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Endogenous transport prices and trade imbalances

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Abstract

According to economic theory, imbalances in trade flows affect transport prices because (some) carriers have to return without cargo from the low demand region to the high demand region. Therefore, transport prices in the high demand direction have to exceed those in the low demand direction. This implies that transport costs, and therefore trade costs, are fundamentally endogenous with respect to trade imbalances. We study this effect using transport prices for the inland waterway transport market in north-west Europe. We find that imbalances in trade flows have substantial effects on transport prices. We estimate that a one standard deviation increase in the trade imbalance from region A to region B decreases transport prices from A to B by about 8 percent.

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1. Introduction

Transport costs play a fundamental role in the determination of the location of regional economic activities (see, e.g., Krugman, 1991, 1998; Ottaviano and Puga, 1998; Neary, 2001). A characteristic assumption in studies of regional activities is that transport costs are exogenous. However, recently, a number of studies have emphasized that transport costs may be endogenous. For example, Behrens et al. (2006) introduced the presence of density economies into a new economic geography model by assuming that unit shipping costs decrease with the aggregate volume of trade. Endogeneity of the transport costs is clearly also important for studies on international trade. For example, Anderson and van Wincoop (2004) stress the need to deal with this issue in studies of trade. [1]

There are a number of reasons why transport costs may be endogenous (for recent studies which discuss this issue, see Duranton and Storper, 2008, and Anderson, 2008). One reason is that the unit shipping costs decrease with the volume of trade due to the presence of density economies (as assumed by Behrens et al., 2006). The current article emphasizes, however, that the endogeneity of transport costs is perhaps even more fundamental, as is prominently featured in transport economic textbooks such as Boyer (1998). The main reason is that, at least theoretically, an imbalance in terms of trade volumes between two regions causes the transport price in one direction to exceed the price in the opposite direction when *a positive proportion of carriers are required to return without paid cargo*.[2] One of the implications is that, ceteris paribus, unit shipping costs increase with the relative volume of trade between regions, implying that the transport costs increase with trade (as opposed to the assumption by Behrens et al. 2006).

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[1] Note that, although transport costs, i.e. the physical costs of a shipment, are only a share of trade costs, i.e. the sum of all the costs incurred to deliver a good to its user (Duranton and Storper, 2008), transport costs are generally thought to be the most important trade cost *within* countries and one of the most important components of trade costs *between* countries**.** This certainly applies to trade within the EU where artificial trade barriers are absent or limited. According to Sánchez et al. (2003) and Limão and Venables (2001), artificial trade barriers are reduced to low levels as a result of trade liberalization. Therefore, it is plausible that the relative importance of transport costs in total trade costs has increased in recent decades.

[2] For an early discussion of this phenomenon, usually called the “backhaul problem”, see Pigou and Taussig, 1913.

It is therefore theoretically ambiguous what the net effect is of a change in the traded volume on trade costs as it depends on what type of effect dominates. In one market, the net effect may be negative while for other markets it may be positive.

In the current study, we focus on price formation in a spatial inland waterway transport network. In this network, imbalances in transport flows are frequently observed. Imbalances are caused by regional differences in demand and supply for transport. For example, in Europe, most seaports, such as Rotterdam and Hamburg, are import ports of, in particular, bulk goods such as oil, coal, etc. This implies that more cargo is transported from the seaports to the hinterland than in the opposite direction, which causes an imbalance in trade flows.

This is not the first study to focus on endogenous transport prices.[3] We are aware of four studies in which the effect of an imbalance in transport flows on maritime shipping prices has been examined empirically (Blonigen and Wilson, 2008; Wilmsmeier et al., 2006; Márquez-Ramos et al., 2005; Clark et al., 2004). However, in these studies, the imbalance is assumed to be exogenous, which is at odds with theory.[4]

We estimate the marginal effect of an imbalance in transport flows on the unit transport price of a trip between two locations (regions) in the inland waterway transport market in north-west Europe. Some major differences between the current study and the four transport price studies mentioned above must be mentioned. First, these studies only use information on imbalances of bilateral routes, while we also take into account characteristics of the whole network. Hence, we are able to employ a standard and a sophisticated measure of imbalance. Second, to our knowledge, we are the first to consider imbalance as an endogenous variable. Third, we empirically capture density economies in a different, and arguably more fundamental, way than Clark et al. (2004) and Márquez-Ramos et al. (2005). According to theory (see, for example, Brueckner et al., 1992), density economies arise because a higher traffic density on a route allows the carrier to use larger vessels and to operate this equipment more intensively (at higher load

[3] There is an extensive literature, mainly focusing on maritime transport, in which the determinants of transport prices are analysed, but imbalances in transport flows are usually ignored.

[4] Clark et al. (2004) and Márquez-Ramos et al. (2005) allow for density economies by including aggregate trade volume as an explanatory variable and treat trade volume as an endogenous variable.

factors). In addition, higher traffic densities on a route allow for a more intensive and efficient use of the port facilities that serve that route implying lower time costs per unit handled. As we have a very rich data set, we are able to capture density economies more directly by three trip-specific control variables: vessel size; load factor; and travel time.[5] Fourth, our study concerns inland waterway transport, while previous studies focus on the maritime transport sector.

The importance of inland waterway transport as part of the overall transport sector for the regional economy is determined by geographical constraints. Only in those regions where the natural infrastructure offers sufficient opportunities does inland waterway transport play a significant role in inland transport. Examples of such regions include parts of Europe (the rivers Rhine, Danube, and their tributaries), the US (the Great Lakes area and the Mississippi river) and China (the Yangtze and the Pearl River).

The river Rhine is the most important trade river in Europe as it connects large economically important areas within and between the Netherlands and Germany.[6] This river has its source in Switzerland in the Alps and runs through the Ruhr area, one of the most industrialized areas in Germany, to Rotterdam, in the Netherlands, one of the world's major seaports, where it flows into the North Sea. In 2005, 58 percent of all bilateral inland trade, measured in tonnes, from the Netherlands to Germany, was transported by inland waterways.

[5] The travel time of a trip includes the time of loading, transporting, and unloading the cargo. As higher volumes are usually handled in large ports with more efficient handling facilities, this implies relatively short (un)loading times, leading to shorter travel times.

[6] The Netherlands and Germany are neighbouring countries, with a population of 16 million and 82 million, respectively. Trade between these countries is intensive. In 2005, Germany was the most important export country for the Netherlands, and the Netherlands was the fifth export country for Germany. Note that data on levels of trade between two countries may differ from levels of transport flows because of *transit* flows (as trade between two countries may be directed via a third country). Between Germany and the Netherlands, transport flows exceed export and import flows, but the difference is not, however, very substantial (Statistics Netherlands, 2008).

