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A Model on Container Port Competition: An Application for the West European Container Hub-Ports

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The worldwide network of container transport services, both on land and at sea, is becoming increasingly fine-meshed. The growth in the number of intermodal transfer points on the land side, at the sea–land interface in the seaports and at the connecting points of liner services in transhipment ports leads to an increasing number of routing options for a container flow between two regions somewhere on the globe. This increase complicates forecasting the container throughput of a port in the traditional way by linking it directly to a specific hinterland area. In the approach presented here, a port is considered as a nodal point in a network of container routings, where the routings using a certain port add up to the port's container throughput. The model presented here is intended to explain the market share of the port's routings for each of the traffic zones or regions that comprise a port's potential hinterland. Explanatory variables include transport cost, transit time, frequency of service and indicators of quality of service. A logit model is used to quantify the routing choice and to derive from that a demand function to be used for port traffic forecasting and for the economic and financial evaluation of container port projects. The authors had the opportunity to calibrate logit models in the framework of the evaluation of the Maasvlakte-2 container port expansion project in the port of Rotterdam.

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INTRODUCTION

Background

The approach used here to forecast a port's market share, in terms of container throughput, is based on demand choice models, as applied in transportation planning, for modal choice and route choice. First, the choice of a container routing – that is, a sequence of container shipments and transfers from origin to destination, and thereby the implied choice of a container port – is put into a larger framework of transport decision-making. Then, the routing choice model itself is described, followed by a description of results of the calibration of the model for container transport to and from West Europe. Finally, practical applications are presented and discussed. The objective of the paper is to demonstrate the use of a tool to address the issue of competition among container ports. Most applications of the model presented here concern the liner shipping routes serving West Europe.

A model on container port competition

For its imports and exports of containerised cargoes West Europe is served by the Far East shipping routes, the North American shipping routes and a number of less important north–south routes. Different combinations of deep-sea shipping lines, seaports and modes of land transport can serve the various parts of the mainland. Parts of West Europe can be served by a multitude of combinations or routings, and in reality parts of the hinterland are served by routings using each of the seaports in the Antwerp–Hamburg range. Looking from a port's perspective, there appear to exist great overlaps between the hinterlands of the North Sea container ports. This also demonstrates the great amount of competition existing among these ports (see Figure 1).

The large degree of competition makes it difficult to measure the impact on a port's position, of changes in its access to the sea, in its ability to accommodate bigger ships, in its cargo- and ship-handling productivity and in its access to and from the hinterland by road, rail or waterway. This paper aims at demonstrating how the logit model can be used to address the impact of such changes in costs and quality of service.

The port-choice decision within transportation planning

It should be noted that the routing choice for a container shipment, with the implied choice of a seaport, is part of a series of choices. In transportation planning models (De Dios Ortuzar and Willumsen, 1990) the following sequence of choices is distinguished:

- *production-attraction*: the choice to buy or sell a certain type and amount of goods;

Figure 1: Alternative routings for a specific hinterland area

- *distribution*: the choice to buy from a certain group of suppliers or to sell to a certain group of customers; and
- *routing*: the choice to use a certain transport alternative.

A decision leading to a change in transportation costs or in quality of service of container transport to and from a certain region has its impact on all three phases. The impact of, for instance, an increase in transportation costs on production-attraction, for a particular hinterland region, will be negligible, given the small share of such a cost change within total logistics costs. The cost increase itself might lead to a shift towards other ports, making the impact even smaller.

The impact of a cost change on distribution costs should be bigger and it could well be sufficient to cause a change in trading partners. Such a change, however, would only matter if it leads to a shift from an overseas to an overland trading partner or *vice versa*. Also, this impact is most likely negligible. It can be concluded, therefore, that the impact of such a cost change would only matter in routing choice decisions.

With maritime container transport, the routing phase includes at least the following chain of choices:

1. modal choice in region of origin;
2. choice of seaport in region of origin;
3. choice of ocean shipping service;
4. choice of seaport in region of destination; and
5. modal choice in region of destination.

The shipper or receiver of the goods, or its logistics service provider, usually makes these decisions. On the port-choice issue, as is argued later, the related costs and quality of service are aspects not known for all consecutive phases or shackles. However, the mathematical form chosen implies that only differences in the values of attributes play a role, so that the shackles in the chain with equal values can be discarded.

THE ROUTING CHOICE MODEL

Justification of model and functional form

Given the flows of containers shipped from one region to the other, there are various techniques to address the routing choice. Some types of models originate from Operations Research (Ronen, 1983), where cargo flows are allocated in a way that optimises a certain objective function. Generally, such techniques do not include trade-offs between cost and quality of service. Demand choice models are designed to deal explicitly with such trade-offs and are therefore considered to be more suitable.

Various models can describe demand for routing options and, therefore, also the distribution of demand over these options at either the disaggregate level of individual decision-makers or at the aggregate level for groups of decision-makers. Oum (1989) compares such models on aggregated demand. The S-shaped market share curve of the logit model constraints the predicted market share between zero and one, and is intuitively attractive and realistically describes the routing-switching behaviour of decision-makers.

