On the generalized cost - demand elasticity of intermodal container transport

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Elasticities for freight transport in the context of mode choice are hardly available for markets in which intermodal container transport competes with truck only transport. These elasticities are expected to be different, however, from values found in the literature for traditional freight transport, as trucking is a complement to rail or inland waterway transport when used for pre- or post-haulage, but a substitute to these modes when used from the origin to the final destination. This paper presents direct and cross (generalized) cost elasticities for road and rail transport demand for continental intermodal container transport and constitutes an attempt to compare the elasticities for intermodal transport with those for general freight transport. We first look into the sensitivity of elasticities to the total length of the haul and to pre- and post-haulage distances by road using a stylized, theoretical model. The assumption about pre- and post-haulage distances in mode choice appears to be important, as elasticities for road transport in the context of intermodal transport chains can be half of the values currently used in a conventional mode choice situation without access or egress by road. Next we provide empirical values for the market of container transport using a European multimodal network model. The absolute values of the estimated elasticities follow a double trend when the cost for trucking is modified: they increase with the distance between the origin and the destination, but decrease with the length of pre- or post-haulage. In all cases, the values are estimated to be inelastic. Overall, the "complement" component of the computed elasticities for rail-road transport is estimated to be approximately 20% of the total impact.

Keywords: *elasticities, container transport, freight modeling, intermodal transport, mode choice*

1. Introduction

Rail-road (or barge-road) intermodal container transport is an alternative to road only container transport when the total generalized cost[4] of the intermodal trip is competitive in comparison to

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the total generalized cost of trucking. The attractiveness of the intermodal chain depends on the level of the transshipment costs, but also on the length (and thus the cost) of the pre- and post-haulages to and from the intermodal terminals. This paper aims at analyzing the sensitivity of the choice for rail-road container transport to the total distance of transport and the lengths of the initial and final haulage by road transport. The nature of these own and cross elasticities is understood to be different from traditional elasticities, as a change in the cost of trucking also influences the cost of the intermodal transport chain. In other words, the elasticity depends on the mix of substitution (when trucking is used along the whole route) and complementarity (when trucks are only used to/from the intermodal terminals) effects.

After a brief discussion on the available elasticities in the literature, the paper will present a first simple theoretical model, developed in a spreadsheet. The objective of this model is to understand the way the elasticities vary, knowing that trucking plays a double role of substitute for and complement to rail transport. Once the behavior of the elasticities understood, a more realistic and complex set of estimates will be presented over the whole European area, using "real world" relations embedded in an origin-destination (OD) matrix for container transport (NUTS 2 level, year 2005). The Nodus freight transport super network model (Jourquin and Beuthe, 1996) will be used in order to allow an analysis of connected and extensive road, railroad and inland waterway (IWW) networks, including more than 140 intermodal terminals. The model will firstly be limited to the comparison of rail-road container transport with truck-only container transport, in order to facilitate the comparison with the synthetic model. It will finally be enlarged to three modes, putting trucking in competition with intermodal rail and intermodal waterway transport. This provides novel elasticity values, specifically for the market of rail-road container transport in Europe.

2. Overview of existing elasticities for freight transport

There are quite a few published studies on freight transport demand elasticities, but very little is available on intermodal container transport. Reviews of some results were made by Oum (1992), Graham and Glaister (2004) and de Jong *et al*. (2010) on road transport elasticities. More recently, Beuthe *et al* (2014b) have summarized the existing literature and proposed some additional own computed elasticities for the Rhine market area.

It is well known that elasticities vary depending on the different transport markets and commodities, with their specific flows and services. Hence, the range of estimates found in the literature is wide. Furthermore, the data may be of different quality, based on observed statistics or generated through modeling, which may be a source of bias in analysis. As discussed in Beuthe *et al* (2014b), the following caveats must be considered among others:

- Aggregate data concern a mix of different flows and their analysis provides average estimates biased towards context specific commodities. In this paper, the simple stylized model helps to understand how the elasticities behave when the total haul and/or the post-haulage distances change for a single origin-destination pair. In this sense, the estimated values don't suffer from this caveat. However, the real world model assigns a complete OD matrix, so that the estimated elasticities are average values.

- The networks may be unevenly spread over space and impose unequal constraints on modal choice. However, the OD matrix that is used in our model only contains pairs between which it is always possible to choose between a road-only route and a realistic intermodal rail-road transport chain, so that the estimated cross-elasticities are not driven down.