In the opposite direction, inland waterway transport accounted for 41 percent (CBS, 2008; TLN, 2007).[7] So, an understanding of price formation in the inland waterway transport market is fundamental to understand the endogeneity of transport costs between the Netherlands and Germany.

Next, in section 2, we outline the basic theory on transport price formation when imbalance in transport flows is present. We discuss this issue in a perfectly competitive environment. Section 3 describes the data and formulates the model. Section 4 presents the results, and, finally Section 5 makes some concluding remarks.

2. Theory

In this section, we will first discuss the relationship between transport prices and imbalances in transport flows in a two-region network, as featured in transport economic textbooks, which is usually called the “backhaul problem” (see, for example, Boyer, 1998, p. 253). We will only focus on price formation for the physical activity of transporting goods between regions, ignoring other relevant costs such as loading costs, insurance, etc, which are exogenous in this setting. It is explained that, in equilibrium, imbalances in transport flows will affect transport prices, such that the transport price from region A to region B depends negatively on the imbalance of trade flows between these two regions, measured by the ratio of the number of trips from B to A to the number of trips from A to B.

It is then argued that measuring imbalance in this way may be incorrect in a multi-region network. This is particularly the case when some carriers do not move back and forth between the same two regions, but transport goods between more than two

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[7] In 2005, 127 million tonnes were transported from the Netherlands to Germany, and 73 million tonnes were transported from Germany to the Netherlands by road, rail and inland waterways. This implies an overall imbalance proportion of 73/127 = 0.57. If we only focus on inland waterway transport, 74 million tonnes were transported from the Netherlands to Germany and 30 million tonnes in the opposite direction, so the imbalance proportion that concerns only inland waterway transport is equal to 30/74 = 0.41. For the survey data used in the current article, we find an imbalance proportion of 0.49 for inland waterway transport between the Netherlands and Germany, indicating that our data is quite representative for the whole market.

regions. We will proceed by arguing that, in a multi-region network, a more appropriate measure of imbalance is at the level of the region, taking into account the distances between regions. Further, it is argued that, in the standard analysis, time-variation, and therefore uncertainty in imbalance is absent. We will show that, under some reasonable conditions about uncertainty in demand, the time-variation in imbalance will *not* affect time-variation in the transport price.

The textbook explanation that prices depend on imbalances in transport flows is straightforward. It presumes a competitive transport market (with a perfectly elastic supply curve) in a two-region economy. Suppose there is demand for transport between regions A and B. The inverse (downward-sloping) demand function is denoted as p_{ij} (x_{ij}), where x_{ij} denotes the demand in region j for goods from region i (i,j = A, B; $i \neq j$). Goods are transported by carriers. The number of tonnes transported by a carrier is standardized to 1 (so the load factor is either 0 or 1). In this network, each carrier must make a return trip, and hence, in equilibrium, under perfect competition, the following condition must hold:

$$p_{AB}\,(x_{AB}) + p_{BA}\,(x_{BA}) = 2c,$$

where c denotes the one-way cost of transporting between regions for a carrier. In the context of transport, it is reasonable to assume that the inverse demand function drops to zero for a quantity $x_{ij}*$.[8] This means that there exists a finite quantity $x_{ij}*$ for which $p_{ij}(x_{ij}*) = 0$, so given the assumptions, it follows that, in equilibrium, there are three possible regimes with positive trade flows in both directions[9]:

$$x_{AB} > x_{BA} = x_{BA}*;\;\; p_{AB}\,(x_{AB}) = 2c;\;\; p_{BA}\,(x_{BA}) = 0,$$

or

[8] This assumption is reasonable because the demand for transport is a derived demand for goods. So, the customers for the good still have to pay a positive price for the good. For example, when the transport price of, say, coal drops to zero, then the demand for coal will still be finite.

[9] Other regimes can be shown to be inconsistent. For example, $x_{BA} > x_{AB} \geq x_{BA}*$ does not exist.

$$x_{BA} > x_{AB} = x_{AB}^*;\ \ p_{AB}(x_{AB}) = 0;\ \ p_{BA}(x_{BA}) = 2c,$$

or

$$x = x_{AB} = x_{BA};\ \ p_{AB}(x) + p_{BA}(x) = 2c;\ \ p_{AB}(x) > 0;\ \ p_{AB}(x) < 2c.$$

Hence, it immediately follows that the imbalance, defined as the ratio of the trade flow from *j* to *i* to the trade flow from *i* to *j*, negatively affects the transport price p_{ij}. This result is, of course, intuitive. It just formalizes the idea that, given *joint* costs of transport between regions, transport prices are *not* equal to one-way transport cost, *c*, but depend on the *relative* demand for transport between regions. To be more specific, the model makes the rather extreme prediction that, if the transport flow in one direction exceeds the transport flow in the other direction, then one of the one-way transport prices will exactly cover the two-way transport costs, whereas the other one-way transport price will be zero.

It is straightforward to extend the above analysis, while allowing for uncertainty in demand. This is particularly relevant for thin markets, such as the inland waterway transport (spot) market, because demand for inland waterway transport may vary substantially over time between regions in ways that are difficult to anticipate.[10] In this situation, carriers (as well as shippers[11]) will not know for certain what the demand will be for transport in each period. Hence, carriers (and therefore shippers) will face a risk as they do not know the level of the imbalance and therefore the transport price they will receive when they arrive in the other region.

For convenience, assume that there is only uncertainty about demand for transport

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[10] Note that a large proportion of demand is almost completely predictable (e.g. coal demand by electricity producers), but the predictable demand is transported using long-term contracts. Some of the demand is, however, unpredictable and the spot market is used to handle this demand. In the spot market, carriers cruise through a network reacting to changes in demand.

[11] Note that "shippers" arrange for goods to be transported, while "carriers" actually transport the goods along the waterway.

from region B to region A (and demand from A to B is given). We will distinguish between a high and a low demand state. The low demand state occurs with a fixed probability. Further suppose that the inverse demand function of A to B exceeds the inverse demand function of B to A in both states. Given the low demand state, we suppose that in equilibrium, x_{AB} exceeds x_{BA}, whereas, given the high demand state, x_{AB} equals x_{BA}.

