The price sensitivity of road freight transport – a review of elasticities

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ABSTRACT

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. tonne kilometre price on tonne kilometres for mode choice responses) remains substantial. Here differences in type of data used, modelling methodologies and supporting assumptions may be at stake.

1. Introduction

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 and the Czech Republic), 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.)?

The purpose of the study presented in this paper is to provide estimates of price elasticities of road freight transport in the European context, based on a thorough review of results from the scientific literature. Reviews of price elasticities in freight transport exist (e.g. Oum et al., 1992; CE Delft and NEI, 1999 and Graham and Glaister, 2004), but new material has become available since. Moreover, we also try to explain why elasticities from the literature differ, by distinguishing between different types of elasticities and response mechanisms included. In doing this, we 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 provide bandwidths of price elasticities for all direct end-effects. In addition we also provide an estimate of the average European cross elasticity of road freight transport with regard to rail freight transport.

In this review we 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.
- 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. To show this dependence of elasticities on the type of goods transported, we will also present a further segmentation of elasticities as presented by some of the studies reviewed.

This paper is structured in the following way: in section 2 the methodology used is discussed. Potential reasons why elasticity estimates may differ are discussed. Section 3 provides the key results of the literature review. Finally, in section 4 the conclusions and recommendations on elasticity values are presented.

2. Methodology

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 paper we use the following general **definition** of elasticity (also see De Jong and Gunn, 2001):

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.

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 behavioural 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.

Variation in elasticity values

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

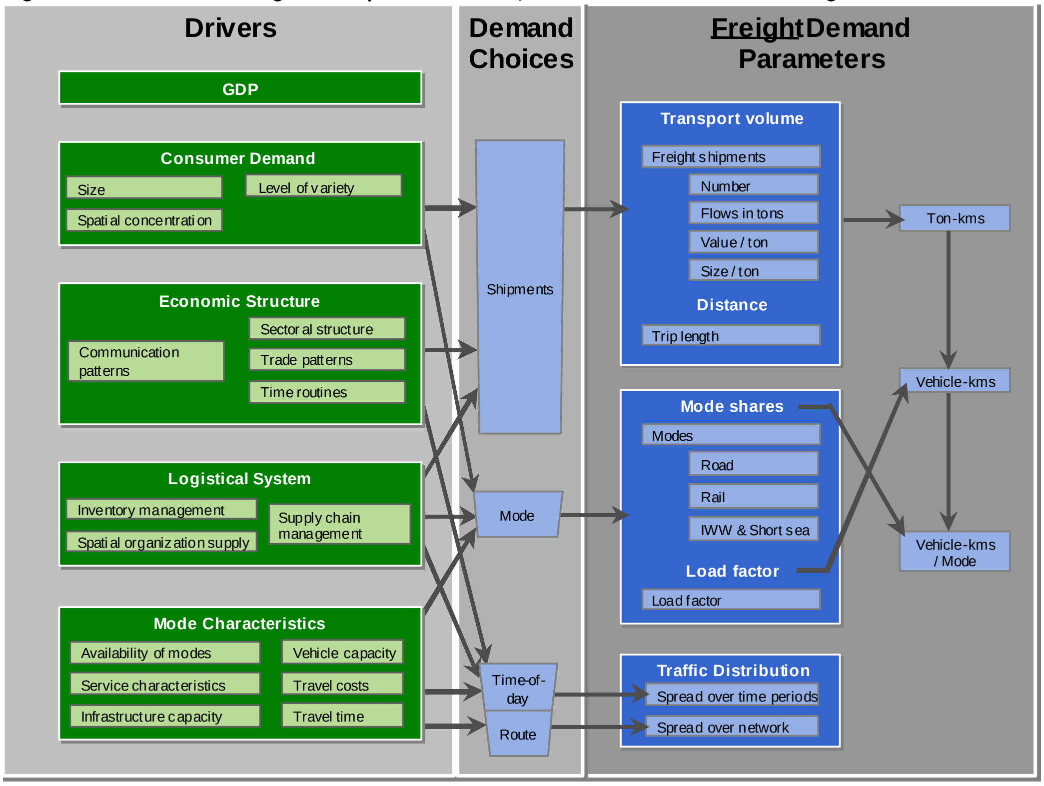
1. Different elasticities seem to be referring to the same thing, but are taking into account different response mechanisms, that may be working at different timescales. The response mechanisms for road freight transport are discussed below.
2. Price elasticities can be different because they refer to:
    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): a relative price change that refers to a larger component of total costs can be expected to have a bigger impact.
    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 (e.g. trip mode versus main mode of a transport chain).

