5">Response mechanisms included</td></tr>
<tr><td>Fuel</td><td>Change fuel efficiency vehicle</td><td>yes</td><td>Change fuel efficiency</td><td>ye</td></tr>
</table>

<table>
<tr><td>efficiency</td><td></td><td></td><td>driving</td><td>s</td></tr>
<tr><td rowspan="3">Transport efficiency</td><td>Optimizing allocation of vehicles to shipments</td><td>yes</td><td>Change in consolidated shipments</td><td>ye s</td></tr>
<tr><td>Change in number and locations of depots</td><td>yes</td><td>Change empty driving</td><td>ye s</td></tr>
<tr><td>Change in shipment size</td><td>yes</td><td>Change in trip length (route planning)</td><td>ye s</td></tr>
<tr><td rowspan="3">Changes in transport volumes</td><td>Change in mode</td><td>yes</td><td>Change in production volumes per location</td><td>ye s</td></tr>
<tr><td>Change in production technology</td><td>yes</td><td>Change in suppliers/customers (change in OD patterns)</td><td>ye s</td></tr>
<tr><td>Change in commodity demand</td><td>yes</td><td></td><td></td></tr>
<tr><td>Additional remarks</td><td colspan="4">Next to diesel price the empirical model only contains a transport price index as independent variable. So, all response mechanisms are included.</td></tr>
<tr><td colspan="5">Description of empirical data</td></tr>
<tr><td>Type of data</td><td colspan="4">Aggregate time series data (1998-2006) are used. Data on tonnes-kilometres and vehicle kilometres are coming from a survey of the French HDV fleet, based on registration documents. Data on diesel prices are from the road national committee.</td></tr>
<tr><td>Geographical scope + distance class</td><td colspan="4">France</td></tr>
<tr><td>Type of goods</td><td colspan="4">No distinction between goods is made</td></tr>
<tr><td colspan="5"></td></tr>
<tr><td>Own price elasticities</td><td colspan="4">In Table 33 the fuel price elasticities with respect to tonnes-kilometres and vehicle kilometres of road freight transport in France are presented

Table 33 Fuel price elasticities with respect to tonnes-kilometres and vehicle kilometres of road freight transport
<table><tr><td></td><td>Tonnes-kilometres</td><td>Vehicle-kilometres</td></tr><tr><td>Own account</td><td>-0,141</td><td>-0,263</td></tr><tr><td>Hire and reward</td><td>-0,054</td><td>-0,252</td></tr></table></td></tr>
<tr><td>Cross elasticities</td><td colspan="4"></td></tr>
<tr><td colspan="5">Additional remarks</td></tr>
</table>

IEA (International Energy Agency) (1994), *World Energy Outlook,* OECD, Paris				
Description of the study				
Dependent variable	The demand for gasoline and diesel (measured in millions tonnes of oil equivalent, Mtoe). All road transport is included.			
Independent variable	Changes in fuel prices			
Research method	Elasticities are estimated by using the long term world energy model (WEM) of IEA. This model provides long term projections of energy demand in various economic sectors on a fairly aggregate regional scale. Demand equations are based on single equation techniques.			
Response mechanisms included				
Fuel efficiency	Change fuel efficiency vehicle	?	Change fuel efficiency driving	yes
Transport efficiency	Optimizing allocation of vehicles to shipments	yes	Change in consolidated shipments	yes
	Change in number and locations of depots	yes	Change empty driving	yes
	Change in shipment size	yes	Change in trip length (route planning)	yes
Changes in transport volumes	Change in mode	yes	Change in production volumes per location	yes
	Change in production technology	yes	Change in suppliers/customers (change in OD patterns)	yes
	Change in commodity demand	no		
Additional remarks	Since a long term energy model is used, most response mechanisms are taken into account when estimating the elasticities. Exception is the change in commodity demand, which is included as exogenous variables into the model. Changes in fuel efficiency of the vehicle are included as endogenous variable in the model for passenger road transport. However, it is not clear whether this is also the case for road freight transport.			
Description of empirical data				
Type of data	The elasticities are based on time-series data (1965-1991). Aggregate data on fuel demand are based on the IEA's Energy Balances of OECD			

	Countries databases. Data on energy prices and taxes since 1978 come from IEA's Energy Prices and Taxes databases. For the period before 1978 data is coming from a variety of sources.
Geographical scope + distance class	Fairly aggregate date is used for three regions: North America, Europe and Japan.
Type of goods	No distinction is made between different types of goods.
Estimates of elasticities	
Own price elasticities	The fuel price elasticities estimated by the IEA for North America, Japan and Europe are presented in Table 34. **Table 34 Fuel price elasticities of the demand for fuel** (see table below)
Cross elasticities	
Additional remarks	

Table 34 Fuel price elasticities of the demand for fuel

	North America	Japan	Europe
Gasoline demand	-0,46	-0,49	-1,0
Diesel demand	-0,26	-0,19	-0,38

Inaba, F.S., Wallace, N.E. (1989), Spatial price competition and the demand for freight transportation, *The review of Economics and Statistics* 71, 4, p. 614-625	
Description of the study	
Dependent variable	The dependent variable is the demand for wheat transport (measured in tonne kilometres). In total seven transport modes are considered: truck, rail, barge and four types of multi-modal transport (single car rail , multiple car rail, truck/barge and truck/multiple car rail). Here we will only discuss the own elasticities with regard to trucks (no cross elasticities are estimated).
Independent variable	The price change considered is the market price change in truck rates (probably measured in $ per tonne kilometres).
Research method	A freight demand model is developed which jointly estimates the quantity shipped and the mode and destination choice. The effect of spatial price competition on the demand of transport is taken into account. Firms can increase their market area if for example transportation rates are reduced. In this case more destinations of the

	shipment can be chosen. So transport prices also influences transport demand indirectly via the impact on destination choices. The model is estimated using switching regression techniques. The model provide estimates of unconditional freight demand, which can be used to derive unconditional price elasticities.			
Response mechanisms included				
Fuel efficiency	Change fuel efficiency vehicle	no	Change fuel efficiency driving	no
Transport efficiency	Optimizing allocation of vehicles to shipments	no	Change in consolidated shipments	no
	Change in number and locations of depots	no	Change empty driving	no
	Change in shipment size	yes	Change in trip length (route planning)	no
Changes in transport volumes	Change in mode	yes	Change in production volumes per location	no
	Change in production technology	no	Change in suppliers/customers (change in OD patterns)	ye s
	Change in commodity demand	no		
Additional remarks	The model estimated deals with a short-run decision, namely: which mode, destination and shipment size should be chosen for a single shipment. These endogenous variables in the model do affect the value of the elasticities estimated, which means that the following response mechanisms are included in the elasticity estimate: change in shipment size, change in mode and change in OD patterns. Production processes are assumed to be fixed, so changes in production technology and changes in production volumes per location are not included. Also total commodity demand is assumed to be fixed.			
Description of empirical data				
Type of data	Cross section (disaggregated) data was gathered from a questionnaire survey of all grain elevators with either federal or state licences in the US states of Idaho, Oregan, Montona and Washington. The empirical data refer to transport of wheat in 1984. Wherever possible the data obtained from the survey were verified with records kept by the Federal and State licensing agencies.			
Geographical scope + distance class	Elasticities based on data of freight transport by grain elavators in Montana and East Washington are presented in the paper. In addition, seven destinations are distinguished: Seatle, Portland, River, California, Great Falls, Ogden and Minneapolis. So, the elasticities refer to long-distance transport.			
Type of	The elastisities refer to the transport of wheat.			