Let us now suppose that *carriers are risk averse*, whereas shippers are risk neutral. This assumption is reasonable in the context of inland waterway transport as the carriers are small firms (in the majority of cases, firms only operate one barge), whereas the shippers, which demand transport, are frequently large industrial firms. Standard microeconomic theory tells us then that the shippers will be willing to absorb all risk related to price variation, whereas the carriers will carry no risk.[12] This has three main implications. First, it implies that the observed transport price in the market is the *expected* price, where the expectation is taken with respect to the distribution of the uncertainty in the transport market. Second, given uncertainty about demand, the expected imbalance negatively affects the expected price, because transport prices depend negatively on the probability of finding a paid return trip.[13] Third, one-way transport prices will never fall to zero.

The general principle that transport prices depend on the relative demand for transport between regions is a more general result which also holds in multi-region networks. In a multi-region network, however, carriers will not move back and forth between two regions but will make more complicated journeys. Measuring imbalance in a multi-region network is not standard. Therefore, measuring imbalance at the level of *routes* will generally not adequately capture the effect of imbalances on prices in a multi-region network, when carriers do not move back and forth between the same two regions. It is straightforward to give relevant examples.

[12] The formal proof of these claims can be received upon request from the authors.

[13] This is consistent with our finding in the empirical application, which identifies a negative effect for the time-averaged imbalance on transport prices, but we do not identify this effect using time-variation in imbalance and transport prices.

An illuminating example is when carriers transport goods from A to B, but a positive proportion of these carriers move from B to C (possibly without goods), and then transport goods from C to A. In this example, the transport price from A to B depends not only on the demand from A to B, as well as the demand from B to A, but also on the cost and demand characteristics of the B to C and C to A routes.[14] Measuring imbalance at the level of routes implies that only the demand from A to B, as well as the demand from B to A, is used in order to explain the price from A to B. It follows that an empirical analysis of the effect of imbalance on transport prices in multi-region networks which only includes measures of route imbalance is likely to underestimate the importance of the effect of imbalance flows on transport prices, because the route imbalance does not adequately capture imbalance.[15] This implies that it is important to measure imbalance taking network characteristics into account.

In a multi-region network, one may measure imbalance for a trip between two regions at the level of the *route* (for example, the ratio of the size of the outgoing flow on the route to the size of the incoming flow on the route) or at the level of the *region* (for example, the ratio of the size of the outgoing flow of the region to the size of the incoming flow in the region). In the current paper, we will measure imbalance at the level of routes, as well as of regions. For the region measure, we will use a spatially-weighted regional imbalance measure, in line with other economic applications of spatial problems (see, for example, Boarnet, 1994a, 1994b; Rice et al. 2006). By spatially weighting, we take the network characteristics into account. Weights are based on information about the size of the transport flows *without cargo* between regions. As we will see in the next section, these empty flows are strongly related to the inverse of distance, because empty vessels primarily cruise to nearby regions to collect cargo.

[14] Another straightforward example is to presume that there exists demand for transport from region B to C (but not from C to A). The transport price from A to B then depends not only positively on the demand for transport from A to B and negatively on the demand for transport from B to A, but also negatively on the demand for transport from region B to C.

[15] To be more precise, if the route imbalance variable is a proxy variable for the theoretically correctly specified imbalance variable, and the difference between the route imbalance and the correctly specified imbalance travel is random error, then the estimated effect of the route imbalance variable underestimates the effect of imbalance (Verbeek, 2000, p.120).

Further, note that, in multi-region networks, transport prices are expected to depend negatively on the imbalance in the region of *destination*, as well as positively on the imbalance in the region of *origin*. So, it may be necessary to use *two* indicators of region imbalance.[16]

3. Methodology and data

3.1 Methodology

Our aim is to estimate the effect of an imbalance in transport flows on the transport price in a spatial network. Imbalance, which is an aggregate variable, will be measured at the route level, as well as at the regional level, for reasons discussed in the previous section. Imbalance may be measured in terms of either the tonnes transported or the number of trips between regions. In our empirical application, these measures are almost identical. In the current paper, we will construct the imbalance variable on the basis of the number of trips.

At the *route level*, imbalance is measured bilaterally, so on every route the imbalance is measured by the ratio of the number of trips in one direction to the number of trips in the opposite direction. Hence:

$$M_{ij} = T_{ji}/T_{ij}, \qquad (1)$$

where M_{ij} is the route-imbalance for the route from region i to region j; T_{ji} is the number of trips from j to i, and T_{ij} is the number of trips from i to j.

At the *regional level*, imbalance is measured as the number of trips originating from region i divided by the number of trips arriving in region i, taking into account the spatial dimension of the network. Within a spatial network, carriers navigate without cargo to other, usually adjacent regions, to pick up freight. To take this into account, we

[16] In a two-region network, imbalance can be measured by a *single* indicator, for example the ratio of the size of the outgoing flow to the size of the ingoing flow in one of the regions. In this context, there is no distinction between measuring at the level of the region or at the level of the route.

construct a spatially-weighted imbalance variable, I_i, which is defined as follows:

$$I_i = \frac{\sum_j w_{ij} O_j}{\sum_j w_{ij} D_j}, \qquad (2)$$

where O_j is the number of trips departing from region j; D_j is the number of trips arriving in region j; and w_{ij} is a weighting factor. One may define w_{ij} in several ways. For example, if $w_{ii} = 1$ and $w_{ij} = 0$ for $i \neq j$ then regions other than i do not play a role in the determination of the imbalance in region i ,so $I_i = O_i/D_i$. In our empirical specification, we define w_{ij} as follows:

$$w_{ij} = \frac{F(d_{ij})}{\sum_j F(d_{ij})}, \quad \text{so} \quad \sum_j w_{ij} = 1. \qquad (3)$$

We will use $F(d_{ij}) = e^{-\gamma d_{ij}}$, so F can be interpreted as an exponential-decay factor; d_{ij} is the distance between regions i and j; and γ is a decay parameter.[17] This parameter γ will be estimated using information about the distance navigated without cargo by carriers before starting a new paid trip. The weight w_{ij} may thus be interpreted as an inverse indicator of economic distance: the shorter the distance between two regions, the higher the probability that empty trips will be made to collect cargo from these regions.

As every trip has an origin and a destination region, we are able to estimate the effect of the imbalance in the 'origin' and 'destination' region on the transport price. Later on, we will show that, after a logarithmic transformation, these two imbalance variables have opposite signs. Therefore, we will use a more parsimonious and intuitive measure of the pair of regions i and j, I_{ij}, which is defined by the ratio of the imbalance in the destination region and the imbalance in the origin region:

$$I_{ij} = I_j/I_i. \qquad (4)$$

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[17] The use of the distance-decay principle is not new. For example, Hojman and Szeidl (2008) recently constructed a model of network formation in which benefits from connections decay with distance.