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 paper 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.

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 1):

Changes in fuel efficiency

1. Fuel efficient vehicles: buying 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: changing the style of driving (more energy efficient driving).

Changes in transport efficiency (changing the load factor, which is the amount of goods measured in tonnes, divided by vehicle capacity

3. Optimizing the allocation of vehicles to shipments (e.g. acquire larger vehicles and group shipments, so that the same amount of tonnes can be transported with fewer vehicles).
4. Change 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).

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.

6. Consolidation:
    a. Consolidating shipments originating from the same company
    b. 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).

7. Getting more return loads to reduce empty driving.

8. More efficient route planning, given the sender and receiver locations (e.g. fewer detours).

Changes in transport volumes

9. Change of mode: substitution to and from rail, inland waterways, sea and air transport.
10. Changes in production technology (affecting the weight of the goods, e.g. trends towards lighter products).
11. Reducing kilometres per tonne by revising the 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.

12. Reducing kilometres per tonne by revising the 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.

13. Reduction in demand for the product.

Apart from this, there can also be 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).

Reactions 1-4 and 6-8 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 and 9-12 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).

Table 1. 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	C	S-M		X			X	
4	C/S	S-M		X			X	
5	S/R	S-M		X			X	
6 a	C/S	S-M		X			X	
6 b	C	S-M		X			X	
7	C	S-M		X			X	
8	C	S			X		X	X
9	S	M-L			X	X	X	X
10	S	L			X	X	X	X
11	S	L			X		X	X
12	S	L			X		X	X
13	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.

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 13).

The mechanisms 9, 10 and 13 will influence the number of tonnes transported by road transport. These mechanisms plus mechanism 3–7 will influence the number of vehicles used. Vehicle-kilometres by road are influenced by all of these mechanisms plus the trip lengths (mechanisms 8, 11 and 12). Tonne kilometres by road are influenced by mechanisms 8–13.

Many of these reactions (especially 10 – 12 and changes in vehicle technology) will only occur in the long run. Mechanisms 2 and 8 can be relevant in the short run and 1, 3-7 and 13 in the short to medium run, whereas 9 is most relevant in the medium long run.

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.

3. Results of the literature review

Structure of the literature review

We reviewed 36 scientific papers that contain road freight transport price elasticities (all primary studies, not themselves reviews). Each study was described using a fixed format (the outcomes are in: Significance and CE Delft, 2010). 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 response mechanisms (see Table 1) are included in the elasticity estimate?
- *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.*

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).

Outcomes for tonne kilometre price elasticities

Changes in tonne kilometre prices may result in various responses of the shipper:

- *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 2) we discuss the price sensitivity of these three effects separately.

Table 2. 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	1995	Tkm	9	-1.1 to –1.3
Bjørner & Jensen (1997)	Denmark	1967-1990	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
Inabe & Wallace (1989)	USA	1984	Tkm	5/9/12	-0.3 to –0.9
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
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
				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					
Abdelwahab (1998)	USA	1977	Tonnes	5/9/13	-0.75 to –2.53
Beuthe el al. (2001)	Belgium	1995	Tonnes	9	-0.6
Chiang, Roberts & Ben-Akiva (1981)	USA	70ties	Tonnes	5/9/12	-0.00 to –9.86
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	9oties	Tonnes	9/11/12	-0.15
NEA (2007)	Europe (Transtools)	Around 2001	Tonnes	9	-0.16 to –1.10; average: -0.42
Windisch (2009)	Sweden	2003-2004	Tonnes	5	0 to –1.4
				9	0
Winston (1981)	USA	1975-1977	Tonnes	9	-0.14 to –2.96