goods	
Estimates of elasticities	
Own price elasticities	The short-run own price elasticities of the demand for truck transport are presented in Table 35. Table 35 Own-price elastiticities of the demand for truck transport (see table below) The differences in estimated elasticities between Montana and Eastern Washington can partly be explained by differences in trip length. Since Seatle and Portland are situated in Eastern Washington, average trip length for these destinations is shorter for shippers from Eastern Washington than for shippers from Montana. Therefore rail and multi-modal transport modes are less attractive for shippers from Eastern Washington than for shippers from Montana, and hence elasticities of the demand for truck transport are smaller for the former region.
Cross elasticities	
Additional remarks	

Table 35 Own-price elastiticities of the demand for truck transport

Destination	Region	
	Montana	Eastern Washington
Seatle	-0,733	-0,607
Portland	-0,615	-0,433
River	-0,346	-0,253
California	-0,690	-0,921
Great Falls	-0,445	-
Ogden	-0,603	-
Minneapolis	-0,459	-

G Jovicic - Tetraplan AS, Application of Models Based on Stated and Revealed Preference Data for forecasting Danish International Freight Transport, Aalborg, Denmark, 1998 - trg.dk	
Description of the study	
Dependent variable	Mode choice model for choice per shipment
Independent variable	The price change considered is +10% for the road (lorry) transport cost (which is given per shipment). Elasticities are estimated with respect to lorry, rail/combined and sea transports.

Research method	Mode choice model for Danish international freight to forecast the future demands for rail together with rail-road combined transport and sea transport relative to lorry transport, when supply variables change. The model was calibrated on the basis of the observed Danish export/import volumes (tonnes) for the two commodity groups and three modes of transport in 1995. Arc elasticities have been estimated.			
Response mechanisms included				
Fuel efficiency	Change fuel efficiency vehicle	No	Change fuel efficiency driving	No
Transport efficiency	Optimizing allocation of vehicles to shipments	No	Change in consolidated shipments	No
	Change in number and locations of depots	No	Change empty driving	No
	Change in shipment size	No	Change in trip length (route planning)	No
Changes in transport volumes	Change in mode	yes	Change in production volumes per location	No
	Change in production technology	No	Change in suppliers/customers (change in OD patterns)	No
	Change in commodity demand	No		
Additional remarks				
Description of empirical data				
Type of data	Stated Preference and Revealed Preference data have been used in the model simultaneously. The data were collected during three different projects: 1 in 1993 and 2 in 1996-1997. The total number of observation is 11337, of which 1012 (847 road transport users, 90 combined transport users and 75 sea transport users) are RP.			
Geographical scope + distance class	International Danish freight.			
Type of goods	Two types of goods categories: - Low Value Commodity Groups (Vegetables products, animal products, beverages, feeding stuffs, metal products, paper and wood products); - Low Value Commodity Groups (Chemical products, machineray, electronical products, textile and clothing, other products).			
Estimates of elasticities				
Own price elasticities	Increasing lorry transport cost by 10% leads to the following elasticities:			

	- 0.07 (lorry transport) for Low Value Commodities, and; - 0.03 (lorry transport) for High Value Commodities
Cross elasticities	
Additional remarks	

Holguín-Veras, J. (2002) Revealed Preference Analysis of the Commercial Vehicle Choice Process, **Journal of Transportation Engineering, American Society of Civil Engineers 128**(4), 336-346.				
Description of the study				
Dependent variable	Commercial Vehicle (CV) choice model: choice of vehicle type within road transport			
Independent variable	Point elasticities: Changes in operating costs and changes in XL (variable that gives an indication of how appropriate a particular type of vehicle is for handling a given shipment)			
Research method	The CV choice process is modelled using a discrete-continuous choice model, in which the choice of the type of vehicle (pickups, trucks or semi-trailers) is the discrete variable, while the shipment size represents the continuous choice variable. In a first step, a shipment size sub-model is estimated. In a second step, the shipment size is entered as variable of the vehicle type discrete model. Then two different models are estimated: - Multinomial Logit Model (MNL) - Heteroscedastic Extreme Value Model (HEV)			
Response mechanisms included				
Fuel efficiency	Change fuel efficiency vehicle	No	Change fuel efficiency driving	No
Transport efficiency	Optimizing allocation of vehicles to shipments	Yes	Change in consolidated shipments	No
	Change in number and locations of depots	No	Change empty driving	No
	Change in shipment size	Yes	Change in trip length (route planning)	No
Changes in transport volumes	Change in mode	No	Change in production volumes per location	No
	Change in production	No	Change in	No

	technology		suppliers/customers (change in OD patterns)	
	Change in commodity demand	No		
Additional remarks				
Description of empirical data				
Type of data	Disaggregate data. Revealed Preference data collected through a survey amongst truck drivers randomly selected. The sample contains 5,276 observations of both empty and loaded trucks, and contains information on shipment size, commodity type and choice of commercial vehicle.			
Geographical scope + distance class	Guatemala city			
Type of goods				
Estimates of elasticities				
Own price elasticities	(see Tables 7 and 8 below)			

Table 7. Elasticities Estimated from Multinominal Logit Model

Variable is in utility function of	Elasticities of cost in choice of *P*	*T*	*S*
	(a) Simple average of individual elasticities		
Pickups (*P*)	−0.027	0.133	0.061
Trucks (*T*)	0.087	−0.040	0.061
Semitrailers (*S*)	0.087	0.133	−0.124
	(b) Weighted average of individual elasticities		
Pickups (*P*)	−0.064	0.024	0.000
Trucks (*T*)	0.028	−0.020	0.007
Semitrailers (*S*)	0.003	0.033	−0.025