In our application, we will use the logarithm of I_{ij}, which can be interpreted as a measure of the (relative) difference in the imbalance between two regions.[18] As mentioned in the Introduction, one main difference between the current study and the above-mentioned studies that concern maritime transport is that, in case of the latter, imbalance is measured on the route level on the basis of country-specific export and import data, whereas the current study concerns inland waterway transport, in which imbalance is measured at both the regional level and the route level. In maritime transport, especially in the liner shipping market, it may be sufficient only to use the route level imbalance because carriers often transport solely between two seaports and do not visit other ports. In that context, only the imbalance on the route between the two ports is relevant.

In the case of the inland waterway transport market analysed by us, carriers cruise within a full network of waterways which means that, after a carrier has been unloaded, it will usually not return to the region of origin, but will continue on a different route.[19] Therefore, it is highly likely that, besides the route imbalance, the regional imbalance is also relevant in the inland waterway transport market.

3.2 Data

We employ a data set, the Vaart!Vrachtindicator, which contains detailed information about trips made by inland waterway transport carriers in north-west Europe.[20] The carriers report information (via the Internet) about their trips, such as the transport price, region and date of (un)loading, capacity of the ship, number of tonnes transported, type of cargo, etc. We distinguish between trips from and towards 20 regions.[21] Although the data set can be characterized as an unbalanced panel data set, for our research purpose it

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[18] We will demonstrate later on that to measure imbalance as the ratio of imbalance between two regions gives the same result as to measure imbalance separately for both regions. We use the natural logarithm of I_{ij} in the regression analysis later on. Note that $\log(I_{ij}) = \log(I_j) - \log(I_i)$, so that we model the effect of the difference in imbalance between the origin and destination region on the transport price.

[19] We have examined this for a randomly-selected sample of carriers in our data, which will be discussed later on. It appears that only 1 out of 50 carriers immediately travels back to the region of origin.

[20] More information can be found on the website www.vaart.nl, as well as in Jonkeren et al. (2007).

[21] More detailed information on the 20 regions used can be found in Appendix A.

is more convenient to regard the set as repeated cross-section data. The data set contains information on inland waterway transport trips that occur in the spot market where the price for transport is negotiated per trip.[22] In our application we use the logarithm of the price per tonne.

The database contains 21,865 observations of trips in north-west Europe, reported between January 2003 and January 2007. Observations with missing information, a few extreme outliers, and observations that concern container transport were excluded.[23] Further, we excluded a limited number of observations for which the measurement of the route imbalance is unreliable. Ultimately, 16,583 observations remained.[24]

The decay parameter γ has been estimated on basis of the carriers' distribution of distances navigated without cargo before starting a trip (see Appendix B).[25] Frequently, after a carrier has been unloaded, it travels a certain distance without cargo to arrive at a location from where the next trip starts. For example, it appears that in one out of three trips, carriers navigate more than 100 kilometres without cargo before starting a new trip. In one out of nine trips, carriers navigate even more than 200 kilometres without cargo. The average distance navigated without cargo is 90.12 kilometres, which is substantial compared with the average distance navigated with cargo (514 kilometres, see Table 2). We have estimated γ presuming an exponential distribution of distances without cargo. This assumption fits the data well (see Appendix B). Given the exponential assumption,

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[22] Inland waterway transport enterprises that operate in the long-term market (and work under contract) are not included in the data set. Note that the data covers only a limited part of the whole inland waterway transport market, but, descriptives of the imbalance variable between the Netherlands and Germany suggest that the sample is representative in terms of imbalance variables.

[23] We exclude observations referring to container transport because the price for container transport depends on the number of containers transported rather than on the weight of the freight which is the measure used here. We have information on the weight of the freight, but not on the number of containers.

[24] The route imbalance, M_{ij}, may contain substantial measurement error if the number of trips between two regions is small. Therefore, in our empirical application, we select only those observations for which the sum of the number of trips in both directions between two regions exceeds 25.

[25] For the exponential distribution, the mean is equal to the standard deviation. As can be seen in Table 2, this restriction holds almost perfectly in the data.

the estimated γ equals the inverse of the mean distance navigated without cargo (see, for example, Lancaster, 1990). Hence $\hat{\gamma}$ = 0.011.

The descriptives of key variables used in the analysis are shown in Table 2. Note that the average trip (including loading and unloading time) takes five days. The average price per tonne is €7.48.

Table 2: Descriptives of key variables

Variable	Minimum	Maximum	Mean	Std. Deviation
M_{ij}	0.01	100.00	7.16	14.91
$\log(M_{ij})$	-4.61	4.61	0.94	1.40
I_{ij}	0.36	2.76	0.97	0.55
$\log(I_{ij})$	-1.02	1.02	-0.21	0.55
Price per tonne (in €)	0.85	54.55	7.48	5.06
Travel time (in days)	1.00	31.00	5.01	2.45
Distance trip (in km)	12.00	4000.00	514	286
Distance navigated without cargo (in km)	0.00	908.00	90.12	96.11

Source: The Vaart!Vrachtindicator (2003 – 2007).

As an illustration of the effects we aim to capture, it may be useful to focus on the Rotterdam port area. Transport prices for trips originating from Rotterdam are 32 percent higher than prices for trips arriving in Rotterdam, whereas the (weighted) number of loaded trips departing from the port of Rotterdam is about two times higher than the (weighted) number of loaded trips arriving in the port of Rotterdam. Although only suggestive, it seems that the effect of imbalance on transport prices may be substantial. We will examine the effect of imbalance on transport prices, using a number of regression approaches. In addition to the two imbalance measures mentioned above ($\log(M_{ij})$ and $\log(I_{ij})$), we include a large number of control variables in the price equation. These control variables include: a time trend; travel time[26] and distance, both in logarithms; ship size (categorized by 4 dummy variables); 47 cargo dummies (e.g. coal, gravel, fertilizer, wheat, corn, soya), the fuel price in logarithm and the load factor, defined as the ratio of the tonnes transported and the capacity of the inland vessel, also in

[26] For 67 percent of the observations we have the trip-specific travel time. For the other observations this variable is not reported, so we use the region-to-region specific *average* travel time. This introduces some measurement error in this variable.

logarithm. Furthermore, we include the water level as an explanatory variable by means of 9 dummies. As shown by Jonkeren et al. (2007), water levels have strong effects on prices, as low water levels impose restrictions on the load factors of inland waterway vessels. Water level is measured at Kaub because Kaub is the critical bottleneck in the Rhine river basin, which determines the maximum load factor of many inland ships. As not all trips pass Kaub, we make a distinction between the effect of the water level for trips that pass Kaub and that for trips that do not pass Kaub. Finally, we include a dummy variable for each month (11 dummies) to control for unobserved monthly changes in supply and demand factors. A discussion of the results of our analysis will be presented in Section 4.