An implicit assumption of logit models is that the cross-elasticities of demand for one alternative, with respect to an attribute of any given alternative, are restricted to be equal. This is generally seen as a strong limitation in the form of the model. The Translog demand function, for instance, is the most widely used demand model without such a limitation and it is applied in modal split issues with two modes (Oum, 1989). This type of models however is too complex, given the multitude of alternative choices applicable.

The logit model for container routing options

Choice of container routing and choice of port

For this analysis, the number of shackles in the chain of container transport and transfer services of a door-to-door shipment, as described earlier, can be reduced without losing much explanatory power. The costs and quality of service aspects of the pre- and on-carriage and of the port transfer in the country of the overseas trading partner are most likely of negligible influence on the choices to be made at the West European end. The analysis therefore can be restricted to a chain of services at the European end, including the ocean-going sea-leg, the container transfer in port, and the inland transport.

The North Sea ports in the Hamburg-Le Havre range serve the major part of the container traffic to and from the West European continent. The present analysis, concentrating on the competitive position of the port of Rotterdam, involves, as a consequence, the ports of Hamburg, Bremen, Rotterdam and Antwerp. The port of Le Havre is left out, as it is more important as a competitor of Antwerp. Smaller ports such as Amsterdam and Zeebrugge can also be excluded given their small market share. Shippers and receivers located in, say, Ludwigshaven have the choice to have their containers, to or from the Far East, shipped and transferred *via* different combinations of:

- shipping line;
- port of call; and
- mode of inland transport.

With, say, 25 shipping lines, four ports of call and three modes of inland transport (though not all combinations are relevant), the number of different routings serving a particular region easily exceeds 100. For routings including a transhipment port, the number of options is even greater.

The probability of choosing a routing depends on costs and quality of service aspects such as transit time and frequency of service of all competing routings. User surveys generally produce a longer list including aspects such as reliability of service, availability of EDI services, responsiveness to customer's wishes and so on. These factors were excluded as they cannot be quantified at the appropriate level of aggregation.

The logit model

The probability that shippers and receivers serving a particular region choose routing r (a combination of a port of transfer in West Europe, a shipping line and a mode of hinterland transport) among the set of all possible routings, can be expressed as

$$P_m(m = r|r = 1\ldots M) = \frac{\mathrm{e}^{U_m}}{\sum_{r=1}^{r=M} \mathrm{e}^{U_r}} \tag{1}$$

where P_m is the probability of choosing routing m from all possible routings, $r = 1\ldots M$; U_m the 'utility' attached to route m; and m the routing index.

The probability P_m can be interpreted as the market share of a routing in the set of routings serving a particular region (for the sake of simplicity, the index of the region is omitted).

The utility function

The value that shippers and receivers of a certain region attach to routing m is measured by its utility, expressed as a (linear) combination of all aspects or attributes of importance in the choice of route:

$$U_m = \alpha_{0m}D_m + \alpha_1 C_m + \alpha_2 T_m + \alpha_3 F_m \tag{2}$$

where D_m is the dummy variable indicating whether shippers/receivers have a preference for routing m; C_m the shipping costs of routing m (including freight rate, handling charges, land transport costs, etc.); T_m the transit time for routing m; and F_m the frequency of service of routing m.

The explanatory variables C_m, T_m and F_m are referred to as attributes; α_{0m}, α_1, α_2 and α_3 are the coefficients of the utility function.

By dividing the utility with the cost coefficient α_1, the result becomes equal to the generalised cost of the alternative.

Market share of a container routing or container port

The relative position of one container routing against another is expressed by the ratio of the probability that a shipper/receiver located in a certain region chooses routing m over the probability that he chooses routing n. By substituting m and n in equation 1, this ratio is given by

$$P_m/P_n = \mathrm{e}^{U_m}/\mathrm{e}^{U_n} = \mathrm{e}^{U_m - U_n} \tag{3}$$

The probability ratio is thus a function of the differences in attributes, which, for various reasons, is a convenient form. If, instead of differences, a quotient form is applicable (this is the case where utility functions take a multiplicative rather than a linear form), information on more, or even all, shackles of the transport chain would be needed. A quotient form of attributes would also require data on the absolute level of their values.

The coefficients of the differences in attributes can be estimated by linear regression, after linearising equation 3 by taking logarithms (see equation 5). In support of the difference form, Oum (1989) states that, with the ratio form, the choice of base routing n affects the empirical results, including own and cross-elasticities of demand.

If a shipper/receiver attaches the same utility to routings m and n, the probability of choosing either one is the same. In that case, the difference of the utilities is zero, leading to a value of the ratio P_m/P_n equal to 1. If measurements indicate that the value of α_{0m} differs from zero and equals, for instance, 0.5, the situation is different. If a customer attaches a higher utility to routing m (this can be expressed by letting $D_m = 1$), and he is indifferent with respect to routing