Table 8. Elasticities Estimated from Heteroscedastic Extreme Value Model

Variable is in utility function of	Elasticities of cost in choice of *P*	*T*	*S*
	(a) Simple average of individual elasticities		
Pickups (*P*)	−0.027	0.095	0.007
Trucks (*T*)	0.087	−0.079	0.007
Semitrailers (*S*)	12.353	0.549	−4.121
	(b) Weighted average of individual elasticities		
Pickups (*P*)	−0.036	0.067	0.007
Trucks (*T*)	0.032	−0.065	0.007
Semitrailers (*S*)	0.013	0.120	−0.373

Cross elasticities	
Additional remarks	

Holguín-Veras, J., M. Silas, J. Polimeni and B. Cruz (2006b) An Investigation on the Effectiveness of Joint Receiver-Carrier Policies to Increase Truck Traffic in the Off-Peak Hours. Part II: The Behavior of Carriers, **Networks and Spatial Economics**.				
Description of the study				
Dependent variable	Point elasticities of choice for deliveries in peak versus off-peak.			
Independent variable	Changes in policies are made to test the sensitivity of receivers and carriers to accept off-peak hours delivery's incentives (toll savings or financial rewards, as a fixed amount or per vkm).			
Research method	The authors carried out the analysis by means of Mixed Logit model and Binary Logit model. The best models are presented in the paper and used to calculate the elasticities.			
Response mechanisms included				
Fuel efficiency	Change fuel efficiency vehicle	No	Change fuel efficiency driving	No
Transport efficiency	Optimizing allocation of vehicles to shipments	Yes	Change in consolidated shipments	No
	Change in number and locations of depots	No	Change empty driving	No
	Change in shipment size	No	Change in trip length (route planning)	No
Changes in transport volumes	Change in mode	No	Change in production volumes per location	No
	Change in production technology	No	Change in suppliers/customers (change in OD patterns)	No
	Change in commodity demand	No		
Additional remarks				
Description of empirical data				
Type of data	Stated Preference data targeting companies with at least 25 employees, from two groups:			

<table>
<tr><td></td><td>1) for-hire carriers, namely those that provide services to the open market;
2) private carriers, namely those that provide transportation service to a parent or a related company.</td></tr>
<tr><td>Geographical scope + distance class</td><td>New Jersey and New York</td></tr>
<tr><td>Type of goods</td><td>Food, furniture, household goods/various, textiles/clothing, machinery, chemicals, computer/electronics, paper, wood/lumber, office supplies, metal, medical supplies, jewelry/art, alcohol, petroleum/coal, stone/concrete, plastics/rubber, printed material, non-alcoholic beverages.</td></tr>
<tr><td colspan="2">Estimates of elasticities</td></tr>
<tr><td>Own price elasticities</td><td>
<table>
<tr><th>Scenario</th><th>Elasticity to Policy Variable</th><th>Model Type</th></tr>
<tr><td>Receivers</td><td></td><td></td></tr>
<tr><td>R1)tax deduction for accepting off-peak deliveries (0 to 10,000$)</td><td>0.189</td><td>Mixed logit</td></tr>
<tr><td>R2) Lower shipping cost during off-peak hours (0 to 100%)</td><td>0.242</td><td>Mixed logit</td></tr>
<tr><td>Carriers</td><td></td><td></td></tr>
<tr><td>C1) A given percentage of customers requesting OPD (0 to 75%)</td><td>0.719</td><td>Mixed logit</td></tr>
<tr><td>C2) A given percentage of customers requesting OPD (0 to 75%) and toll savings if using the off-peak hours ($3/axle to 7$/axle)</td><td>0.3
0.004 to 0.055[a]</td><td>Mixed logit</td></tr>
<tr><td>C3) A given percentage of customers requesting OPD (0 to 75%) and financial reward per mile travelled during off-peak hours (5 to 10 $ cents/mile)</td><td>0.269
0.019 to 0.061[b]</td><td></td></tr>
</table>

[A] only food, textiles/clothing, wood/lumber and petroleum were found to have some sensitivity to toll savings
[B] only food, textiles/clothing and computer/electronics were found to have some sensitivity to financial rewards
</td></tr>
<tr><td>Cross</td><td></td></tr>
</table>

elasticities	
Additional remarks	
This paper does not really address the research question of the project, but it is worthwhile mentioning it.	

Marzano V., A. Papola (2004), Modelling freight demand at a national level: theoretical developments and application to italian demand, Paper presented at the European Transport Conference 2004, Strasbourg				
Description of the study				
Dependent variable	Mode choice model for choice per shipment. The modes under consideration are rail, combined and lorry. Ferry is not in the model due to the unavailability of level of service data.			
Independent variable	Arc elasticities are calculated on the change of (10%) lorry time, which given the information in the paper can be transformed in cost elasticity (cost per shipment).			
Research method	Multi-regional input-output model with elastic trade coefficients and a mode choice model. The Italian freight national model simulates each individual (single) consignment mode choice model. The model has been estimated on the basis of an available database of interviews to Italian firms and shippers.			
Response mechanisms included				
Fuel efficiency	Change fuel efficiency vehicle	No	Change fuel efficiency driving	No
Transport efficiency	Optimizing allocation of vehicles to shipments	No	Change in consolidated shipments	No
	Change in number and location of depots	No	Change empty driving	No
	Change in shipment size	No	Change in trip length (route planning)	Yes
Changes in transport volumes	Change in mode	Yes	Change in production volumes per location	Yes
	Change in production technology	No	Change in suppliers/customers (change in OD patterns)	Yes
	Change in commodity demand			

Additional remarks	
Description of empirical data	
Type of data	Disaggregate data. Revealed Preference.
Geographical scope + distance class	Italy for all distances.
Type of goods	Goods are grouped into two macro-classes perishable-high value and not perishable-industrial; and four weight classes each.
Estimates of elasticities	
Own price elasticities	Short-term (not clearly defined in the paper) lorry arc elasticity for the impact on tonnes has been found equal to – 0.1548 (e_{time}* $\beta_{cost}/\beta_{Lorry\ Time}$). No other elasticities were given.
Cross elasticities	
Additional remarks	
Change in production volumes per location and change in suppliers/customers (change in OD patterns) are for long term elasticities. In the short term they were negligible in EXPEDITE runs (an earlier version of this model was used in the EXPEDITE study).	