4. Results

4.1 The effect of imbalance on the transport price

We examine the impact of an imbalance in transport flows on the transport price per tonne. In Section 3.1, we explained how to construct two different measures for imbalance. As the effects of these two imbalance variables may be difficult to identify separately, we have also estimated models including only one measure for imbalance.

The first model includes only the route imbalance variable, the second model includes only the regional imbalance variable, whereas the third model includes both types of imbalance variables. These models have been estimated using ordinary least squares. So, for now, endogeneity of imbalance will be ignored. As the imbalance variables are aggregate measures, we allow for clustering on the basis of the region of destination. This prevents the standard errors to be biased downward (Moulton, 1990).[27] Table 3 presents the regression results for the three models.

[27] Clustering on the basis of region of origin or on the basis of routes generates almost identical results. However, as clustering on the basis of the region of destination is the more conservative, in the sense that the standard errors are larger, we opt to report this way of clustering. Not allowing for clustering results in standard errors which are about four times smaller for some variables.

Table 3: Estimation results for the transport price in the inland waterway transport market

	(1)		(2)		(3)	
Explanatory Variables	***Coefficient***	***Std. Error***	***Coefficient***	***Std. Error***	***Coefficient***	***Std. Error***
Regional imbalance, log(I_{ij})	-	-	-.186	.029	-.201	.028
Route imbalance, log(M_{ij})	-.016	.014	-		.012	.006
Log(travel time)	.207	.024	.166	.015	.164	.016
Log(distance)	.468	.035	.493	.027	.493	.027
Time trend/1000	.265	.023	.272	.025	.272	.025
Log(fuelprice)	.032	.043	.029	.047	.031	.047
Log(loadfactor)	-.406	.076	-.431	.071	-.429	.071
Vessel size						
0 – 1000 tonnes	.318	.022	.320	.020	.323	.020
1000 – 1500 tonnes	.225	.020	.230	.019	.232	.019
1500 – 2000 tonnes	.122	.016	.130	.016	.131	.016
2000 – 2500 tonnes	.084	.013	.086	.012	.086	.012
> 2500 tonnes	Reference		Reference		Reference	
Water level, trips via Kaub						
< 180	.422	.045	.406	.042	.408	.041
181 – 190	.319	.043	.305	.043	.306	.043
191 – 200	.295	.032	.281	.030	.282	.030
201 – 210	.229	.032	.214	.031	.215	.031
211 – 220	.141	.034	.126	.032	.126	.032
221 – 230	.134	.026	.124	.025	.124	.025
231 – 240	.094	.022	.084	.021	.085	.020
241 – 250	.066	.019	.058	.017	.059	.017
251 – 260	.027	.012	.024	.012	.025	.012
≥ 261	Reference		Reference		Reference	
Water level, trips not via Kaub						
< 180	.168	.064	.168	.058	.169	.057
181 – 190	.124	.055	.119	.048	.122	.047
191 – 200	.022	.052	.023	.045	.023	.044
201 – 210	.025	.056	.021	.049	.021	.047
211 – 220	-.046	.049	-.042	.042	-.041	.041
221 – 230	-.086	.042	-.084	.040	-.082	.039
231 – 240	-.071	.047	-.067	.042	-.066	.041
241 – 250	-.086	.041	-.082	.039	-.080	.038
251 – 260	-.087	.036	-.087	.036	-.085	.035
≥ 261	-.118	.038	-.112	.037	-.110	.036
Month dummies						
January	Reference		Reference		Reference	
February	-.057	.012	-.062	.012	-.062	.012
March	-.116	.013	-.116	.012	-.117	.012
April	-.089	.011	-.090	.010	-.089	.009
May	-.075	.014	-.077	.014	-.077	.014
June	-.063	.018	-.067	.017	-.067	.016
July	-.039	.020	-.041	.018	-.041	.018
August	-.116	.017	-.114	.016	-.115	.016
September	-.036	.018	-.039	.016	-.041	.016
October	.039	.015	.041	.015	.041	.015
November	.070	.016	.075	.015	.075	.015
December	.149	.017	.154	.016	.155	.016
Cargo dummies, 46	Included		Included		Included	
R^2	0.806		0.822		0.823	

Note: The dependent variable is the logarithm of the price per tonne.

Let us first focus on the results when the two types of imbalance variables, $\log(M_{ij})$ and $\log(I_{ij})$, are separately included in the model. In line with theory, we find that both imbalance variables negatively affect the transport price.

If we focus on the route imbalance effect, however, we must conclude that its impact on the transport price is rather limited in size and statistically insignificant.[28] In contrast, the effect of the regional imbalance is quite strong and statistically very significant. The effect of the regional imbalance measure is a much larger than the effect of the route imbalance measure. To be more precise, the effect of an increase of one standard deviation of the regional imbalance measure is about *five* times larger than the effect of an increase of one standard deviation of the route imbalance measure.

If we now focus on the model where both imbalance variables are included (the partial correlation between these two variables is 0.40), we find that the estimated effect of the regional imbalance measure is almost the same, whereas the effect of the route imbalance measure remains small and statistically insignificant, and even becomes positive. This strongly suggests that the regional measure is the superior measure. Therefore, in the remainder of the paper, we will continue employing the regional imbalance measure only. This not only improves the interpretation of the results, but also simplifies the other statistical analyses, for example when we deal with endogeneity issues later on.