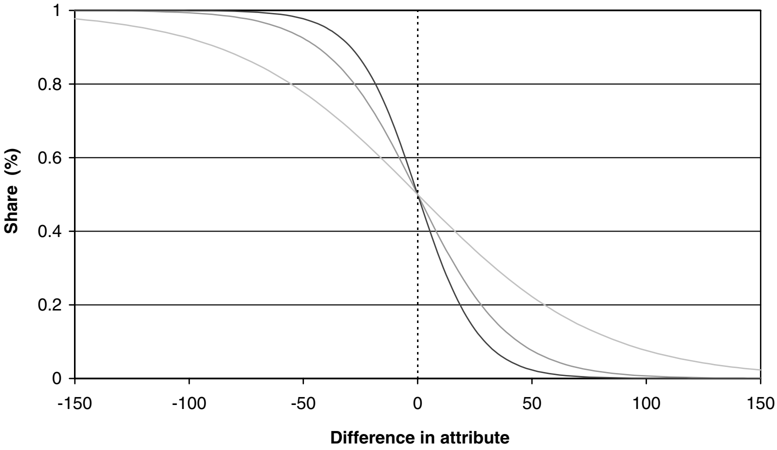

Figure 2: The share of a routing as a function of the difference in attributes

n ($D_n = 0$), with all other values of the attributes (tariff, time, etc.) equal, the right-hand side of equation 3 becomes $e^{0.5} = 1.65$. This means that the probability of choosing routing m is 1.65 times the probability of choosing routing n. In case there are no other routings, the probable market share of routing m would be $1.65/(1.65 + 1) = 62\%$ instead of 50%.

The dummy variable D_m refers to aspects not yet included in the attributes, such as the relative advantage of a certain routing or group of routings. These advantages or disadvantages concern, for instance, routings using a certain mode of transport or a certain group of shipping lines (or combinations thereof), and relate to attributes not explicitly included in the utility function, due to, for instance, lack of information. One may also think of aspects such as reliability of service or availability of EDI services, applicable in certain routings.

The absolute value of the coefficients reflects the sensitivity of the share of a routing to changes in the differences of attributes: the higher the value of the coefficient, the steeper the S-curve in Figure 2, indicating a high sensitivity.

The ratio of the two coefficients indicates the trade-off between two attributes, such as, for instance, the trade-off between time and costs.

Finally, the market share of a particular container port can be determined by normalising the ratios against base routing n in such a way that all shares add up to one, and subsequently adding the ratios of all routings including the port in question.

VALUES OF COEFFICIENTS

In a previous application of the logit model in a similar setting (Bückmann and Veldman, 2000), the values of the parameters of the utility function were taken from studies based on other situations. This necessarily leads to inaccuracies, as the coefficient values depend on the choice situation, the geographical setting, the model specification, the method of estimation and the level of aggregation. Of the studies considered, three concerned modal split situations (Blauwens and Van de Voorde, 1988; Oum, 1989; Dekker, 1999) at aggregate level and one study dealt with the choice between liner shipping services (Simons and Veldman, 1992) at disaggregate level, using stated preferences. Our involvement in a market study (CPB *et al*, 2001a, b) for the Maasvlakte 2 project of the port of Rotterdam, gave us the opportunity to further test logit models.[1]

Continental hinterland flows

The basic data of the continental hinterland used here concerned container flows generated by 33 hinterland regions in the Netherlands, Germany and Belgium, and routed through the ports of Antwerp, Rotterdam, Bremen and Hamburg, covering together 83% of the continental hinterland of the port of Rotterdam. Container flows were distinguished by mode of transport-but not further by type (full/empty)-size (20 ft and other), commodity type and direction (incoming/outgoing). The explanatory variables tested included differences in transport costs, transport time and frequency of service of the inland modes, and liner service frequency by seaport and major trade route. The frequency of service variables were expressed as the reciprocal of the frequency, that is, the average inter-arrival time (IAT) of two consecutive calls of a liner service or of an inland transport mode. Also included were the market share of a port, as a proxy for quality of service, and a set of dummy variables related to inland transport modes, sometimes in combination with a seaport.

The probability of choosing a route to/from a certain region in the hinterland is defined by the ratio of the containers on that route to the total amount of maritime containers transported to/from that region. This information was collected from national transport and port statistics.

Transport costs include the costs of transporting a container between the stack in a seaport and the centre of a hinterland region by road, rail or barge. For multi-modal transport, an allowance is made for transport by truck and the costs of transporting the empty container to a depot. It should be noted that the sea freight of the deep-sea trades has no influence on the cost variable in the logit function, as carriers apply the same tariff to each of the continental seaports. Transport time is the time interval between departure of a container from a seaport and the arrival at the final destination in the hinterland, and *vice* *versa*. Data on costs and time were collected from an international freight forwarder, a barge operator and a railway operator.

The 'IAT in port' variable is an index based on the reciprocal of the average number of calls, which is proportional to the average number of weekly services calling at a port of the transatlantic and Europe-Far East trade routes. For a port with 10 lines calling weekly on the Europe-Far East trade route, the IAT value would be $365/(10*52)=0.7$ days. It is not clear what this time interval means to a particular shipper/receiver and what he considers important for his choice: the number of calls offered by all operators, one operator, an Alliance, a consortium or a combination of these? The number of services connecting with the particular ports in the Far East he is trading with? The IAT variable describes the fact that a particular port offering a great number of services is thereby attractive. The index variable therefore rather reflects the quality of service of a port.

The 'IAT of a hinterland mode' is defined in a similar way and it is proportional to the average number of weekly services of the particular hinterland mode between the selected port and the hinterland region. The market share of a port is defined as the ratio of the hinterland throughput of a port to the total hinterland throughput of all ports and is derived from port statistics.

To estimate the model, an arbitrary base route was chosen: road transport between the port of Rotterdam and the hinterland region. The differences in probability, costs, time, IAT and market share are all compared to this base routing (see equation 5).