- Elasticities derived from cross section data most often are conditional or partial elasticities, which neglect the induced effects of a price change on the transport's total volume. Induced effects are also neglected in both our models.

- Other modes may well react and adjust to pricing policies of a single mode, with effects that are generally ignored by lack of sufficient information, which is unfortunately also our case.

- Most estimated elasticities do not incorporate changes that could only incur in the longer run, like changes in location or investments in appropriate equipment. The long-term effects are also not captured by our model, as it estimates the impacts of a transport cost change using a given OD matrix for the year 2005.

- The classic multinomial logit model implies that the relative shares of two modes are not impacted by a change affecting another mode, a somewhat unrealistic assumption of independence of irrelevant alternatives (IIA). In the stylized model, only two modes are available (road and intermodal rail-road), so that the IIA problem doesn't occur. However, the real World model also suffers from this caveat, but only for the scenario in which road and rail-road transport solutions are competing with intermodal barge transport.

Different methodologies with different functional forms or alternative choice models may also induce biases. This is a difficult issue, since comparative analyses on the same data set are rare. Kim (1987) and Oum (1989) make such comparisons, testing various functional specifications. In these, and later comparisons, results from both aggregate and disaggregate models are discussed together. De Jong and Johnson (2009) and Windisch (2009) compare different models combining shipments sizes and mode choices. From one model to another, Oum, for instance, finds out that trucking own-price elasticities vary from -0.69 to -1.34. One must thus be aware that published elasticities cannot be taken as unique universal values, but that they have to be interpreted with caution. This is especially true for elasticities relative to intermodal container transport as they are less present in the literature. To some extent, the problem of main haulage and pre- post-haulages can be considered as similar to what can be found in the literature that handles transport chains, such as the paper of Windisch (2009) or in the Dutch national freight transport model BasGoed (de Jong *et al*, 2011). However, even if pre- and post-haulages are included in these models, their impact on the elasticities remains implicit. Ben-Akiva and de Jong (2013) contains a discussion of sensitivity analyses for the freight transport model for the Mobility Masterplan of Flanders that distinguishes road transport cost elasticities for the effect on tonnes by road (around 0) and for vehicle kilometres by road (around -1). They attribute the differences to the difference in shipment sizes, but also to the fact that shifts from direct road transport to transport chains like road-rail-road, count twice for road tonnage, but these have much shorter road distances than direct road transport.

The studies discussed above concern areas where intermodal transport only accounts for a very small share of all flows; therefore the results can only to a limited extent be regarded as representative for intermodal transport. One of the first studies available for the European intermodal transport market was carried out by STRATEC (Lobé, 2001) in 1999-2000. Examining 12 corridors in Europe, the study found that, although there are many factors influencing demand, price is still critical. Elasticities were found to be complex to derive and also highly dependent on the corridor. In his paper based on the European RECORDIT Research project, Ricci (2003) even came to the conclusion that any assumption about an average elasticity for intermodal transport in Europe is disguising a wide variation on different routes. However, using the output from Lobé, he deduced that an average cross elasticity (intermodal demand with respect to road price) might be of the order of 1.7. Elasticity estimates for inland waterways and short sea shipping based on the same study are 1.2 and 0.5, though the small sample size means the estimates are subject to a wide margin of error. As part of the European EXPEDITE

Research Project, RAND Europe (2002) proposes a series of own and cross price elasticities for trucking at different (long) transport distances in competition with intermodal transport. In the range between 500 and 1000 km, they obtain, when the cost of truck transport is changed, an own demand elasticity for road transport of -0.7 and a cross-elasticity with respect to price change in combined transport of 1.1. These figures are increased (in absolute values) to -0.8 and 1.2 if the total distance is higher than 1000 km. Note that these values are related to general cargo, and not specifically to container transport. At the same period, a report written for the French "Commissariat Général du Plan" (TN Sofres consulting, 2003) reviewed a number of French studies. It came to the conclusion that "credible" direct demand elasticities for combined transport, when the price of the latest changes, were in a range going from -0.45 to 1.7 and that, therefore, an elasticity of -1.0 should be used in further studies for the government. More recently, Rich *et al*. (2011) use a Scandinavian transport network model for road, rail and ships, covering Scandinavia and part of Occidental Europe, in which mode combinations are made possible. Five modes are considered: trucking, rail, ship, combined road-rail and combined road-ferry transport. They obtain elasticities in the range of -0.08 to -0.41 for combined transport. These values are very close (-0.40) to those published for combined transport by Marzano and Papola (2004), who set up a full multi-regional transport model for Italy, including the generation and distribution of flows. Note however that, in the latest papers, the assumptions concerning the complementary use of networks are unclear.