Recall that I_{ij} is defined as I_j/I_i, and we use the logarithm of this variable. Our main result is that the elasticity of I_{ij} is statistically significant and equal to -0.186. To understand the size of the effect, it is also useful to consider a one standard deviation increase in the imbalance between two regions, I_{ij} (0.55). Suppose that we compare the transport prices of a trip from region A to B with those of A to C, assuming that the regional imbalance between A and B is one standard deviation greater than the imbalance between A and C, which is equal to the mean imbalance in the network (I_{ij} = 0.97). In this

[28] If we cluster on the basis of the region of origin or on the basis of routes, then the route imbalance variable is just significant.

case, the transport price from A to B will be 8.0 percent lower than from A to C.[29] It is also interesting to compare the effect of imbalance focusing on the Rotterdam port area, where a large seaport is located, with that in the Neckar area. In the latter area, the (weighted) number of trips with cargo leaving the Neckar area is 34 percent fewer than those arriving whereas the (weighted) number of trips with cargo leaving the Rotterdam port area is 81 percent higher than those arriving. Making a trip from the Rotterdam port area to the Neckar area (I_{ij} = 0.656/ 1.81 = 0.362) instead of the other way around (I_{ij} = 1.81/ 0.362 = 2.761) implies a transport price difference of 46 percent.[30]

We will now briefly discuss the results for the control variables. It appears that the travel time elasticity is about 0.17, and the distance elasticity is about 0.49. The sum of these elasticities is less than 1, suggesting economies of scale in terms of the length of the trip. We find that low water levels increase the transport costs for water levels lower than 260 cm, in line with Jonkeren et al. (2007). We find that the effect is stronger for trips that pass Kaub than for trips that do not pass Kaub. The load factor elasticity is

[29]This has been calculated by $\left(\frac{0.97+0.55}{0.97}\right)^{-0.186} - 1$ = -0.080. As the transport price includes the costs of navigation plus the time costs of loading and unloading (the handling costs of loading and unloading are paid for by the shipper), the calculated decrease applies to this "full" transport price.

[30] In the above methodology used to identify the effect of imbalance on transport prices, we have *not* exploited any time-variation in regional imbalances. There are a number of reasons why identification of the effect of imbalance on transport prices using time variation in imbalances may not be successful. The main theoretical reason is that the cost of *unexpected* variation in regional balance is likely to be borne by shippers and not by carriers (see Section 2). There are, however, also empirical reasons. In particular, it is plausible that much of the time variation observed in the regional imbalance variables is due to measurement error, which induces measurement error bias. This bias is likely to be only minimal for trips towards and from the region of the Rotterdam port area, the region with the largest number of departing and arriving trips. Therefore, we have measured the (average) imbalance for each two-week period. Unfortunately, the imbalance variable for Rotterdam in each period is far above 1, suggesting that the time-variation in imbalance will have minimal influence on the transport price (recall that, according to the standard two-region model, the effect would indeed be absent). Despite these arguments, we have examined the effect of time-variation in imbalance for trips departing from Rotterdam (5720 observations), as well as for trips arriving in Rotterdam (1833 observations). We do not find any evidence that time-variation in the imbalance in Rotterdam affects time-variation in transport prices towards or from Rotterdam.

estimated to be about -0.40, implying lower prices per tonne at higher load factors. Further, we find that the price decreases as the vessel size increases, indicating economies of vessel size. The December dummy shows higher transport prices confirming a phenomenon which is well known in this sector.[31] The barge-fuel price effect is not statistically significant even at the 10 percent level.[32]

4.2 Sensitivity analyses

In this section, we test for the robustness of the reported imbalance variable effect. To be more specific, we examine the sensitivity of the results with respect to the assumption that the effect of the logarithm of the imbalance variable for the origin region is equal in value (but with opposite signs) to the effect of the logarithm of the imbalance variable for the destination region (4.2.1), endogeneity of imbalance (4.2.2), controls for cargo type (4.2.3), the number of empty kilometres navigated before a trip starts (4.2.4), unobserved route-specific factors (4.2.5), and the value of the decay parameter γ (4.2.6).

4.2.1 Measuring imbalance: distinguishing between origin and destination regions

The regional imbalance variable is measured as the difference between the natural logarithm of the origin-and destination-region imbalances. However, it could be argued that this specification is too restrictive, so we allow here for a separate impact of the origin-and destination-imbalance variables on the transport price. We find that the effect of the origin-imbalance variable, $\log(I_i)$, is 0.151 (s.e. 0.039), and the destination-imbalance variable, $\log(I_j)$, -0.220 (s.e. 0.042). In line with theory, the effect of the origin variable is positive, whereas the effect is negative for the destination imbalance variable. Furthermore, it appears that the sum of the coefficients is not statistically different from zero (the sum equals -0.069 with a standard error equal to 0.055) justifying the use of $\log(I_{ij})$.[33] Moreover, it turns out that using the effect of the measure of the regional

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[31] Many inland waterway transport enterprises do not work at the end of the year for holiday reasons, and because they put their inland ship in maintenance. As a result, supply falls and transport prices rise.

[32] Note that we control for a time trend, and that, during the period analysed, fuel prices strongly correlate with this time trend, so this effect is difficult to identify.

[33] The standard error of the sum of the coefficients is calculated using standard covariance rules.

imbalance as reported in Table 3, $\log(I_{ij})$, leads to only a slightly different predicted effect of imbalance on the transport price than when the effects of both measures ($\log(I_i)$ and $\log(I_j)$) are used.[34]

4.2.2 Endogeneity of imbalance

Another reason why our estimate of imbalance in Table 3 may be biased is due to endogeneity of the imbalance variable. As emphasized in Section 2, transport prices and transport flows are simultaneously determined as the demand for transport, and therefore the imbalance, depends on the price. Hence, shippers in regions with a, for them, favourable imbalance (i.e. in regions where supply of carriers is relatively large) will increase their demand for inland transport capacity because the transport price for trips that depart from that region is low. Note that, in the case of inland waterway transport, the endogeneity of imbalance with respect to the price per tonne may be potentially important, as the inland waterway transport sector competes with the rail and road sectors for the same cargo. On the other hand, one may think that endogeneity is not an issue, as, especially over long distances, the cost advantage of using inland waterway transport instead of alternative transport modes is greater. Furthermore, as the inland waterway transport costs are only a small part of the overall production costs of the goods, it may be thought that demand for transport is quite inelastic with respect to the unit price of transport. We are aware of a number of recent studies which demonstrate that demand for inland waterway transport in Europe is inelastic. For example, Jonkeren et al. (2007) report that the demand elasticity is about -0.5.