A considerable number of models was tested, five of which are discussed here (see Table 1). In the first model, differences in costs, time, IAT of inland transport modes and an inter-arrival index for liner service frequency per port were taken as explanatory variables. Except for the time variable, all coefficients appeared to have the right sign and to be statistically significant, having a P-value of less than 5%. Most probably, the low significance of the time variable can be explained by the lack of distinction between the different routings for this variable. The explanatory power of the model, as given by the value of the adjusted R^2, was rather low (0.11).

Various models were tested, and it appeared that importers and exporters located further away from the ports had a different perception of time- and cost-related factors than the ones located closer (see Figure 3). A Chow break-test[2] confirmed this. To solve this problem, the variables were split into a distance-dependent and a distance-independent part. This led to a better fit as it appears from models 2 to 5. In models 2 and 3, the sign of the constant cost coefficient is positive, which seems inappropriate. However, the total cost coefficient, the sum of constant and variable part, is negative for the range of

Table 1: Equations tested for routing choice with respect to continental hinterland regions

Variable	Coefficient	s.e.	*t*-Statistic	*P*-value
Model 1				
ΔCosts	−0.0016	0.0002	−6.97	0.00
ΔTime	−0.1179	0.1265	−0.93	0.35
ΔInter-arrival time in port	−0.5105	0.0435	−11.73	0.00
ΔIAT hinterland modes	−0.8177	0.2978	−2.75	0.01
R^2	0.1242		s.e. of regression	2.3077
Adjusted R^2	0.1147		Observations	246
Model 2				
ΔCosts	0.0014	0.0006	2.37	0.02
ΔCosts p. avg. dist.	−0.9228	0.1953	−4.73	0.00
ΔTime	−0.1919	0.1183	−1.62	0.11
ΔInter-arrival time in port	0.0769	0.1139	0.68	0.50
ΔIAT port p. avg. dist.	−166.9038	33.060	−5.05	0.00
ΔIAT hinterland modes	−0.6157	0.2794	−2.20	0.03
R^2	0.2457		s.e. of regression	2.1496
Adjusted R^2	0.2318		Observations	246
Model 3				
ΔCosts	0.0014	0.0006	2.24	0.03
ΔCosts p. avg. dist.	−0.9167	0.1965	−4.67	0.00
ΔTime	−0.2523	0.1167	−2.16	0.03
ΔMarket share hub-port	−3.4802	2.4276	−1.43	0.15
ΔMarket share port p. avg. dist.	4018.790	708.39	5.67	0.00
ΔIAT hinterland modes	−0.6386	0.2777	−2.30	0.02
R^2	0.2508		s.e. of regression	2.1423
Adjusted R^2	0.2371		Observations	246
Model 4				
ΔCosts	−0.0008	0.0004	−1.81	0.07
ΔCosts p. avg. dist.	−0.6752	0.1367	−4.94	0.00
ΔTime	0.0579	0.1237	0.47	0.64
ΔMarket share hub-port	−3.2195	1.6910	−1.90	0.06
ΔMarket share port p. avg. dist.	2756.291	500.20	5.51	0.00
Dummy rail	−3.4428	0.1979	−17.40	0.00
Dummy IWT	−2.1957	0.5693	−3.86	0.00
Dummy IWT Rotterdam–Antwerp	2.6222	1.5391	1.70	0.09
R^2	0.6442		s.e. of regression	1.4817
Adjusted R^2	0.6350		Observations	246
Model 5				
ΔCosts	−0.0008	0.0004	−1.77	0.08
ΔCosts p. avg. dist.	−0.6798	0.1361	−4.99	0.00
ΔMarket share hub-port	−3.3274	1.6728	−1.99	0.05
ΔMarket share port p. avg. dist.	2790.387	494.16	5.65	0.00
Dummy rail	−3.4101	0.1849	−18.44	0.00
Dummy IWT	−1.9633	0.2787	−7.04	0.00
Dummy IWT Rotterdam–Antwerp	2.4773	1.5055	1.65	0.10
R^2	0.6439		s.e. of regression	1.4796
Adjusted R^2	0.6361		Observations	246

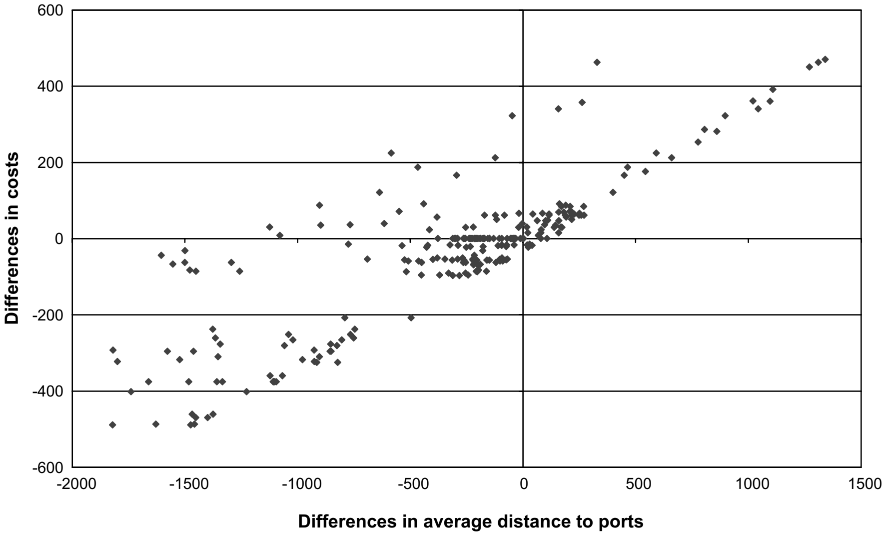

Figure 3: Relation between differences in costs and differences in average distance to the ports for all routes

average distances considered here. The same applies to the 'IAT in port' coefficient in model 2.