The few values that have been published gives some ideas on the level of the elasticities for intermodal container transport, seen as an integrated transportation mode, compared to the elasticities for the other modes, used alone. To our knowledge, the fact that a change in the (generalized) costs of trucking has, on origin destination relations between which trucking only and intermodal rail-road transport are possible, an impact on the choice for both modes, has never been explicitly estimated. In the remainder of the paper we will focus on the following question: what are the impacts of the total distance and the pre- and post-haulage distances by truck on the elasticities of intermodal container transport? When the cost of trucking is modified, both substitution and complementary effects are integrated and estimated, because trucks are used in both "mode" choices. When the cost for railway transport is changed, only a substitution effect can be estimated.

3. Understanding the elasticities for intermodal transport

Two approaches are used in this paper to estimate the elasticities for intermodal transport. The first is a simple, stylized model, by which we can systematically study the effect of changes in route share between road and rail-road on elasticities. The second concerns an empirical setting of a full European, multimodal freight network model. To provide comparable outputs, the same basic assumptions are made in both approaches. This will provide an understanding of realistic elasticity levels at system level, including an indication of the practical relevance of changing route shares.
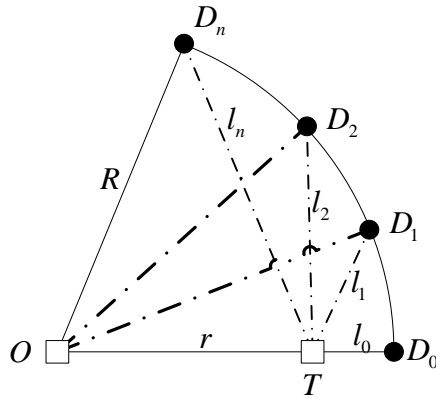
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Figure 1.   *Intermodal network consisting of truck-only and rail-road transport*

The stylized model is based on a simple theoretical single origin–destination relation, between which both road only and intermodal transport are possible, and is illustrated in Figure 1 by means of a fan-shaped diagram. Both O and T are terminals, and D_i $(i=0,1,\ldots,n)$ are various customers distributed around terminal T. R is road transport distance, and r is the rail transport distance within the rail-road transport route, and l_i $(i=0,1,\ldots,n)$ is the post-haulage distance.

In the above network, the post-haulage distance l_i is gradual increased, with a fixed R. We calculate road and rail-road elasticities for different R.

The generalized costs function can be denoted as:

$$C_g^{road} = a_{road}(h_{road} / f_{road} + e_{road}) \tag{1}$$

$$C_g^{rail-road} = a_{rail}(h_{rail} / f_{rail} + e_{rail}) + b_{rail-road}(h_{road} / f_{road} + g) + (d_{rail-road} + h_{rail}c_{rail-road}) \tag{2}$$

With

C_g^{road} and $C_g^{rail-road}$	: Generalized costs for road and rail-road transport, per loaded ton.
a_{road} and a_{rail}	: Truck-only and rail-only distances.
$b_{rail-road}$	: Post-haulage distances for rail-road transport.
$c_{rail-road}$	: Transshipment times for rail-road transport.
$d_{rail-road}$	: Transshipment costs for rail-road transport.
e_{road} and e_{rail}	: Transport costs for road and rail-road transport.
f_{road} and f_{rail}	: Transport speeds for road and rail-road transport.
g	: Post-haulage cost.
h_{road} and h_{rail}	: Value of time.

The mode shares S are calculated using the formulation proposed by Abraham and Coquand (1961), with an exponent set to -1. In other words, the shares are proportional to the (inverse of) the generalized cost of each alternative (Jourquin and Limbourg, 2007):

$$S_{road} = \frac{1/C_g^{road}}{1/C_g^{road} + 1/C_g^{rail-road}}, \; S_{rail-road} = \frac{1/C_g^{rail-road}}{1/C_g^{road} + 1/C_g^{rail-road}} \tag{3}$$

With S_{road} and $S_{rail-road}$ being the mode shares of road and rail, given that $S_{road} + S_{rail-road} = 1$.

These shares are computed for each origin-destination pair, and applied to the total quantity that must be transported on each relation.