H. Maurer (2008). Development of an Integrated Model for Estimating Emissions from Freight Transport. Ph.D. thesis. University of Leeds.	
Description of the study	
Dependent variable	Dependent variables: 1) tonne kilometres 2) vehicle kilometres 3) fuel consumption 4) emissions (CO_2, SO_2, NO_x, PM_{10}, CO) 5) external costs Mode was defined as main mode of a transport chain. Considered modes: road and rail freight transport in GB.
Independent variable	Several tests were carried out: 1) Government policy: Effect of marginal social cost pricing mode split for road and rail transport demand, logistics design and air pollution was tested. It was not specified which cost variable would be affected when the policy is implemented. MSC implied an increase in variable transport costs by £0.15 per km (see Sansom, T., Nash, C.A., Mackie, P.J., Shires, J., and Watkiss, P., (2001) Surface transport costs and charges: Great Britain 1998.

	Final report for the Department of the Environment, Transport and the Regions. Institute for Transport Studies, University of Leeds, Leeds, July 2001.). 2) Market forces: Effect of a change in logistics structure on transport costs and vehicle kms using different scenarios, i.e. decentralized structure, implying more depots in the network and centralized distribution strategy.			
Research method				
Response mechanisms included				
Fuel efficiency	Change fuel efficiency vehicle	No	Change fuel efficiency driving	No
Transport efficiency	Optimizing allocation of vehicles to shipments	No	Change in consolidated shipments	Yes
	Change in number and locations of depots	Ye s	Change empty driving	No
	Change in shipment size	Ye s	Change in trip length (route planning)	Yes
Changes in transport volumes	Change in mode	Ye s	Change in production volumes per location	Yes
	Change in production technology	No	Change in suppliers/customers (change in OD patterns)	Yes
	Change in commodity demand	No		
Additional remarks	Change in shipment size (effect of different ss on transport demand is estimated, as part of the logistics model). SS was defined as the quantity of goods which belongs to one single order and delivery Change empty driving; empty driving assumptions were kept constant Change in mode, as part of the freight demand module Change in production volumes per location, as part of the logistics module which optimizes also the choice of sourcing locations Change in suppliers/customers (change in OD patterns) as part of the logistics module			
Description of empirical data				
Type of data	Annual data for 1998, data sources for transport data: e.g. UK Department for Transport, Freight Transport Association; surveys were			

	not carried out
Geographical scope + distance class	Freight demand module (which provides modal split) uses Generalised costs to estimates changes in market size (modal shifts). Changes (new vkms) are given by commodity and distance-bands, not by vehicle type. Introduction of Marginal social cost pricing (increase by £0.15 per km) for different vehicle types reduced vehicle kms in GB in 1998 by 9.38 %. Geography: Great Britain Distance classes: 1-25 km 2. 25-50 km 3. 50-100 km 4. 100-150 km 5. 150-200 km 6. 200-300 km 7. 300-400 km 8. 400-500 km 9. Over 500 km
Type of goods	A Food, Drink and Agricultural Products B Coal, Coke and related items C Petroleum and Petroleum Products D Metals and Ores E Aggregates and Construction F Chemicals and Fertilisers G Other, including manufactures, miscellaneous, containerised and international. Logistics module only for Type A
Estimates of elasticities	
Own price elasticities	Not explicitly calculated (+ 67.76% in road cost leads to – 9.38% road vehicle-kilometres). Therefore, elasticity (+10% increase in road costs) is -0.138.
Cross elasticities	
Additional remarks	
The model consists of four modules: Freight Demand Module, the Logistics Module, the Emissions Module and the Module for Policy Testing	

<table>
<tr><td colspan="5">McFadden, Winston Boersch-Supan (1985), Joint estimation of freight transportation decisions under nonrandom sampling, in Daughety (ed.): Analytical Studies in Transport Economics, Cambridge University Press, Cambridge.</td></tr>
<tr><td colspan="5">Description of the study</td></tr>
<tr><td>Dependent variable</td><td colspan="4">Mode choice; probability shipper chooses for rail or road transport</td></tr>
<tr><td>Independent variable</td><td colspan="4">Road and rail freight charges, probably per tonne-kilometres.

In this study marginal and fixed transport rates are distinguished. Here we only consider the marginal road freight charges.</td></tr>
<tr><td>Research method</td><td colspan="4">A (theoretical) model is developed to analyze the mode choice decision jointly with the shipment size, shipment frequency and production decisions. This model is empirically estimated by full-information maximum likelihood (FIML). Using the estimated coefficients, elasticities with respect to joint probability of mode choice and shipment size were computed for (among other variables) marginal freight rates.</td></tr>
<tr><td colspan="5">Response mechanisms included</td></tr>
<tr><td>Fuel efficiency</td><td>Change fuel efficiency vehicle</td><td>no</td><td>Change fuel efficiency driving</td><td>no</td></tr>
<tr><td rowspan="3">Transport efficiency</td><td>Optimizing allocation of vehicles to shipments</td><td>no</td><td>Change in consolidated shipments</td><td>no</td></tr>
<tr><td>Change in number and locations of depots</td><td>no</td><td>Change empty driving</td><td>no</td></tr>
<tr><td>Change in shipment size</td><td>yes</td><td>Change in trip length (route planning)</td><td>no</td></tr>
<tr><td rowspan="3">Changes in transport volumes</td><td>Change in mode</td><td>yes</td><td>Change in production volumes per location</td><td>yes</td></tr>
<tr><td>Change in production technology</td><td>yes</td><td>Change in suppliers/customers (change in OD patterns)</td><td>yes</td></tr>
<tr><td>Change in commodity demand</td><td>yes</td><td></td><td></td></tr>
<tr><td>Additional remarks</td><td colspan="4">Actual decisionmaker in produce shipping activity is the receiver, so most transport efficiency response mechanisms are not taken into account. Exception is change in shipment size, which is included in the model as an endogenous variable, and which indirectly influence the mode choice decision of the receiver. Additionally, no restriction on total market size is assumed, so changes in transport volumes are taken into account.</td></tr>
<tr><td colspan="5">Description of empirical data</td></tr>
</table>

Type of data	Cross section data on transportation of agricultural goods in 1977. Mostly aggregated data. Data is coming from the Department of Transportation and the Department of Agriculture.
Geographical scope + distance class	Geographical scope: USA. Nothing is mentioned on the average length of road and rail haul transport
Type of goods	The elasticities are derived for agricultural commodities (lettuce, tomatoes, cabbage, onions, oranges, grapes and apples).
Estimates of elasticities	
Own price elasticities	The elasticity of the probability to choose truck transport with respect to marginal truck rate is equal to -0,7488.
Cross elasticities	The cross elasticity of the probability to choose rail transport with respect to the marginal truck rate is equal to 1,2547.
Additional remarks	

