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THE INFLUENCE OF LOAD SIZE AND DISTANCE ON MARITIME FREIGHT RATES

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Abstract

This paper concentrates on the competition between ports, and more particularly on two aspects which are related to the nautical positions of a port: its draught and its distance. The draught has an effect on the size of the ships entering the ports, and as such also on the cost per transported ton. An inland port requires a longer approach and it can be reasonably assumed that this has an upward effect on the maritime transport costs per ton.

INTRODUCTION

The present paper is part of a research project on the structural competitiveness of sea ports. The competition between ports and the optimal ship size are undeniably linked to each other. Over the past decades, the strong scale increase in maritime transport has led to the assumption that it was crucial to use the biggest vessel able to call at both the port of origin and the port of destination and was available at the required moment (Kendall 1972:128). As a result, every port had an incentive to strive for the largest possible ships.

Theory as well as practice has shown, however, that factors like the volume of trade, the transport distance and the value of the products to be transported are also important determinants of the optimal ship size, and can therefore not be neglected.

The present contribution will concentrate on the competition between ports, and more particularly on two aspects that are related to the nautical position of a port: draught and distance. The draught of a port has an influence on the size of the vessels that can call at the port, and even more on the load a ship can carry, and as such also on the cost per transported ton: transporting larger quantities is possible at lower unit costs.

An inland port requires a longer approach and it can reasonably be assumed that as a consequence maritime transport costs per ton will be higher.

But then again, transport in smaller vessels has a positive effect on storage costs. An inland port finds itself closer to the markets and, as a result, brings about lower hinterland costs. The only correct way to investigate the structural competitiveness of ports is to consider the entire transport chain. This includes the cost of the actual sea transport, the storage costs on the goods (cyclic, buffer stock, transport), the costs of hinterland transport, and the goods handling costs. This paper only deals with the effect of draught and voyage distance on the cost of the actual seaborne transport.

The methodology used in this study is based on modelling. Our knowledge of the cost structure is used to define an econometric cost specification which will be estimated empirically by using observed market data. This method allows us to determine how factors like load size and distance to be covered are of absolute and relative importance to freight rates. For the time being, the empirical work will be limited to the transport of dry bulk goods, more specifically grain.

MODEL SPECIFICATION

The majority of the literature on cost analysis for maritime transport makes use of the engineering method, which systematically composes and simulates the cost structure on the basis of distinct components: crew, fuel, capital interest and depreciation, insurance, maintenance and repair, goods handling costs and overheads. Recent examples of this approach can be found in the work of Chrzanowski (1985), Benford (1985), Heaver (1985), Buxton (1985), Moreby (1985), Blauwens and Van de Voorde (1991).

Examples of econometric modelling of seaborne transport costs are scarce, but we could name, eg Jansson en Shneerson (1982), De Borger and Nonneman (1981). In the latter paper, the authors specified and estimated a model in which the freight rate for a certain voyage is a function of the following independent variables: ship size, voyage distance, surplus capacity, seaborne capacity, and a vector of other characteristics (eg calling at more than one port). This model therefore also incorporates variables that reflect the general condition of the shipping market.

Freight rates are indeed determined, across time, by the interplay of supply and demand: an excess supply of tonnage will for instance induce downward pressures on prices. Yet freight rates can also be influenced by other exogenous powers that have not been taken up in the model of De

Borger and Nonneman. A typical example is an oil shock, which suddenly forces up freight rates for speculative and other reasons.

In this stage of our research we are mainly interested in the effect of load size and voyage distance on the freight rates. However, we will have to keep in mind that fluctuations in the maritime transport market and in the global economy, and their impact on pricing, could modify the studied effects of load size and voyage length.

The total transport costs per voyage consist of various components. First there are costs that are a function of the duration of the voyage. Beside that, there are costs that are a function of the distance covered. Finally, there are costs relating to the terminal operations (port dues, handling costs, storage costs) and to the inland transport.

For the time being, we abstract from the costs incurred in the port (ie the costs that are related to the terminal operations) and the costs related to inland transport, and we will concentrate on the costs that are linked to the actual maritime transport, costs that are reflected in the freight rates to be paid for seaborne transport. In the literature (see, eg Jansson and Shneerson 1982:217) it is claimed that for the actual maritime transport the costs per ton diminish with increasing ship sizes, whereas the costs for the port operations rise with increasing ship sizes. Hence, there is a trade-off between economies of scale in the transport operations and diseconomies of scale in terminal operations.