Concerning the mathematical form of the representative utility function (RUF), Gaudry and Quinet (2012) recall that, after the publication of Abraham's random utility model (RUM) of road path choice deriving the Probit specification based on the Gaussian error distribution (and another specification based on the Rectangular error distribution), French engineers used this seminal approach as justification of road path choice formulae then in current use and assigned the name "Abraham's Law" to a particular standard one, effectively a "Logarithmic Logit" close to the logarithmic RUF carefully specified for Logit mode choice by Warner(1962). One can easily find the specification of the below model when the natural logarithm of costs is used as the argument in the Logit model's utility function.

The elasticities are given by eq.4 :

$$\varepsilon_{road} = \frac{\ln(S_{road}^A) - \ln(S_{road}^B)}{\ln(C_{gA}^{road}) - \ln(C_{gB}^{road})}, \quad \varepsilon_{rail-road} = \frac{\ln(S_{rail-road}^A) - \ln(S_{rail-road}^B)}{C_{gA}^{road} - C_{gB}^{road}} \tag{4}$$

With ε_{road} and $\varepsilon_{rail-road}$ being the elasticities of road and rail-road transport.

Combining eq. 3 and eq. 4 to a new equation 5:

$$\varepsilon_{rail} = \frac{\ln((1 + C_{gB}^{road} / C_{gB}^{rail-road}) / (1 + C_{gA}^{road} / C_{gA}^{rail-road}))}{\ln(C_{gA}^{road} / C_{gB}^{road})},$$

$$\varepsilon_{rail-road} = \frac{\ln((1 + C_{gB}^{rail-road} / C_{gB}^{road}) / (1 + C_{gA}^{rail-road} / C_{gA}^{road}))}{\ln(C_{gA}^{road} / C_{gB}^{road})} \tag{5}$$

The assumptions concerning costs of transport (Table 1) used in the model are those published by Limbourg and Jourquin (2010).

Table 1.   Input used in the models

Network attributes of transport modes	road (truck-only)	Intermodal rail -road
a. Main distance (km)	R=(200,250,…,1500)	r=R-5
b. Post-haulage distance (km)	n.a.	L=(5,10,…,200)
c. Transshipment time (hours)	n.a.	12
d. Transshipment costs (€/ton)	n.a.	2.27
e. Transport tariff (€/ton.km)	0.072	0.042
f. Transport speed (km/hour)	50	30
g. Post-haulage tariff (€/ton.km)	n.a.	0.105
h. Value of time (€/ton/hour)	1	1