McKinnon (1998), Logistical restructuring, freight traffic growth and the environment, in: Banister, D. (ed.), *Transport Policy and the Environment*, London, p. 97 - 109				
Description of the study				
Dependent variable	The dependent variable is transport volume. Since the study performs a qualitative analysis, this variable is not defined in more precise terms.			
Independent variable	Road transport costs to shippers.			
Research method	Based on questionnaire survey with manufacturing firms the price sensitivity of logistical systems to large transport cost increases (50%) is estimated. With the help of the results of this survey a computer simulation was developed to model the effect of increasing road transport costs on logistical systems and distribution patterns. Different types of distribution systems were tested, ranging form one in which all inventory was dispersed to twelve regional depots. Based on these simulations some tipping points at which significant changes in the logistical systems will take place are estimated. However, no estimates of elasticities are provided.			
Response mechanisms included				
Fuel efficiency	Change fuel efficiency vehicle	No	Change fuel efficiency driving	No
Transport efficiency	Optimizing allocation of vehicles to shipments	no	Change in consolidated shipments	no

	Change in number and locations of depots	yes	Change empty driving	no
	Change in shipment size	no	Change in trip length (route planning)	no
Changes in transport volumes	Change in mode	No	Change in production volumes per location	yes
	Change in production technology	No	Change in suppliers/customers (change in OD patterns)	no
	Change in commodity demand	no		
Additional remarks	The study focuses on the price sensitivity of logistical structures(changes in number and locations of depots and changes in production volumes per location) on the short term. However, it is questionable whether these changes will take place on the short term. Especially changes in the number and locations of depots may occur to a larger extent on the long term. This may be an explanation of the relatively low price sensitivity found by the authors (see: estimates of elasticities).			
Description of empirical data				
Type of data	The analysis is based on a questionnaire survey with manufacturing firms in the UK in 1993 (stated preference data). This survey provides cross section data on possible responses of firms on a increase in road transport costs by 50%. The manufacturers were drawn form sectors which exhibited a high rate of road tonne-km growth over de past decade.			
Geographical scope + distance class	UK			
Type of goods				
Estimates of elasticities				
Own price elasticities	No price elasticities were estimated in this study. However, the study makes clear that even the transport costs of products with a relatively low value density would have to rise by over 100% to make it economically beneficial to more to a more decentralized logistical system. So, this study indicates that the price sensitivity of logistical structures is quite price insensitive (especially on the short term).			
Cross elasticities				
Additional remarks				

<table>
<tr><td colspan="5">Nam, K.C., A study on the estimation and aggregation of disaggregate models of mode choice for freight transport, Transportation Research E 33, 3, p. 223-231</td></tr>
<tr><td colspan="5">Description of the study</td></tr>
<tr><td>Dependent variable</td><td colspan="4">Mode choice; probability shipper chooses truck or rail transport</td></tr>
<tr><td>Independent variable</td><td colspan="4">Rate per kg, both for rail and road transport</td></tr>
<tr><td>Research method</td><td colspan="4">The binary choice (truck or rail transport) is estimated with a logit model. Based on the coefficients of this model aggregate elasticities are computed
on disaggregate data by taking the weighted average of the elasticities at individual observations with the weight being the probability of choosing the mode. The estimated elasticities are direct point elasticities.</td></tr>
<tr><td colspan="5">Response mechanisms included</td></tr>
<tr><td>Fuel efficiency</td><td>Change fuel efficiency vehicle</td><td>no</td><td>Change fuel efficiency driving</td><td>no</td></tr>
<tr><td rowspan="3">Transport efficiency</td><td>Optimizing allocation of vehicles to shipments</td><td>no</td><td>Change in consolidated shipments</td><td>no</td></tr>
<tr><td>Change in number and locations of depots</td><td>no</td><td>Change empty driving</td><td>no</td></tr>
<tr><td>Change in shipment size</td><td>no</td><td>Change in trip length (route planning)</td><td>no</td></tr>
<tr><td rowspan="3">Changes in transport volumes</td><td>Change in mode</td><td>yes</td><td>Change in production volumes per location</td><td>no</td></tr>
<tr><td>Change in production technology</td><td>no</td><td>Change in suppliers/customers (change in OD patterns)</td><td>no</td></tr>
<tr><td>Change in commodity demand</td><td>no</td><td></td><td></td></tr>
<tr><td>Additional remarks</td><td colspan="4">Actual decisionmaker in produce shipping activity is the receiver, so transport efficiency response mechanisms are not taken into account. Additionally, shipment weight, distance and origin-destination pair are included as exogenous variables in the model, which implies that the related transport mechanisms (change in trip length, change in production volumes per location, change in production technology and change in suppliers/custormers, change in commodity demand) are not included in the estimated elasticity.</td></tr>
<tr><td colspan="5">Description of empirical data</td></tr>
<tr><td>Type of data</td><td colspan="4">Cross sectional data on road and rail transport of small consignments</td></tr>
</table>

	(size is mostly less than 100 kg). The sample of disaggregated data represents shipping that took place during the 1988-early 1989 period.
Geographical scope + distance class	The study considers intercity rail and road transport of small consignments in Korea.
Type of goods	Six commodity groups are distinguished: - textiles - paper - chemicals - basic metal - earthenware - electrical housewares
Estimates of elasticities	
Own price elasticities	The own prices elasticities of choosing truck transport with respect to truck charges are: - textiles: -0,002 - paper: -0,253 - chemicals: -0,107 - basic metal: -0,212 - earthenware: 0,121 - electrical housewares: 0,085 Notice that the elasticities for both earthenware and electrical housewares have incorrect signs.
Cross elasticities	
Additional remarks	

NEI & CE (1999), Prijselasticiteiten in het goederenwegvervoer (Price elasticities of road freight transport), Rotterdam/Delft	
Description of the study	
Dependent variable	Demand of freight transport by road, rail and inland shipping (measured in tonnes-kilometres)
Independent variable	Changes in prices of road transport (measured in tonnes-kilometres)
Research method	Three research methods are applied in this study: - a review of international literature on relevant price elasticities. Since most studies reviewed are also included in this project, we will not discuss the results of this analysis. - A questionnaire survey to estimate cross elasticities - Elasticities are derived from the transport model SMILE.