We use an instrumental variable approach to test for the presence of, and to solve for, endogeneity. Our instrument is a dummy variable that is equal to 1 if I_{ij} exceeds 1, and zero otherwise. This instrument can be argued to be exogenous with respect to the unit transport price, because, although the price plausibly affects the imbalance, the price

[34] For example, employing the measure of regional imbalance as reported in Table 3, for a carrier going from the Rotterdam port area to the Neckar river area instead of from the Neckar river area to the Rotterdam port area, the price per tonne increases by 46 percent. Employing the separate measures of imbalance, the effect of a change in regional imbalance on the price per tonne in this extreme case is equal to 42 percent.

is unlikely to affect whether the trade flow in one direction exceeds the trade flow in the other direction. That is, if in a certain region the number of trips in one direction exceeds the number of trips in the other direction at a certain price level, then a change in prices is very unlikely to result in a situation where the number of trips in the other direction exceeds the number in the reverse direction.[35] We believe that this is plausible. The imbalance dummy is not only exogenous, it is also a strong predictor of the regional imbalance variable and therefore an appropriate instrument.[36]

We perform IV estimation with the same control variables as presented in Table 3, using the imbalance dummy as an instrument. The estimated elasticity is now -0.177 (s.e. 0.033), only slightly weaker than the elasticity of the OLS estimation (-0.186). A Hausman t-statistic (t = 0.571) implies that we do not reject the null hypothesis of exogeneity at the 95 percent confidence level, indicating that the OLS estimates are consistent (see Wooldridge, 2002, p.120).

4.2.3 Controls for cargo type

In the previous section, we have shown that our measure of the regional imbalance in transport flows has a strong negative effect on the transport price. We have controlled for cargo type, as it may be argued that the cargo transported affects the unit costs via the density (mass per volume) of the cargo. So, the cargo type is a relevant control variable, as there is correlation between imbalance and cargo type.[37] However, one may argue that the effect of the type of good transported, and therefore the imbalance effect, is biased because the type of good transported may be endogenous. For example, because of a decrease in transport prices, it may become profitable to transport certain goods that otherwise would not have been profitable (e.g. bricks). A counterargument would be that demand for inland waterway transport is price inelastic as discussed above, so it is not

[35] Note that the assumption that whether I_{ij} exceeds 1 is exogenous with the price, essentially implies for a two-region network that the demand curve in one direction universally exceeds the demand curve in the reverse direction.

[36] This claim has been examined by regressing the logarithm of the imbalance variable on the control variables of the transport price and the instrumental variable. It turns out that the instrumental variable is highly significant, with a t-value of 10.23 (allowing for clustering).

[37] Imbalance is region-specific but also the production of certain goods and raw materials is region-specific.

very likely that the cargo type is strongly endogenous with respect to the transport price.

In a sensitivity analysis we have therefore excluded the 47 dummy controls for cargo. The regional imbalance effect is then equal to -0.202 (s.e. 0.024).[38] Hence, our results are robust with respect to controlling for cargo type, indicating that this is a minor issue in the market analysed.[39]

4.2.4 Controlling for the distance navigated without cargo before starting a trip

We have argued above that due to imbalance differences between regions, it will be frequently beneficial for carriers to navigate without cargo to a region with a more favourable imbalance. Therefore, trips that start from regions with an imbalance that is favourable for the carriers are likely to be preceded by a relatively long distance navigated without cargo.[40]

In a perfectly competitive transport market,[41] the distance navigated without cargo before starting a paid trip should not have any effect when controlling for imbalance factors, but, in a market with substantial imperfections (e.g. search costs), the bargaining position of carriers may depend on this distance, and therefore affect the bargained transport price. It appears that controlling for distance navigated without cargo in the regression hardly affects the regional imbalance coefficient (which is equal to -0.178 with an s.e. equal to 0.028). We find that the effect of distance navigated without cargo on the transport price is small with an elasticity of only 0.02.

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[38] Note that, in this analysis, the imbalance parameter may also be biased because of omitted-variable bias.

[39] Note that this issue is likely to be relevant in the maritime transport market. For example, most of the goods shipped from the Netherlands to China appear to consist of used paper, which is transported at bottom transport prices.

[40] This conjecture is confirmed by a weak negative correlation between the natural logarithm of the empty kilometres variable and the natural logarithm of the regional imbalance variable.

[41] In a perfectly competitive market, the effect of the number of empty kilometres made before starting a trip on the price for that trip must be absent. A shipper will choose the inland waterway transport company that offers the lowest price, so an inland waterway transport company cannot ask a higher price if it has to navigate empty to the place of loading for a particular trip.

4.2.5 Bilateral route fixed effects

As there may be unobserved, route-specific, factors that are correlated with imbalance, the coefficient of the imbalance variable may be biased. In particular, it may be imagined that we do not sufficiently control for the characteristics of the network. To deal with this potential bias, we have included bilateral route dummies (131 dummies).[42] So, for each transport route between two regions (independent of the direction of the trip), we have included a dummy.

We now find that the regional imbalance elasticity is equal to -0.235 (s.e. 0.013). Therefore, we may conclude that the reported elasticity of -0.186 in Table 3 can be considered as an underestimate.

4.2.6 Different values for the decay parameter

Recall that the value of the decay parameter γ has been estimated assuming an exponential distribution, and is therefore equal to the inverse of the average distance navigated without cargo before starting a trip, which is slightly more than 90 kilometres. We have examined the robustness of our results by assuming that the distance navigated without cargo is 70 or 110 kilometres, implying a γ of 1/70 and 1/110 respectively. We find that the results and, in particular, the effect of the regional imbalance on the transport price remain essentially unaltered for these other values for γ. An increase of one standard deviation in the regional imbalance variable now results in a decrease of 7.3 percent and 8.8 percent of the transport price, respectively.[43]

[42] If the trips in our data set covered all routes, the total number of dummies would be ((20 * 20)/2 =) 200. However, because there is no transport between some of the regions, the number of bilateral route dummies is equal to 131.

[43] More extreme values for γ lead to larger (+25% if γ is 1/170) or smaller (-60% if γ is infinite) effects of the regional imbalance. However, very small values for γ imply that navigating without cargo is costless, whereas very large values for γ imply that navigating without cargo is prohibitively expensive. Both implications are unrealistic and inconsistent with the data. Thus, extreme values for γ are not realistic.

5 Conclusion

In the extensive literature on (regional and international) trade and regional activity, it is common to assume that transport costs are exogenous, but recently a new literature has emerged which argues that these transport costs may be endogenous. For example, Behrens et al. (2006) make the assumption that unit transport prices negatively depend on trade volume using density economies arguments. In the current paper, we also argue that transport costs are endogenous, but use an entirely different argument. Our argument is that, at least according to textbook transport economics theory, transport costs depend on imbalances in trade flows because carriers have to return to high demand regions without paid cargo. This implies that, ceteris paribus, unit transport prices positively depend on trade.