When the generalized costs for road transport is decreased by 5%, the maximum absolute value of both own-elasticity of road transport and cross-elasticity of rail-road transport are -0.51 and 0.61, respectively. Figures 2a, 2b and 3 show the trends when post-haulage and main distances vary.
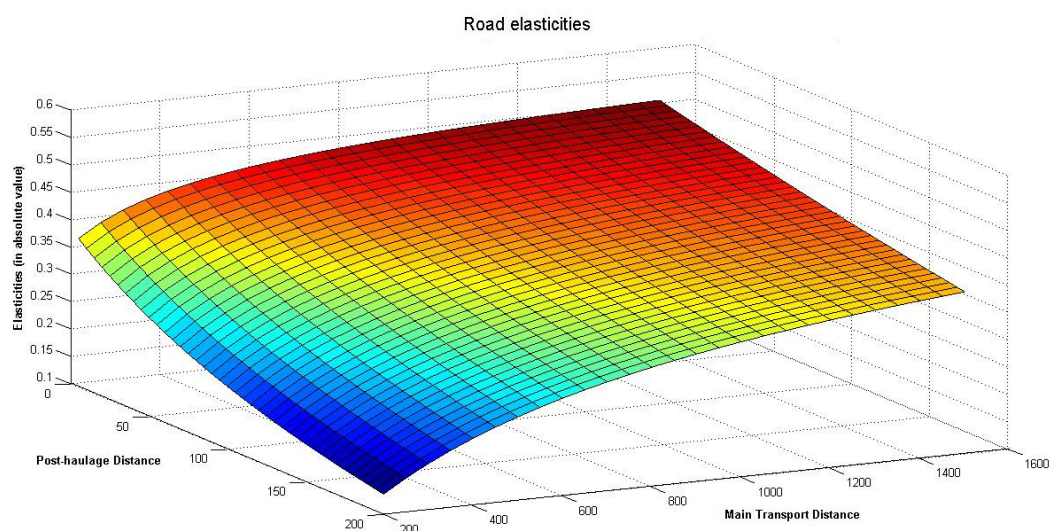
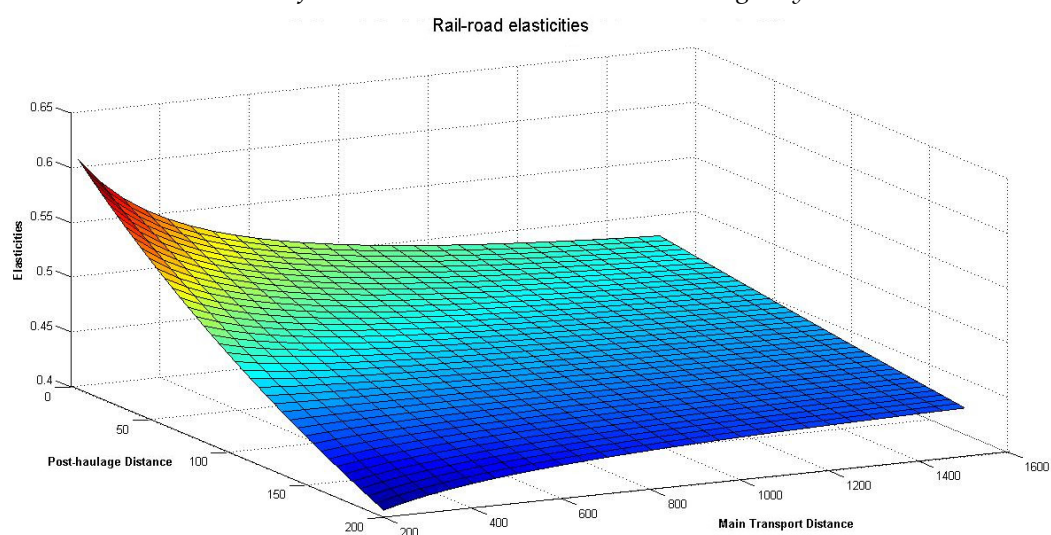*Figure 2.   Absolute values of road elasticities when road costs changes by -5%*

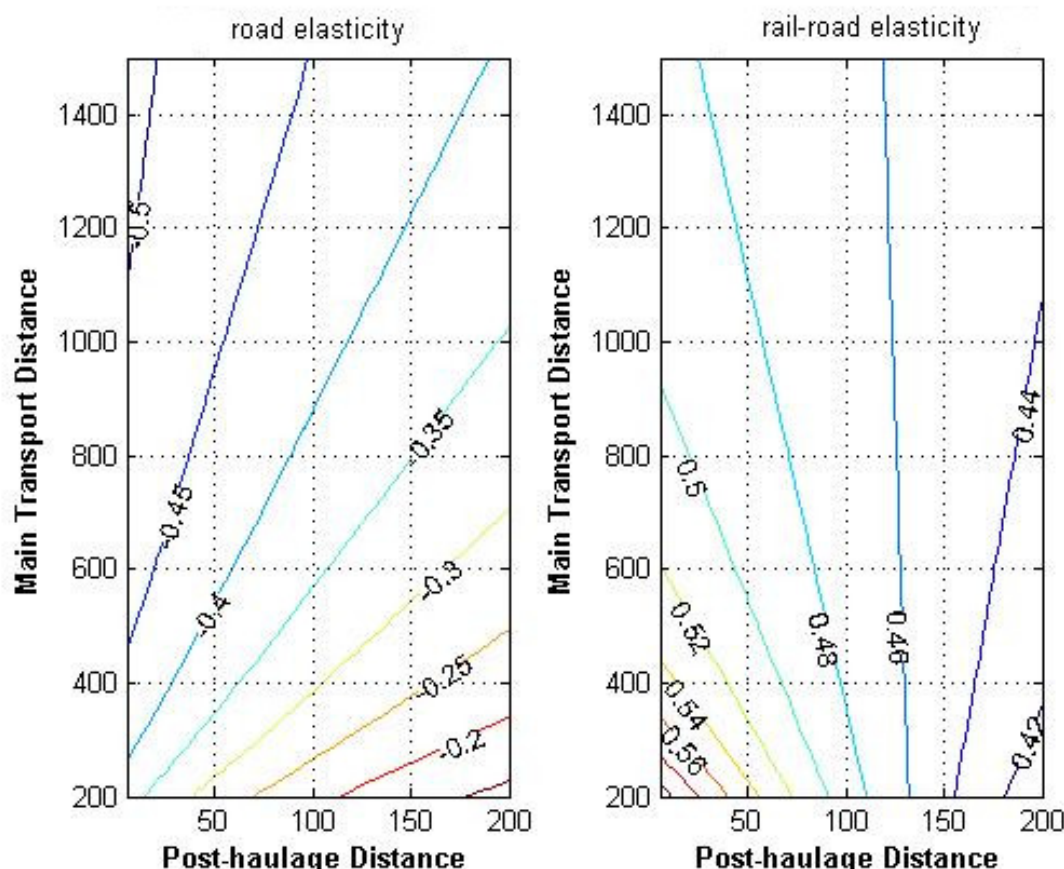*Figure 3.   Rail-road elasticities when road costs changes by -5%*