A further improvement appeared to come from the replacement of the 'IAT in port' variable, being a proxy for quality of service, by the market share of ports. This variable is also split up into a distance-dependent and a distance-independent part. The sign of the combined market share coefficient is positive. The constant part of the coefficient is not significant. The result is still poor in terms of the value of R^2 (see model 3).

The inclusion of mode-specific dummy variables appeared to lead to further improvement (see model 4). By including dummies, the 'IAT of hinterland modes' variable is no longer significant. The dummies for rail transport and inland waterway transport (IWT) have both negative signs, implying that less container flows use these modes than explained by the other variables, such as the cost difference. The dummies can be interpreted as a proxy for quality of service of these modes, with rail transport scoring lower than IWT.

Further data analysis revealed that a great number of containers is shipped between Rotterdam and Antwerp by barge. The explanation of this phenomenon lies in the practice of discharging containers with Bill-of-Lading 'Antwerp' in Rotterdam and transporting them to Antwerp by barge. In this model, the positive sign of the time variable is not as expected; this variable is therefore dropped from the final model.

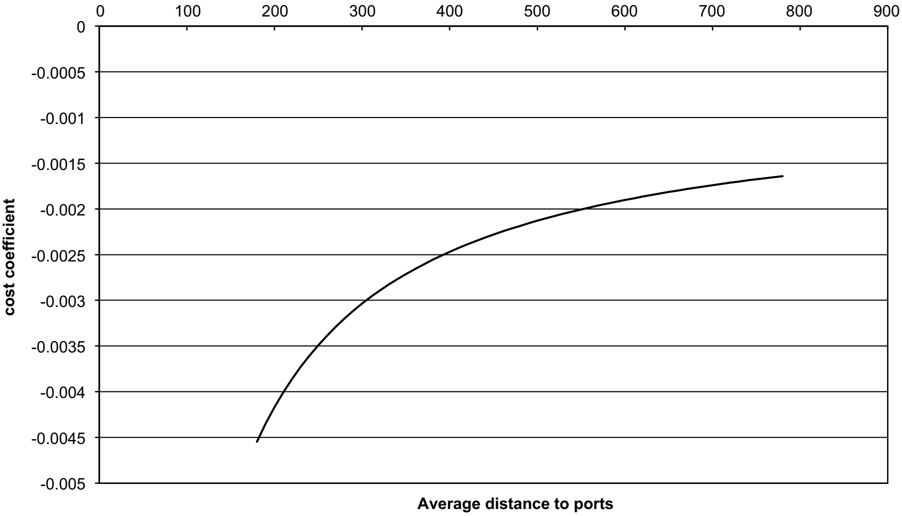

Figure 4: Value of cost coefficient depending on the average distance of a hinterland region to each of the four ports

In the final model, model 5, the cost variable is not statistically significant, but is included in order to be used for forecasting purposes. The Bill-of-Lading dummy also remains since data research has demonstrated its significance. The cost coefficient varies between −0.0045 and −0.0016, depending on the distance between hinterland region and ports (see Figure 4).

Transhipment flows

Generally, the choice of a transhipment port is made by the shipping line and it is not of direct importance to the shipper/receiver. Apart from the port of origin or destination, users cannot influence this choice directly by, for instance, naming a port in the Bill of Lading, as is the practice with merchant haulage. The user, however, values the choice of a transhipment port on the basis of the impact it has on the value of its attributes, such as costs and transit time. Through the interactions between users and carriers, the selection of a good transhipment port is rewarded by a higher market share.

A similar statistical analysis was conducted for the choice of transhipment port. Given the competitive situation among transhipment ports, we needed to expand the geographical scope by including the seven major ports, that is, the four major continental ports, two UK transhipment ports (Felixstowe and Southampton) and Le Havre, as well as 14 West European feeder regions, generating together 88% of Rotterdam's transhipment volume. The remaining

12% concern containers transhipped between the West European major ports themselves and containers generated by feeder regions outside West Europe.

Transhipment flows were assessed on the basis of incoming and outgoing flows through the hub-ports, the ship call patterns of feeder services connecting hub-ports and feeder areas, and the average capacities of the ships used on these services by each shipping line. The total volume to/from a transhipment port was assumed to be distributed over the feeder services calling at the port according to the annual capacity of the service. Per feeder service, the volume was assumed to be distributed over the overseas hinterland regions according to the number of calls to that region. Finally, the container flows to/from each overseas region were checked against the container throughput of its port.