Here, we have studied this effect empirically using an ongoing survey for carriers in the inland waterway spot market in north-west Europe, which covers mainly the Netherlands and Germany. Between these two countries, about 50 percent of all physical trade is transported by inland waterways, so the price formation in the inland waterway transport market is fundamental to our understanding of the cost of trade between these two countries. The survey, provides not only information about prices for each trip, but also detailed micro-information about a large number of control variables.

One important difference between the current study and existing empirical maritime transport studies is that the latter studies consider that transport costs vary with the imbalances because of density economies, whereas in our empirical application, which is novel, we control for density economies directly (e.g. by vessel size), and emphasize that transport costs are endogenous with respect to the imbalance in traded volumes between regions.

Although standard transport economic theory on pricing of transport services within a two-region setting motivates our study, we have argued that in the case of a multi-region network, the traditional measure of trade imbalances at the level of the route may be less appropriate than a measure of imbalances at the level of the region. In our empirical application we employ both measures.

Our main finding is that regional imbalances play a much more prominent role than route imbalances in the determination of transport prices. We find that a one standard deviation increase in the regional imbalance from region A to region B decreases the transport price from region A to region B by about 8 percent. A range of sensitivity analyses show that this effect is robust.

The inland waterway transport market we have studied covers ‘exporting’ regions (regions from which more trips with cargo depart than arrive) along the North Sea coast, and ‘importing’ regions in the hinterland. The exporting regions include the seaports of Hamburg, Amsterdam, Rotterdam and Antwerp. Most bulk cargo enters Europe via these ports and is then transported further to the hinterland making use of inland waterway transport. The hinterland regions do not export bulk goods on a large scale (they tend to export manufactured goods and services). Hence, the *physical* transport flow, and therefore the number of inland waterway transport trips, between seaports and hinterland is very unbalanced. One of the main consequences is that unit transport prices from the seaports to the hinterland are substantially higher than the other way round. For example, for trips from the Rotterdam port area to the Neckar area in Germany, transport prices are 37 percent higher than in the opposite direction. Our results also have implications for (studies on) international trade. Transport prices from the Netherlands to Germany are substantially higher than the other way round because the Netherlands exports much more to Germany then it imports from Germany.

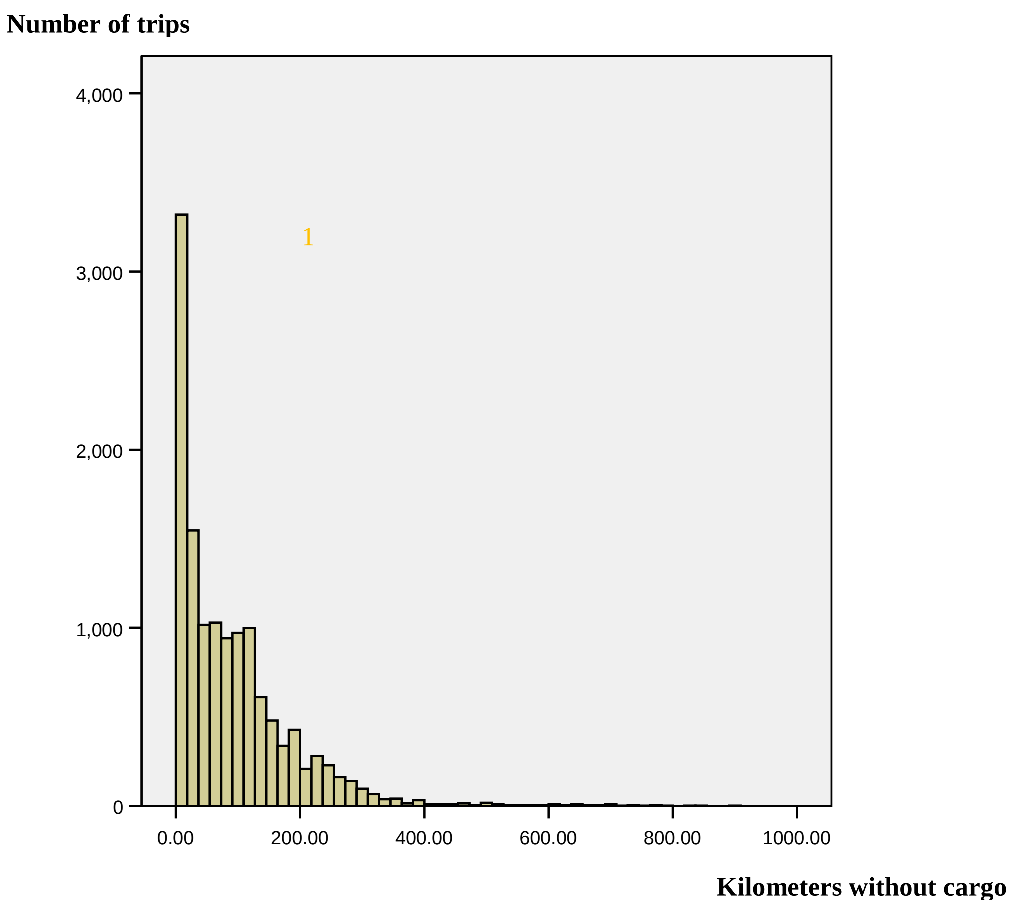
Appendices

Appendix A: Imbalance by region, I_i

Region	I_i	$\log(I_i)$
Rotterdam port area (NL)	1.811	0.594
Amsterdam port area (NL)	1.649	0.500
Netherlands, South (NL)	1.626	0.486
Northern France (F)	1.523	0.421
Antwerp port area (B)	1.409	0.343
Flanders (B)	1.230	0.207
Netherlands, Centre (NL)	1.154	0.143
Wallonia (B)	1.103	0.098
Netherlands, North (NL)	1.060	0.058
Meuse area (NL, B)	1.050	0.049
Upper Rhine area (D, F, CH)	1.002	0.002
Main and Danube (D, H)	0.960	-0.041
North German Canals (D)	0.923	-0.08
Ruhr area (D)	0.829	-0.187
Netherlands, East (NL)	0.811	-0.21
Middle Rhine area (D)	0.808	-0.213
Lower Rhine area (D)	0.761	-0.273
West German Canals (D)	0.746	-0.293
Moselle and Saar area (D, F)	0.742	-0.299
Neckar area (D)	0.656	-0.422

Note: NL = the Netherlands; B = Belgium; D = Germany; F = France; CH = Switzerland; H = Hungary.

Appendix B: Distribution of distance navigated without cargo before starting a paid trip



Note that the variable "kilometers without cargo" is missing for observations in the period up to June 2004 as it was not included in the first 18 months of the survey. Therefore, the number of observations for this variable is somewhat smaller and equal to 13,133.

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