Response mechanisms included				
Fuel efficiency	Change fuel efficiency vehicle	n/n	Change fuel efficiency driving	n/n
Transport efficiency	Optimizing allocation of vehicles to shipments	n/n	Change in consolidated shipments	n/n
	Change in number and locations of depots	n/n	Change empty driving	n/n
	Change in shipment size	n/y	Change in trip length (route planning)	n/n
Changes in transport volumes	Change in mode	y/y	Change in production volumes per location	n/y
	Change in production technology	n/n	Change in suppliers/customers (change in OD patterns)	n/y
	Change in commodity demand	n/y		
Additional remarks	*The first character in the scheme above refers to the survey research, the second one to the estimations by the transport model SMILE (y=yes; n=no).* Survey The survey research estimates cross elasticities by only taking changes in transport mode into account. Transport model The shipper is assumed to be the decision maker. Changes in mode, shipment size, distribution structures (production volumes per location, OD patterns) and total transport demand are taken into account. It is not clear whether changes in production technology are included in the estimates of elasticities.			
Description of empirical data				
Type of data	Survey For the survey research cross section data is used from 193 shippers. Among other questions they are asked at which price increase of road transport they would consider a switch to another transport mode. For every level of price increase the total shift of transport from road to other			

	modes is calculated. Based on this information, cross price elasticities are estimated. <u>Transport model</u> The estimates of elasticities are based on model runs. No information is provided on which empirical data is used to calibrate the model.
Geographical scope + distance class	<u>Survey</u> The study considers national and international transport by Dutch shippers. <u>Transport model</u> Both national (the Netherlands) and international transport (from or to the Netherlands) are considered.
Type of goods	<u>Survey</u> For two types of transport separate elasticities are presented, viz. general cargo and container transport. Additionally, aggregate elasticities are estimated. <u>Transport model</u> Elasticities estimates are presented for two types of transport: bulk transport and transport of general cargo. In addition, aggregate elasticities of all transport are estimated.
Estimates of elasticities	
Own price elasticities	<u>Transport model</u> According to SMILE, own price elasticities of road freight transport depends heavily on the size of the price change. Therefore a range of elasticities is presented. The lower limit of this range refers to a price change of 10%, while the upper limit refers to a price change of 100%.

Table 36 Own price elasticities of road transport

Type of transport	Own-price elasticity of road transport
Total transport	-0,63 to -0,43
National transport	-0,75 to -0,48
International transport	-0,41 to -0,23
Bulk: national transport	-0,84 to -0,57
Bulk: international transport	-0,31 to -0,19
General cargo: national transport	-0,43 to -0,45
General cargo: international transport	-0,63 to -0,24

Cross elasticities

Survey

In Table 37 cross elasticities of the demand for rail transport with regard to changes in road transport prices are presented for various types of transport.

Table 37 Cross-elasticities of the demand for rail transport with regard to changes in road tranport prices

Type of transport	**Cross elasticity**
Transport of general cargo	8,3
Container transport	1,8
National transport	0,8
International transport	3,1
All transport	3,0

Note: all elasticities are based on price changes up to 40%.

According to this study cross elasticities are higher for small price increases (up to 40%) than for large price increases (above 40%). For example, a cross elasticity of rail transport based on price changes up to 40% is estimated to be equal to 3,0 (see Table 37), while the same elasticity estimated on basis of all price changes (also above 40%) is equal to 1,1.

Transport model

Like the own-price elasticities estimated by SMILE also the cross elasticities depends heavily on the price change considered. Therefore, ranges of estimates are presented. The estimates of cross elasticities of national rail transport are counterintuitive, in the sense that elasticities increase when price changes increase. According to the authors this is caused by the relatively small market size of rail transport.

Table 38 Cross elasticities of rail freight transport with respect to changes in road transport prices.

Type of transport	Cross elasticity of rail transport
Total transport	1,9 to 1,4
National transport	1,9 to 3,7
International transport	1,9 to 0,6
Bulk: national transport	1,8 to 3,6
Bulk: international transport	2,3 to 0,6
General cargo: national transport	2,3 to 4,7
General cargo: international transport	0,9 to 0,5

Additional remarks

Oum, T.H. (1989), Alternative demand models and their elasticity estimates, Journal of Transport Economics and Policy, p. 163-187				
Description of the study				
Dependent variable	The dependent variable is ton-miles of both road and rail freight transport.			
Independent variable	Changes in the market price of road and rail transport per ton-mile.			
Research method	Point elasticities of road and rail ton miles are estimated using five different functional forms: - Linear demand model - Log-linear demand model - Box-Cox model - Logit model applied to aggregate market share data - Translog demand system based on neoclassical demand theory These five models are theoretically, methodologically and empirically compared. Main objective of the study is to investigate the impact of the functional form chosen on the value of the estimated elasticities.			
Response mechanisms included				
Fuel efficiency	Change fuel efficiency vehicle	no	Change fuel efficiency driving	no
Transport efficiency	Optimizing allocation of vehicles to shipments	no	Change in consolidated shipments	no
	Change in number and locations of depots	no	Change empty driving	no
	Change in shipment size	yes	Change in trip length (route planning)	no
Changes in transport volumes	Change in mode	yes	Change in production volumes per location	yes
	Change in production technology	yes	Change in suppliers/customers (change in OD patterns)	yes
	Change in commodity demand	yes		
Additional remarks	For all functional forms ordinary price elasticities are estimated, which means that both substitution and output effects are included. Additonally, compensated price elasticities are derived with the help of the translog demand system; these elasticities only include substitution effects.			

<table>
<tr><th colspan="2">Description of empirical data</th></tr>
<tr><td>Type of data</td><td>The elasticities are estimated by using cross section (aggregate) data for Canadian inter-regional freights flows in 1979.</td></tr>
<tr><td>Geographical scope + distance class</td><td>The study considers inter-regional transport flows in Canada.</td></tr>
<tr><td>Type of goods</td><td>Both elasticities of total road freight transport and road transport of fruits, vegetables and edible foods are estimated.</td></tr>
<tr><th colspan="2">Estimates of elasticities</th></tr>
<tr><td>Own price elasticities</td><td>The own price elasticities estimated for the different functional forms are presented in Table 39.

Table 39 Price elasticities of tonnes-miles estimated for five different functional forms
<table>
<tr><th rowspan="2"></th><th colspan="2">Translog</th><th rowspan="2">Log-linear</th><th rowspan="2">Linear</th><th rowspan="2">Box-Cox</th><th rowspan="2">Logit</th></tr>
<tr><th>Ordinary</th><th>compensated</th></tr>
<tr><td>All commodities</td><td>-0,692</td><td>-0,646</td><td>-1,341</td><td>-0,048</td><td>-1,140</td><td>-0,928</td></tr>
<tr><td>Fruit and vegetables</td><td>-0,652</td><td>-0,459</td><td>-1,542</td><td>-0,318</td><td>-1,248</td><td>-0,970</td></tr>
</table>

The various estimates of price elasticities differ widely. According to the author the estimates for the Box-Cox and the log-linear models appear to be on the high side. Additionally, the elasticities associated with the linear models are likely to be biased, since all quality of service variables are excluded by this functional form. Therefore, the elasticities estimated for the translog function are the preferred ones (also because the theory-based model is highly robust).