Figure 4.   *Elasticity isograms when road costs are reduced by 5%*

Figures 2a, 2b and 3 show how a -5% change of road costs increases the modal share of this mode. These graphs show a number of things:

- As expected, the impact of cost changes of road transport on the modal split is less strong with multimodal transport than in the case of competing single modes, as post-haulage by truck acts as a complement to rail transport and affects the cost of the intermodal routes as well.

- Own elasticities for road transport vary between about -0.5 and -0.2. The former are in line with typical values from the literature for mode choice (de Jong *et al*, 2010) and are reached for longer transport distances, without road as egress mode. In absolute values, elasticities become lower with increasing total transport distance and with longer egress distance. In competition with intermodal transport, road transport elasticities are less than half of the conventional choice elasticities.

- Cross-elasticities for intermodal transport lie between 0.4 and 0.6, depending mostly on post-haulage distance, and less on total transport distance. A longer transport distance may imply higher or lower elasticities, depending on the egress distance. In practice, egress distances will be below 150km, and cross-elasticities will lie around 0.5.

4. Elasticity estimations for European container transport

Now that we have a better insight in the way elasticities behave when the haulage and access/egress distances vary, we can setup a more complex empirical model. We use the Nodus software (Jourquin and Beuthe (1996) and Jourquin and Limbourg (2007)), which was already

used to describes the trans-European freight network for all inland modes of transport. For the model created for this paper, specific cost functions are used for intermodal transport, including transshipment costs fore containers, and the OD matrix is an estimation of container flows to and from the ports of Antwerp and Rotterdam, as setup in the framework of the European FP7 ECCONET project (Beuthe *et al*, 2014a). Each origin or destination corresponds to the centroid of a NUTS 2 region. These centroids are always connected to the road network. Connectors to the railway or waterways network exist only if the corresponding NUTS 2 region can be deserved by these modes. In the model that is set-up for this paper, railway (or inland waterway transport) is never used as a single mode from the origin to the destination, but always in combination with trucking.

The basic data was a set of OD matrixes, split by mode and by NST-R groups of commodities. Container flows were "extracted" from the each NST-R chapter in order to create an additional category of goods. The global market shares for road and rail-road in this new category were estimated respectively to 84% and 16%. When inland waterways transport is also considered, the same market shares are estimated to 59% and 11%, the remaining 30% being transported by barges. We have thus three matrixes for containers. Those for road and railway transport are merged and the resulting matrix is used as input for the Nodus model. Later in this paper, the possibility to use also intermodal IWW-Road transport will be introduced. Therefore, the three matrixes for containers will be merged.

So, between each OD pair, two alternative routes are computed: trucking only and intermodal rail-road. Intermodal transshipments are possible at one of the 143 terminals included in the digitized network and spread over the European continent. At the two ports, we have considered that there is no pre- or post-haulage by truck. To be inline with the stylized model described above and the methodology used in Beuthe *et al* (2014b), the flow between each OD pair is distributed among the modes according to their relative generalized costs. More precisely, the share of modes is calculated using the formulation of Abraham and Coquand (1961) as discussed above. For each of the sub-markets that will be presented, the model has been calibrated on observed market shares, expressed in loaded tons per mode in the OD matrix. Once the model calibrated for the whole market for road and rail-road intermodal transport, the r^2 computed when comparing the estimated market share to the "observed" one in reference matrixes, on a per OD basis, is equal to 0.95. Although this calibration of a comprehensive empirical model may result in other elasticities than those of a stylized model, the patterns observed should remain consistent.