Feeder flows between the major ports themselves were discarded. The costs of these flows are not charged directly to shippers and receivers, as they are included in the ocean-sea freight. Feeder costs for ports outside the continental port range, however, are charged to the shippers/receivers on top of the ocean-sea freight. For the UK ports, a difference in ocean-sea freight has to be adopted too, as they face a deep-sea freight rate level in excess of the continental ports, due to the weaker position of shippers and receivers *vis-à-vis* carriers. The transport costs include the average costs of transporting a container between the stack in one of the transhipment ports and the stack in the port of the overseas region, thus including terminal handling charges. For the UK ports, the difference in ocean-sea freight rate was also included. The information was collected from shipping lines.

The quality of feeder services, in terms of sailing time, differs only slightly among the different transhipment ports, while the frequency of service is similar. These variables were therefore not included in the analysis. Since some ports are visited more often than others, the total number of calls of feeder services differs among transhipment ports and is thus included as a variable. Its value is based on the weekly ship call patterns of all feeder services.

Same as in the analysis of the continental hinterland, the market share of a hub-port is included as a proxy for quality of service. It is defined as the ratio of the total container throughput of a port to the total throughput of all seven ports. The data have been collected from port statistics.

Similar models were tested as for the choice of the continental ports (see Table 2). The first model includes the 'difference in costs', 'market share' and 'number of calls at the major ports' as explanatory variables. The adjusted R^2 value was 0.64, which is quite high compared to continental hinterland flows. Only the cost variable appears to be statistically significant; the market share variable shows the wrong sign. Both the number of calls and the market share variable are proxies for 'quality of service' in a port and are thus highly

Table 2: Equations tested for routing choice with respect to overseas hinterland regions

Variable	Coefficient	s.e.	t-Statistic	P-value
Model 1				
ΔCosts	−0.0042	0.0007	−6.15	0.00
ΔMarket share hub-port	−1.5459	6.3194	−0.24	0.81
ΔCalls hub-port	0.0186	0.0148	1.26	0.22
R^2	0.6558		s.e. of regression	0.6993
Adjusted R^2	0.6386		Observations	43
Model 2				
ΔCosts	−0.0016	0.0011	−1.43	0.16
ΔCosts p. avg. dist.	−2.6704	1.3264	−2.01	0.05
ΔMarket share hub-port	5.3591	1.1795	4.54	0.00
ΔMarket share port p. avg. dist.	521.95	1250.4	0.42	0.68
R^2	0.7130		s.e. of regression	0.6467
Adjusted R^2	0.6909		Observations	43
Model 3				
ΔCosts	−0.0014	0.0010	−1.42	0.16
ΔCosts p. avg. dist.	−3.0394	0.9787	−3.11	0.00
ΔMarket share hub-port	5.7660	0.6573	8.77	0.00
R^2	0.7117		s.e. of regression	0.6400
Adjusted R^2	0.6973		Observations	43

correlated. Since both of them were not statistically significant, a model including only one pair of these variables was tested.

The split of the variables in a distance-dependent and a distance-independent part led to mixed results: an increase in the value of R^2, but generally lower t-values. The market share variables again show the wrong sign (see model 2). In the final form, the distance-dependent part of the market share was discarded due to the low t-value. The cost variable was not statistically significant in model 3, but it was kept for forecasting purposes.

Conclusions on statistical tests

In most models, explanatory variables such as differences in costs, frequency index and port market shares appear to be statistically significant, both in absolute terms and when divided by the average distance to the ports. The impact of differences in transit time is weak and the most likely explanation of this is the lack of distinction in the differences in time.

The market share variable, however, requires some attention. On the one hand, it corresponds to frequency of service or, in its reciprocal form, to IAT. On the other hand, it includes aspects related to the supply side. A port with relatively low port call costs (deviation costs of main-line, cargo-handling costs and accessibility for large ships together cause differences in port-related costs) is attractive for shipping companies as port of call. Therefore, in their interactions with shippers and receivers, shipping companies may call more at these low-cost ports, than what would be expected considering hinterland costs and quality of service aspects only. Price-setting practices and market forces oblige carriers not to discriminate between the major continental ports.[3] If a certain port is more attractive to operators, they just call there more often and accept the higher inland transport costs. The common practice of 'carrier haulage' offers them the instrument to achieve the preferred frequency of their port call pattern.

The increase in container traffic volumes leads to a combination of an increase in the size of ships deployed and in the frequency of service, which as such fuels a further increase in traffic volumes. In the literature, the latter effect is referred to as the Mohring effect (Sansom *et al*, 1999).

APPLICATIONS OF THE MODEL

Three applications of the logit model for container port planning purposes are discussed. The first concerns the port of Gdynia in Poland, where container throughput crucially depends on the competitive position of feeder line transport against land transport. This situation concerns a trade-off between a low-cost–low-quality routing against a high-cost–high-quality routing. The assessment of a trade-off between costs and quality of service is the core of the container throughput forecast. The example is based on the application of plausible assumptions rather than on statistical measurements. The second example concerns a study on the impact of a change in port-cost recovery on the market shares of the major North Sea container ports. The coefficients used are taken from other situations. The third example concerns the assessment of market share as a function of changes in generalised costs of the Maasvlakte 2 project in the port of Rotterdam.