The small difference in ordinary and compensated elasticities for the translog model indicates that output effects are relatively small.</td></tr>
<tr><td>Cross elasticities</td><td>Cross price elasticities for rail ton-miles with respect to changes in road transport prices are presented in Table 40.

Table 40 Cross elasticities of rail ton-miles with respect to changes in road transport prices for five different functional forms
<table>
<tr><th rowspan="2"></th><th colspan="2">Translog</th><th rowspan="2">Log-linear</th><th rowspan="2">Linear</th><th rowspan="2">Box-Cox</th><th rowspan="2">Logit</th></tr>
<tr><th>Ordinary</th><th>compensated</th></tr>
<tr><td>All commodities</td><td>0,498</td><td>1,190</td><td></td><td>0,059</td><td></td><td>-0,175</td></tr>
<tr><td>Fruit and vegetables</td><td>0,495</td><td>1,147</td><td></td><td></td><td></td><td>-0,466</td></tr>
</table>

The cross elasticities obtained from the logit model are negative. No clear explanation is given for this counter-intuitive result. According to the author the cross elasticities for the translog model seem to be</td></tr>
</table>

	favoured over the other models.
Additional remarks	
There is no scientific approved method for selecting the best model from a set of alternative models. Therefore the author ranks the models by using a evaluation of the models. This evaluation was based on a comparison of reasonableness of the signs and magnitudes of the parameters of the model and various elasticity estimates. The author concludes that the translog demand system clearly performs the best. The Box-Cox model is placed second in the overall ranking, and the log-linear model is a close third. The linear logit and linear regression models perform rather poorly.	

Windisch, E. (2009) A disaggregate freight transport model of transport chain and shipment size choice on the Swedish Commodity Flow Survey 2004/2005, MSc thesis, Delft University of Technology.	
Description of the study	
Dependent variable	Multinomial Logit and Nested Logit are used to model the choice of transportation chain and shipment size simultaneously. Mode of transportation is here the main mode of a transport chain. The modes taken into account are: lorry, vessel, rail, air, ferry. Arc elasticities are calculated in terms of number of shipments and number of tonnes.
Independent variable	Elasticities are calculated by increasing the total cost for the shipment for each transport chain alternative by 10%.
Research method	Disaggregate freight transport model (Multinomial Logit and Nested Logit), which model the choice of transportation chain and shipment size simultaneously by incorporating both choices in the endogenous choice set (logistics perspective). Decision makers of the modelled choices are sending firms or their commissioned shippers. The model comprises a logistics perspective by: - modelling the shipment size (decisions relating to inventory strategies are endogenous); - modelling the configuration of delivery chain (number of legs, mode used for each leg); - incorporating a holistic cost approach, which accounts for all assessable logistics costs of the delivery process. Arc elasticities are calculated, based on the model, in terms of number of shipments and number of tonnes.
Response mechanisms included	

Fuel efficiency	Change fuel efficiency vehicle	No	Change fuel efficiency driving	No
Transport efficiency	Optimizing allocation of vehicles to shipments	No	Change in consolidated shipments	No
	Change in number and locations of depots	No	Change empty driving	No
	Change in shipment size	Yes	Change in trip length (route planning)	No
Changes in transport volumes	Change in mode	Yes	Change in production volumes per location	No
	Change in production technology	No	Change in suppliers/customers (change in OD patterns)	No
	Change in commodity demand	No		
Additional remarks				
Description of empirical data				
Type of data	Disaggregate data. Revealed preference. Data set describing shipments (3 millions entries) on a disaggregate and individual level of the Swedish Commodity Flow Survey 2004/2005.			
Geographical scope + distance class	Sweden			
Type of goods	(see Cargo Type table below)			
Estimates of elasticities				

	Cargo Type
0	Liquid bulk goods
1	Solid bulk goods
2	Large freight containers
3	Other freight containers
4	Palletized
5	Pre Slung
6	Mobile self-propelled units
7	Other mobile units
8	Unknown
9	Other cargo types, boxes

Own price elasticities

Table 41. Cost elasticities based on MNL and NL models – num of shipments and num of tonnes. Elasticities by commodity type were not presented.

			10% increase of the total cost			
			Num of shipments		Number of tonnes	
Chain #	*Descr.*	*Main mode*	*MNL*	*NL*	*MNL*	*NL*
Ch1	Lorry	Lorry	-0.00693	-0.00009	-0.02259	-0.00003
Ch6	Lorry-Lorry-Lorry	Lorry	-0.56590	-0.12500	-1.43228	-0.40404

Table 42. Cost elasticities of shipments size alternatives (Wgt indicates the different weight categories from light to heavy)

+10%	Lorry	
	MNL	Nested
Wgt1	-0,0103	-0,7073
Wgt2	0,0076	-0,7588
Wgt3	0,0024	-0,8019
Wgt4	0,0002	-0,9302
Wgt5	0,0004	-0,8134
Wgt6	-0,0002	-0,8632
Wgt7	-0,0009	-1,2208
Wgt8	0,0004	-1,4384
Wgt9	0,0000	-0,7905
Wgt10	0,0000	0,1613
Wgt11	0,0000	0,5862
Wgt12	0,0000	2,2831
Wgt13	0,0001	1,4968
Wgt14	0,0000	0,0027
Wgt15	0,0022	2,6423

Cross elasticities

Additional remarks

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

Description of the study				
Dependent variable	Aggregate demand for various modes (probably measured in tons; not explicitly mentioned in the study). The modes under consideration are rail, regulated road transport and private road transport.			
Independent variable	Road and rail freight transport charges (probably measured in tons; not explicitly mentioned in the study).			
Research method	To estimate the point elasticities of road and rail freight transport a probit demand model was used. The exogenous variables included into this model are: value of the commodity, shipment size, freight charges, mean and standard deviation of transit time, reliability , firm location and sales. The own price elasticities for road and rail transport are derived from this demand model.			
Response mechanisms included				
Fuel efficiency	Change fuel efficiency vehicle	No	Change fuel efficiency driving	No
Transport efficiency	Optimizing allocation of vehicles to shipments	No	Change in consolidated shipments	No
	Change in number and locations of depots	No	Change empty driving	No
	Change in shipment size	No	Change in trip length (route planning)	No
Changes in transport volumes	Change in mode	Yes	Change in production volumes per location	No
	Change in production technology	No	Change in suppliers/customers (change in OD patterns)	No
	Change in commodity demand	No		
Additional remarks	In this study the receiver is considered as the decisionmaker. They cannot influence most of the transport efficiency measures, with the exception of shipment size. However shipment size is included as exogenous variable in the econometric model, and hence has not been a possible response mechanism. Also total production of goods and firm locations are fixed, which indicate that change in commodity demand and OD patterns are not included in the elasticities estimates.			
Description of empirical data				
Type of data	Two choice based, disaggregate data sets are used. One data set accounted for shipments by rail and exempt motor carriers, which occurred during the 1975-1976 period. The other data set contained shipments of a wide range of agricultural and industrial commodities, which occurred during the 1976-1977 period. Modes under consideration			