Figure 4 illustrates a typical case, between the port of Antwerp (Belgium) and the city of Trier (Germany). There is a direct trucking-only route, but also an intermodal itinerary using the railway between Antwerp and the terminal of Bettembourg (Luxemburg), with a post-haulage by road between Bettembourg and Trier. Obviously, other alternative road and rail-road routes often exist between an origin and a destination. We decided however to keep only the cheapest itinerary for both modes, so that the network model remains easily comparable to the synthetic one presented in section 3.

The arc elasticities (comparing the market shares at the reference cost with the one at the modified costs) are also computed for a -5% change of trucking costs. Estimates are provided for different sub-markets. Indeed, beside the complete matrix, the traffic to/from Antwerp and Rotterdam were analyzed separately. Further, the matrix was split into three subsets, according to the total length of the trip, using thresholds set to less than 200km, between 200 and 700 km and above 700 km. These values were retained in order to keep roughly one third of the volume of the total matrix in each sub-matrix. This limits the bias that could be introduced in the elasticity calculation if the volumes in each class were really different. Table 2 presents all the obtained elasticities, and it appears that they are stable across the subsets. In all the cases, intermodal rail-road transport is also inelastic to a variation of the cost of trucking.
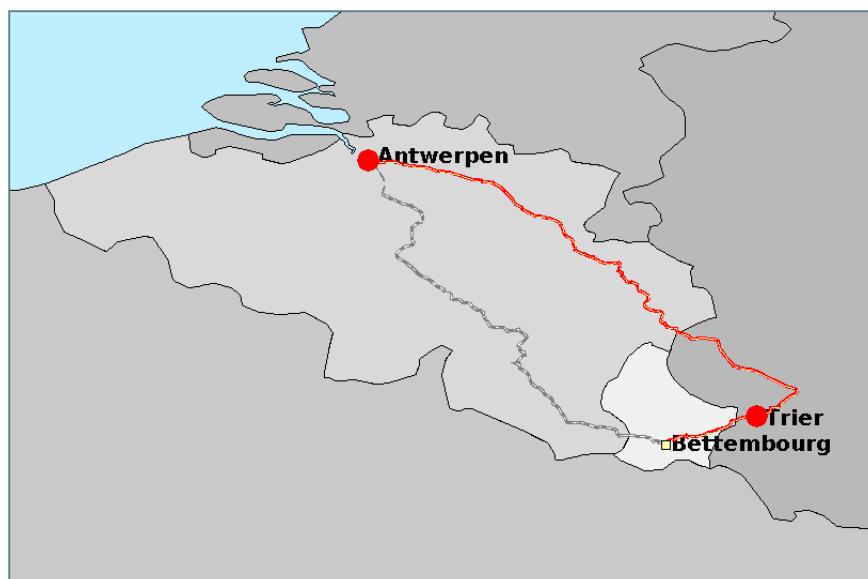
Figure 5.   Antwerp –Trier by road and by rail-road via Bettembourg

Table 2.   Elasticity for total haulage distances (road cost -5%)

	All	Antwerp	Rotterdam	Short haul	Medium haul	Long haul
Road	**-0.14**	-0.16	-0.10	-0.10	-0.14	-0.19
Rail-Road	**0.70**	0.81	0.56	0.54	0.71	0.98

It must be clear that these elasticities are computed with a 5% decrease of the cost of road transport, including the pre- and post-haulage movements by road for intermodal routes. If this cost reduction is not applied to these initial or final chunks, the elasticities (for the whole matrix, represented by the "All" column in Table 2) become respectively -0.16 and 0.85. These latest figures can be considered as including only the substitution effect between the two modes, and their (absolute) values are thus higher. The "complement" effect introduced by the fact that a change in the cost of road transport also impacts the cost of pre- and post-haulages can be estimated as being 0.15 (0.85–0.70) for intermodal transport, which corresponds to more than 20% of the "substitute only" elasticity.

Table 3.   Elasticity per Pre- Post-Haulage (PPH) distance, road cost -5%

	Short PPH	Medium PPH	Long PPH
Road	-0.19	-0.12	-0.05
Rail-Road	0.97	0.66	0.29

Table 4.   Elasticity per Pre- Post-Haulage (PPH) distance, rail cost -5%

	Short PPH	Medium PPH	Long PPH
Road	0.11	0.14	0.13
Rail-Road	-0.54	-0.70	-0.72

In a second set of sub-markets (Tables 3 and 4), the OD matrix is split according to the pre- and post-haulage (PPH) distance. Here also, we tried to keep roughly one third of the total matrix in each subset. Therefore, the following thresholds were used: a PPH distance of less than 10 km, a "medium" class between 10 and 60 km, and a PPH length of at least 60 km.