Equation (1) specifies the total cost of actual seaborne transport as the summation of fuel costs and other costs.

$$TCOST_{ij} = (DAYCOST_l)(TTIME_{ij}) + FUEL_{ij} \tag{1}$$

where $TCOST_{ij}$ = total cost linked to maritime transport between i and j
$DAYCOST_l$ = daycost of a vessel with size l
$TTIME_{ij}$ = total time needed for seaborne transport between i and j
$FUEL_{ij}$ = fuel costs for seaborne transport between i and j

The total time consists of loading and unloading time on the one hand, and the actual voyage time on the other.

$$TTIME_{ij} = LTIME_l + VOTIME_{ij} \tag{2}$$

where $LTIME_l$ = the loading and unloading time of a vessel with size l
$VOTIME_{ij}$ = the actual voyage time between i and j

Substitution of (2) in (1) gives

$$TCOST_{ij} = (DAYCOST_l)(LTIME_l + VOTIME_{ij}) + FUEL_{ij} \tag{3}$$

The components of the total costs can be further specified. The cost per day consists of two parts; namely, the capital cost and the operational cost. The latter component includes crew costs, technical costs and management costs. A ship's day cost can be seen, in its most general conception, as an increasing function of the ship size, which is, say, expressed in tons of loading capacity Q_l:

$$DAYCOST_l = f_D(Q_l) \text{ with } \frac{df_D}{dQ_l} > 0 \tag{4}$$

with: Q_l = ship size, expressed, eg in tons of loading capacity

The loading and unloading time of a ship is equal to the loading and unloading time per ton multiplied by the number of tons to be handled. In general, it can be assumed that the average loading and unloading time per ton declines with increasing ship sizes:

$$LTIME_l = f_L(Q_l).Q_l \text{ with } \frac{df_L}{dQ_l} < 0 \tag{5}$$

The actual voyage time is the product of the distance to be covered, but also of the speed. It is assumed that the velocity increases, with growing ship sizes and as a consequence the voyage time decreases with increasing ship size. We are aware of the fact that velocity is often used by ship owning companies as an operational parameter to influence the company's results.

$$VOTIME_{ij}=f_V(Q_1).DIST_{ij} \text{ with } \frac{df_V}{dQ_1}<0 \tag{6}$$

where $DIST_{ij}$ = distance (in nautical miles) between i and j

The total fuel costs are the product of the distance to be covered and the fuel costs per nautical mile. The latter are an increasing function of the ship size:

$$FUEL_{ij}=f_F(Q_1).DIST_{ij} \text{ with } \frac{df_F}{dQ_1}>0 \tag{7}$$

Equations (1) until (7) will be the starting point for the empirical investigation.

THE DATA BASE

The model is estimated for one of the most important goods categories (together with iron ore, coal, bauxite, phosphates) in dry bulk transport, namely grain. Grain is understood to mean 'wheat, rice (unhulled), barley, millet and sorghum'(see Nagatsuka 1986:2), following the classification of the U.N. Food and Agricultural Organisation FAO).

Grain transport is mostly carried out by specialized bulk carriers, including combined carriers. In the short term, the bulk shipping market is supposed to work under perfect competition (Evans 1994:321). Even for a shipowner with an important fleet it is hard to exert any influence on the market and on the price. It goes without saying that not all cargo is transported by these ships. There are also conventional tramp lines and multi-purpose ships in the market, and this largely depends on the available port facilities and the size of the shipment. Yet, we start by assuming that there is competition, so that the prices mirror the costs. This enables us to use freight rates as the dependent variable instead of costs for which data are lacking.

The form in which the freight rates usually come about is that of a spot contract for cargo handled by a bulk carrier. Throughout time, freight rates will fluctuate according to a rising demand for transport, but the actual grain price will also influence the rates. As a consequence, the relation between freight rates and costs might not always be perfect.

For the commodity group concerned, we use published figures from the *Lloyd's Shipping Economist* on actual voyages, giving the following information: the ports of origin and destination, the quantity of transported goods expressed in tons, and the realized price per ton.