Effect on modal share of road transport					
De Jong & Johnson (2009)	Sweden	2001	Modal share	5/9	-0.03
García-Mendéndz et al. (2004)	Spain	1998	Modal share	9	-0.32 to –0.49
McFadden & Boersch-Supan (1985)	USA	1977	Modal share	5/9/10/11/12/13	-0.75
Nam (1997)	Korea	1988-1989	Modal share	9	0.12 to –0.25

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), Bjørner 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. Winston (1981) finds 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.

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) presents 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. 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.

In Table 2 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.

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: Bjørner and Jensen (1997) and Oum (1989). However, the results of both studies show large differences. Bjørner 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, Bjørner and Jensen present both elasticities of transport demand and mode change. From the estimates of Bjørner 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. It is not clear why these estimates differ so much from the estimates of Bjørner and Jensen. However, for Europe the figures from Bjørner and Jensen (ca.-0.4) seems more reliable.

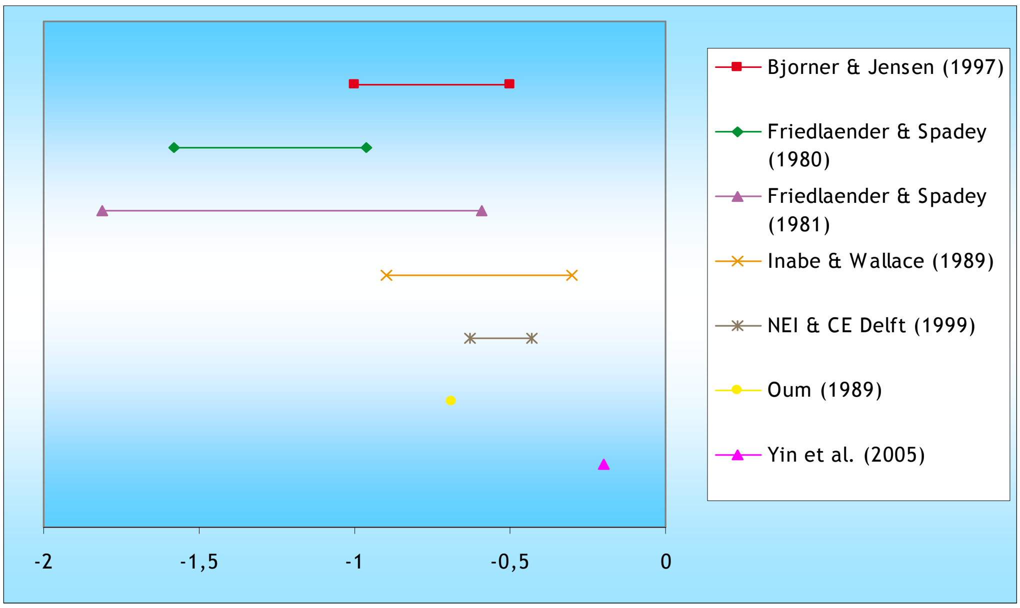
Changes in commodity demand

No studies are found that consider separately the effect of tonne kilometre price changes on commodity demand. In CE Delft and NEI (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 mode change, transport demand and/or commodity demand simultaneously 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: Bjørner 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 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. Bjørner & Jensen, 1997; NEI & CE Delft, 1999; Yin et al., 2005) these estimates are relatively high in absolute values. These results suggest that tonne kilometre price elasticities are higher in the North America than in Europe. Inabe & Wallace (1989), however, present 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 does 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 we 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 Bjørner 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.