Forecasting container throughput in the port of Gdynia, Poland

Polish seaports face competition from other foreign ports and from each other. Ocean-going container traffic can be routed to and from Polish regions directly through Polish ports, indirectly transhipped through North Sea ports connecting with Polish ports and indirectly through North Sea ports over land. During the early 1990s, with the withdrawal of ocean shipping lines connecting ports in the Baltic, the first option has practically disappeared. Forecasting port-throughput in a port like Gdynia, as far as deep-sea containers are concerned, therefore implies forecasting the share of the transhipment routing *via* North Sea ports within the total.

From interviews with shippers and receivers, it appeared that both routing options were used simultaneously, with market shares per region varying with the geography of the country: lower shares for the Gdynia option for the southern and western regions of the country and higher shares for the eastern and northern regions. It was decided to apply a logit model, as a precise demarcation of the hinterland regions could not be assessed.

The parameters of the logit model were derived from assumptions on the value of time (Veldman, 1994) and costs; time and IAT differences were used as explanatory variables. Given the value of time, that is, the ratio of the coefficients of the utility function, the absolute value of the coefficients had to be established. Statistical testing of the model was not possible. Therefore, some broad tests were made by varying the absolute value and comparing the resulting throughput levels with the existing one. This procedure resulted in a set of plausible parameter values. Subsequently, future market shares were assessed by using the latter together with predicted values of the explanatory variables. In this way, sensitivity analyses could be carried out, using alternative assumptions with respect to the impact of envisaged changes in border crossing procedures, new rail services and road infrastructure.

It may be clear that, when port throughput is more sensitive to shifts in market shares than to growth of the total container demand, some broad assessments with the logit model are justified, despite the lacking values of coefficients either statistically calibrated or taken from other choice situations.

Assessment of the impact of changes in pricing policy on port market shares

In the European Union, the present system of pricing port infrastructure with respect to cost recovery is a mixture of national policies. In a study of the European Commission on this issue (ATENCO, 2001), a number of case studies were developed. One of them had, as objective, to assess the impact of a new pricing policy on market shares of container ports. The study concerned the North Sea container ports in the Antwerp-Hamburg range. To meet the targets of a policy of full port-cost recovery, charges for port access (dredging) would have to increase by euro 0.4, 1.2, 4.8 and 4.8 per TEU for the ports of Rotterdam, Antwerp, Bremen and Hamburg, respectively. To assess the impact on port market shares, it was assumed that the increase in costs would not be absorbed by the sea freight, but fully charged to the shippers and receivers.

The only way to quantify this impact is to assess a relation between price and market share of container routings for the various regions of the continental hinterland of the North Sea ports. Information on the actual choice of container routings was available, but no information on the choice attributes and parameters of the logit function.

The application of the model can be better explained by taking the logarithm of equation 3:

$$\mathrm{Ln}(P_m/P_n) = U_m - U_n \tag{4}$$

or

$$\mathrm{Ln}\left(\frac{P_m}{P_n}\right) = \alpha_{0m}D_m - \alpha_{0n}D_n + \alpha_1(C_m - C_n) + \alpha_2(T_m - T_n) + \alpha_3(F_m - F_n) \tag{5}$$

As a result of a change in port costs by ΔC, the utility of routings m and n will change, depending on the ports used in the two routings. The change in routing ratios can be expressed as:

$$\Delta(\mathrm{Ln}(P_m/P_n)) = \Delta(U_m - U_n) = \alpha_{1m}(\Delta C_m - \Delta C_n) \tag{6}$$

The ratios of the routings as experienced in the past can be used as a proxy for the real values of P_m/P_n. To assess the change in market share of the various routings and thereby of the ports, only coefficient α_1 has to be known as this appears in equation 6. A value of –0.035 was taken, derived from literature on modal split (ATENCO, 2001).

The absolute value of the chosen coefficient is substantially larger than those resulting from the statistical estimations mentioned above, leading to a greater sensitivity of the market share to price changes. It should be noted that the model discussed here did not include a frequency or market share variable that interacts with the cost variable, enlarging its impact, as discussed later.

The effect of the above-mentioned changes in port costs would lead to changes in port market shares of 3.2%, 1.2%, −4.3% and –4.2% for Rotterdam, Antwerp, Bremen and Hamburg, respectively.

In practical situations, this approach seems acceptable as a first broad indication of the impact of changes in port costs on port market shares. The outcome, however, is not very convincing, given the lack of knowledge on the value of coefficients. The example that follows overcomes this shortcoming.

The Maasvlakte-2 project

The future container-throughput market share of the port of Rotterdam can be assessed as a function of cost differences in the case the Maasvlakte-2 project is carried out and the one where it is not. By increasing the costs of the port of Rotterdam *vis-à-vis* its competitors, containers are rerouted to competing ports. By systematically increasing the costs of containers passing through the port of Rotterdam, the market share of routings *via* Rotterdam becomes smaller.