In table 2, the average own elasticity for road transport on the total market is estimated to -0.14, but varies from -0.10 to -0.19 with the total length of the haul. Table 3 shows that the sensitivity of the modal choice decreases with the length of the pre- post-haulage (from -0.19 to -0.05). Note that when the cost of the railways is changed (Table 4), the own-elasticity of this mode increases (in absolute value) with the length of the PPH, while the impact on road transport remains almost stable.

Rail-road intermodal container transport is more sensitive than road only transport to a change in the cost of trucking, although the demand remains inelastic, with an aggregated value of 0.70. The values also follow the same double trend described earlier, varying from 0.54 to 0.98 with the total distance from origin to destination, but decreasing from 0.97 to 0.29 with the length of the pre- or post-haulage.

Finally, we have also computed the elasticities when trucking only is put in competition with rail-road and IWW-road transport (Table 5).

Table 5.   Elasticity for the three modes model (-5% of trucking costs)

Mode	ε
Road	-0.28
Rail-Road	0.61
IWW-Road	0.31

It appears that intermodal IWW-Road transport is more inelastic than rail-road transport. This is probably due to the fact that the IWW-Road combination is only possible on a relative small area of the European continent and that IWW is much cheaper, making it less sensitive to a variation of the cost of trucking.

5. Conclusions

When intermodal transport competes with road only transport, trucks play two different roles. When they are used from the origin to the final destination, they are considered as substitute to rail (or inland waterway) transport. However, when they are used for pre- or post-haulage to intermodal transshipment terminals, trucks and trains are complements within the intermodal transport chain.

Although the presented methodology has its limits (no induced effect of a cost change on total demand, no endogenous price equilibrium mechanism between modes and a somewhat unrealistic assumption of independence of irrelevant choice alternative), this paper examines the elasticities that can be estimated for this particular market. As could be expected, own elasticities for road appear to be lower when the intermodal transport market is considered. The general trends are briefly explored with a simple synthetic model, and confirmed using a more complete network model based on realistic demand data and networks.

As existing literature is rather scarce in this domain, the results are difficult to compare with other sources. They can be confronted to published values, varying within the range of 0,08 to 1,7 for intermodal transport, when the cost/price of trucking is modified. Within this range, the most recent estimations are provided by Marzano *et al.* (2004) and by Rich *et al.* (2011) and are close to 0.4 in average, while our estimations vary between 0.29 and 0.98, depending on total length of the trip and the pre- or post-haulage distance. Our estimations for own truck elasticities can also be compared to recent values estimated by Beuthe *et al.* (2014b), who used similar data, networks and methodology, but didn't treat container transport explicitly as an intermodal chain including transshipment facilities at container terminals. As expected, the absolute value of our estimation is lower (-0.14 vs -0.42), as a reduction of trucking costs also benefits to intermodal transport (complementary effect).

Beside these elasticities, both our synthetic and our complete network model yield as result that the absolute values of the estimated own elasticity for road follow a double trend when the cost for trucking is modified: it increases with the distance between the origin and the destination, but decreases with the length of the pre- or post-haulage. In all cases, road transport appears to remain inelastic (elasticity < -1.0). It is also the case for intermodal transport, which is also in line with recent literature.

Finally, the "complement" component of the computed elasticities for rail-road transport is estimated to represent approximately 20% of the total impact. In other words, because a reduction of road transport costs also benefits to intermodal transport, the elasticity of the latest is less impacted (about 20%) than if the haul was performed by rail only. Unfortunately, this value cannot be compared to any other as, to our knowledge, this has never been addressed in any paper.

Future work could go into the effect of alternative methods for mode choice modeling, including more sophisticated cost functions. The value of time could for instance depend on the content of the containers. The transshipment costs could also be differentiated according to the used container terminal or more precisely described for what happens into the ports of Antwerp and Rotterdam. Also, instead of a market segmentation based on total haul length or pre- post-haulage length, a more detailed understanding of market segments of intermodal transport (corridors, content of the containers, reverse logistics of empty containers…) could be valuable to support a more detailed design of freight transport policy on specific corridors.

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