Outcomes for vehicle kilometre price elasticities

Most price elasticities in freight transport refer to changes in the price per tonne kilometre (see above). Results for changes in the price per vehicle kilometre (vkm) are rather scarce (see Table 3). 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 3. Overview of road vehicle kilometre price elasticities on road vkm, tkm or transport demand

Study	Country	Period	Dependent variable	Response mechanisms	Elasticity
Bjørner (1999)	Denmark	1980-1993	Vkm	¾/5/6/7/8/10/11/12/13	-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 Bjørner (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.

Bjørner (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 (where he assumes: 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, we see that the vkm price changes lead to smaller mode and transport demand effects. This is plausible, because shippers and 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.

Outcomes for fuel price elasticities

Changes in fuel prices may lead to various responses of hauliers and/of shippers:

- *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 4). Therefore the results on fuel price elasticities should be interpreted carefully.

Table 4. Overview of road transport fuel price elasticities on road tkm, vkm or diesel consumption

Study	Country	Period	Dependent variable	Response mechanisms included	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	½/3/4/5/6/7/8/9/10/11/12/13	-0,05 to –0,14
			Vkm	½/3/4/5/6/7/8/9/10/11/12/13	-0,3
IEA (1994)	EU	1965-1991	Tons diesel	1(?)/2/3/4/5/6/7/8/9/10/11/12	-0,4

Total fuel demand

The literature review provides only one study that presents 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 CE Delft and NEI (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) mentions 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, both studies were not available for the literature review. Therefore it is not clear which response mechanisms are included. However, the results of both studies correspond with 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 tonne kilometres. First, Hemery and Rizet (2007) 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 tonne kilometres. They found values of –0.05 to –0.3. So, fuel price elasticities on tonne kilometres range from –0.05 to –0.3.

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 5. Overview of road tonne or tkm price elasticities by commodity type

Study	Country	Effect	Commodity type	Response mechanisms included[ab]	Elasticity
Abdelwahab (1998)	USA	Tkm 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 scraps		-1.67
			Metallurgical products		-2.09
			Minerals and building materials		-0.98
			Fertilisers		-0.72

			Chemical products		-1.1
			Diverse products		-1.18
		Tkm price on tonnes	Agricultural products and animals		-0.95
			Food		-0.65
			Solid fuel		-0.39
			Petroleum		-3.98
			Iron ore and scraps		-1.47
			Metallurgical products		-1.98
			Minerals and building materials		-0.77
			Fertilisers		-0.7
			Chemical products		-0.77
Garcia-Mendendz et al. (2004)		Tkm price on modal share	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
Nam (1997)	Korea	Tkm price on mode choice	Textile	9	-0.002
			Paper		-0.25
			Chemicals		-0.11
			Basic metal		-0.21
			Earthenware		0.21
			Electrical houseware		0.09

NEA (2007)	Europe (Trans-tools)	Tkm price on tonnes	Agricultural products	9	-0.26
			Foodstuffs		-0.16
			Solid mineral fuels		-0.29
			Ores, metal waste		-0.66
			Metal products		-0.23
			Building minerals & material		-0.42
			Fertilisers		-1.10
			Chemicals		-0.24
			Machinery & other manufacturing		-0.22
			Petroleum products		-0.57

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 elasticities, 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 elasticities 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.

4. Conclusions and recommended values

By distinguishing between different dependent and independent variables and response mechanisms, a considerable part of the variation in price elasticity values for road transport found in the literature can be explained. But also a large amount of variation remains, that not only has to do with differences between commodity groups, distance class and study areas, but also with the quality of the underlying data and the research methods and supporting assumptions used.

The main quantitative results from the literature review on own-price elasticities are summarized in Table 6. These ranges apply to the European context. 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).

Table 6. 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.

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 review are the elasticity ranges presented above. We also carried out an exercise in which we tried to derive a single set of elasticity values for the European context 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;
- 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.

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 7.

Table 7. 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 in Germany and Ausria (Significance and CE Delft, 2010) 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.

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