	are rail, regulated motor freight and private carrier. Both data sets contain empirical data.
Geographical scope + distance class	Data refer to intercity transport taken place in the USA. A wide range of lengths of haul are considered.
Type of goods	Twelve groups of commodities are distinguished: - unregulated agriculture - regulated agriculture - textiles and fabricated textiles - chemicals - leather, rubber and plastic products - stone, clay and glass products - primary and fabricated metals - machinery including electrical machinery - transport equipment - paper, printing and publishing - petroleum and petroleum products - lumber, wood and furniture
Estimates of elasticities	
Own price elasticities	Short-run price elasticities of road freight transport are presented in Table 43 A distinction is made between private and common road transport.

Table 43 Price elasticities of road freight transport

	Private road transport	Common road transport
Unregulated agriculture	-0,99	-
Regulated agriculture	-0,27	-0,32
Textiles and fabricated textiles	-0,43	-0,77
Chemicals	-2,31	-1,87
Leather, rubber and plastic products	-2,01	-2,97
Stone, clay and glass products	-2,04	-2,17
Primary and fabricated metals	-0,18	-0,28
Machinery including electrical machinery	-0,78	-0,04
Transport equipment	-2,96	-2,32
Paper, printing and publishing	-0,29	-
Petroleum and petroleum products	-0,66	-
Lumber, wood and furniture	-0,14	-

The size of the elasticities varies considerably across the commodity groups. In general, the larger freight charge elasticities are associated with those commodities where the ratio of transportation expenses tends

	to be high.
Cross elasticities	
Additional remarks	

Yin, Y., I. Williams and M. Shahkarami (2005), Integrated regional economic and freight logistics modeling: results from a model for the Trans-Pennine Corridor, UK, Paper presented at the European Transport Conference 2005, Strasbourg.				
Description of the study				
Dependent variable	Three dependent variables are distinguished - tonnes - tonnes- kilometres - trip length Modes of transport: 5 classes of different goods vehicle and rail			
Independent variable	Two types of changes are considered: - changes in the lorry tolls; - changes (+10%) in average payload per goods vehicle, with respect to vehicle-km by type of goods vehicle and road; and with respect to tonnes, tonnes-kms and trip length.			
Research method	Elasticities are estimated by using an integrated regional economic and freight logistic model for the Trans-Pennine Corridor in the north of England. The model aims to forecast the level of goods transport demand and to forecast OD movements of freight that takes due account of changes in the costs, in other supply characteristics of transport, any structural changes in the national and local economies and the influence of logistics decisions on transport demand.			
Response mechanisms included				
Fuel efficiency	Change fuel efficiency vehicle	No	Change fuel efficiency driving	No
Transport efficiency	Optimizing allocation of vehicles to shipments	No	Change in consolidated shipments	No
	Change in number and locations of depots	No	Change empty driving	No
	Change in shipment size	No	Change in trip length	Yes

			(route planning)	
Changes in transport volumes	Change in mode	Yes	Change in production volumes per location	Yes
	Change in production technology	No	Change in suppliers/customers (change in OD patterns)	Yes
	Change in commodity demand	No		
Additional remarks	The demand change taken into account in this study is modal shift, location and redistribution of domestic trades. The response of a change in the tolling needs to be considered as long term effect.			
Description of empirical data				
Type of data	Since elasticities are estimated by using a model, they are not directly based on empirical observations. However, the model is calibrated on empirical data (year 2001 in billion t-km and million tonnes for different modes), which implies that the elasticities are indirectly based on this empirical observations.			
Geographical scope + distance class	Trans-Pennine Corridor in England			
Type of goods	Distinction has been made only for different types (classes) of vehicles: changes in tonnes, tonne-kms and vehicle-kms are given for 5 road vehicle types (and rail), for the case of a 10% increase in the average payload.			
Estimates of elasticities				
Own price elasticities	Given the dependent and independent variables of the model, many relevant elasticities could be calculated using this model. However, only the following elasticities have been presented. Demand elasticity has been calculated as the ratio between the changes in lorry traffic levels (tonne-km) and the average lorry operating costs per tonnes-km, to the road tolls. The demand elasticity for road freight has been found equal to – 0.2 An increase in the average payload factor by 10% (to all road goods vehicle type and all non-bulk flows) leads to a fewer vehicles required to carry the same amount of tonnes, but also a decrease in the cost shared by each tonne-km. The change in vehicle-km travelled by aggregated type of goods vehicle and roads is - 3%, increase in tonne-kms by 2%.			

Cross elasticities	
Additional remarks	

Appendix C: Background data

Table 44 **Data on domestic truck tonne-kilometres and transported tonnes for Germany**

	Gewerblicher Verkehr		Werkverkehr	
	Insgesamt Beförderte Gütermenge 1000 t	Beförderungs-leistung Mill. Tkm	Insgesamt Beförderte Gütermenge 1000 t	Beförderungs-leistung Mill. Tkm
1997	1478210	133284	1421721	70316
1998	1440264	141744	1440425	68462
1999	1531049	153426	1552534	69835
2000	1460740	155582	1440411	68659
2001	1395263	159313	1373621	73466
2002	1368785	160227	1238291	70939
2003	1430790	165950	1188040	70695
2004	1461499	171728	1163507	65240
2005	1533993	180495	1078647	61248
2006	1617911	190872	1140556	60567
2007	1749690	204094	1097585	57115
2008	1759021	204330	1136448	60500

Source: Statistisches Bundesamt, Wiesbaden 2009

Table 45 **Data on all truck tonne-kilometres and transported tonnes for Austria**

Year	Mln tonnes	Mln tkm
1980	245	15305
1981	245	15459
1982	241	15445
1983	236	15329
1984	231	15625
1985	225	15625
1986	229	16184
1987	227	16493
1988	234	17245

1989	242	17857
1990	259	18873
1991	284	20522
1992	297	21631
1993	309	22560
1994	319	23648
1995	332	25040
1996	341	26030
1997	351	27148
1998	364	28890
1999	380	30548
2000	386	31619
2001	396	32585
2002	404	33819
2003	423	35024
2004	430	36801
2005	438	36957
2006	454	37673
2007	463	41896

Source: Austrian Ministry of Transport, Innovation and Technology (2009)