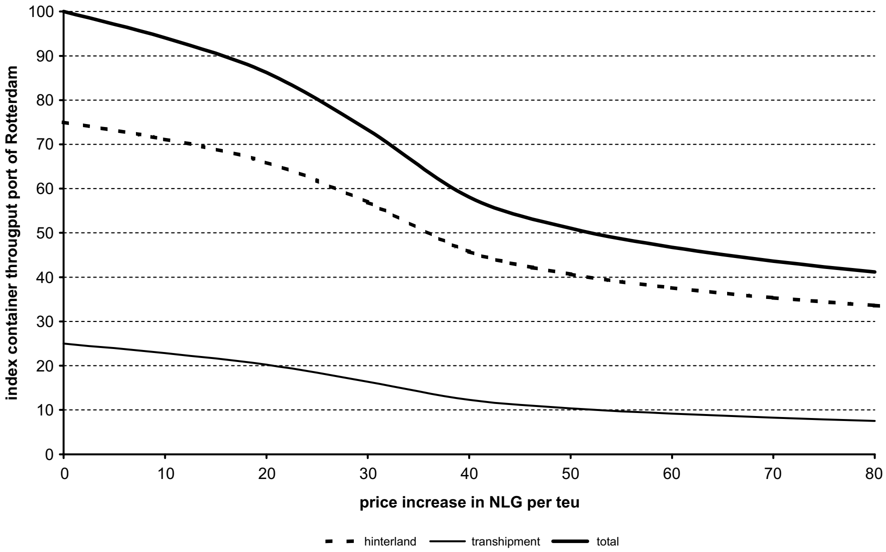

Figure 5: Impact of a price increase of port costs on the choice of port

The market share is assessed in an iterative way. An increase in costs leads to a decrease in market share, which leads to a further decrease through the market share variable and so on. For the estimated values, this process appears to converge, resulting in a demand curve (see Figure 5).

By matching the demand curve with the future supply of the port of Rotterdam without the Maasvlakte-2 project, one obtains a basis for the assessment of economic benefits related to routing cost savings of this project.[4]

Results from the above models (CPB *et al*, 2001b) show that, by increasing the costs of using the port of Rotterdam *visà-vis* competing ports by NLG 60 (EURO 27) TEU, the market share of the container traffic in the West European continent will be halved. For transhipped containers, a halving appears to correspond to a price increase of NLG 40 (EURO 18) TEU.

Once the project is considered viable from the socio-economic point of view, the question arises as to what extent the investment can be recovered through tariffs. The demand curve was therefore also used to assess the financial impact of alternative port cost recovery schemes.

CONCLUSIONS

World container-handling capacity is increasing fast with investments in expansion of existing ports and construction of new ones. Many studies are conducted to forecast demand, but little attention is paid to methodology. Given the strong increase in demand, the accuracy of port capacity forecasts has not been too big an issue and, given the lack of statistical data, not much attention has been paid to methodology. As growth rates in a number of regions are decreasing and as the primary container ports in some regions are declining in importance both in relative and absolute terms, things change and insight in forecasting container market shares is considered more important.

The theoretical framework of transportation planning models offers a good starting point for port demand modelling and its application is only hampered by scarcity of data. Ports are part of a worldwide network of container transport services, which is becoming increasingly more fine-meshed. Assessing a port's role and market share in such a network means that a part of the network has to be singled out without loss of consistency.

A logit model is an important tool for the assessment of container port market shares in situations where competing ports have a large overlap in hinterland. The major constraint in the use of logit models concerns knowledge of the proper model specifications and related coefficients, as it is not always possible to calibrate models. In such circumstances, calibration can be done at an aggregate level or with stated preference analysis.

Results of the assessment were presented for the market shares of the port of Gdynia in the container flows in Polish regions (Veldman, 1994). A logit model was applied to assess the market shares of the Polish regions in combination with a great amount of expert judgement. Essential in this assessment was the trade-off between costs and time of the routing options. The coefficients of the logit function were based on a set of assumptions rather than being calibrated by revealed or stated preferences.

In a second study (ATENCO, 2001) on the assessment of the impact of container port pricing policies on port market shares, a logit model was also employed, concerning this time the West European container ports. The parameters of the logit models were derived from the literature on modal split. The lack of properly estimated coefficients was considered as a major drawback.

Most attention in this paper focused on the container port market share assessment of the port of Rotterdam (CPB *et al*, 2001a, b), where an extensive statistical analysis was performed to estimate the parameters of a logit model for choice of West European container ports. Apart from the usual variables such as costs and time differences, a quality of service variable, related to market share, was also adopted. These variables were statistically significant and thus used for forecasting purposes. The cost variable was not only used for port market share forecasts as such, but also as a basis for economic analysis (ie in order to forecast what would happen with and without the Maasvlakte-2 project, using the outcome as a basis for assessing economic benefits), as well as for the assessment of the impact of alternative port-cost recovery schemes.

ENDNOTES

[1] We thank Mr CJJ Eijgenraam and Mr R Saitua Nistal of the Netherlands Central Planning Bureau for their fruitful discussions on the estimation and use of the logit model.

[2] The data set was split into a set with regions close to the ports and a set with regions further from the ports. The coefficients were estimated for each set separately. The hypothesis of a constant cost coefficient over the sets was rejected by a Chow break test.

[3] This applies both to the transatlantic and Europe–Far East trade routes. The market share of Rotterdam in the latter is considerably greater than in the former. An explanation – going further than just 'tradition' – is that the port of Rotterdam is more accessible for the larger containerships on the Far East trade route than the other ports.

[4] In fact, a supply curve was constructed representing the port capacity of the existing terminal and the new expansion as a function of costs. By increasing port throughput of the terminals, port congestion will rise within the terminal and on the quays alongside, resulting in higher costs of using the port (see CPB *et al*, 2001a).

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