It can be assumed that the rate structure is a reflection of the cost structure in a competitive market. The costs and rates, however, only apply to the actual seaborne transport. For the additional costs Evans (1994:317) claims the following: "Cargo handling costs, port dues, canal charges etc., are not related to supply and demand for sea transport and the shipowner should logically receive compensation for such expenditure in addition to the freight rate".

The quantity of transported tons is used as a proxy for the ship size. With the help of *Lloyd's Maritime Atlas* and the *Nautical Almanac* we calculated the distance (expressed in nautical miles) between the ports of origin and destination Connections for which it was impossible to calculate the distance on the basis of the tables, were not retained in the data.

The estimations reported apply to one period, namely September 1992.

We first of all worked with a sufficiently large database. In practice this means that we can make estimations with the help of a data set in which the place of origin is always the same. In our case, we deal with grain transport from the Gulf of Mexico (New Orleans). The ports of destination are listed in the appendix. In this way, we can abstract from factors like surplus tonnage capacity, as this is constant for all voyages concerned at that moment in that geographical location.

ESTIMATING THE PARAMETERS AND TESTING THE ECONOMIES OF SCALE

In order to use equations (1) to (7) for an empirical application, we need a more specific form for the functions f_D, f_L, f_V and f_F.

We start by linear approximations by means of first order Taylor-expansions in the average ship size, QMEAN.

$$f_D(Q_l) = a + bQ_l \tag{8}$$

$$f_L(Q_l) = c + dQ_l \tag{9}$$

$$f_V(Q_l) = e + fQ_l \tag{10}$$

$$f_F(Q_l) = g + hQ_l \tag{11}$$

There are no economies of scale in the day costs and the fuel costs if a = 0, respectively g = 0. Indeed, the average day and fuel costs are constant in this case. For the loading and unloading time and the voyage time, there are no economies of scale if d = 0, respectively f = 0.

Substituting (8) to (11) in (3) gives:

$$TCOST_{ij} = (a+bQ_l)\{(e+fQ_l)DIST_{ij} + (c+dQ_l)Q_l\} + (g+hQ_l)DIST_{ij} \tag{12}$$

Dividing both sides of equation (12) by Q_l results in the cost per ton, R_{ij}:

$$R_{ij} = \alpha_0 + \alpha_1 Q_l + \alpha_2 Q_l^2 + \alpha_3 \frac{DIST_{ij}}{Q_l} + \alpha_4 DIST_{ij} + \alpha_5 Q_l DIST_{ij} + u_{ij} \tag{13}$$

where
$\alpha_0 = ac$
$\alpha_1 = ad + bc$
$\alpha_2 = bd$
$\alpha_3 = ae + g$
$\alpha_4 = af + be + h$
$\alpha_5 = bf$
u_{ij} = residual term

The conditions for absence of economies of scale can be reformulated as follows:

a = 0	=>	$\alpha_0 = 0$,	$\alpha_1 = bc$,	$\alpha_4 = be + h$
d = 0	=>	$\alpha_2 = 0$,	$\alpha_1 = bc$	
f = 0	=>	$\alpha_5 = 0$,	$\alpha_4 = be + h$	
g = 0	=>	$\alpha_3 = ae$		

Equation (13) was estimated according to the method of the ordinary least squares (OLS). The estimation results are shown in the first column of Table 1.

The problem with specification 1 is that there is a high degree of multicollinearity among the explanatory variables. As such, there is a very strong correlation between Q_l, Q_l^2 and Q_lDIST_{ij}. In order to prevent this, a number of restrictions can be imposed on the parameters. In addition, this will allow us to test for the presence of economies of scale.

It is clear that $\alpha_0 \neq 0$, which means that there are economies of scale in the daycosts. At increasing ship sizes the average daycost (daycost per ton) will diminish.

Neither α_2 nor α_5 are significantly different from zero. As b evidently differs from zero ,$\alpha_2 = \alpha_5 = 0$ is equivalent with d = f= 0, which implies the absence of scale effects for the loading and unloading times or for the voyage times. The coefficients of equation (13) were therefore re-estimated assuming that $\alpha_2 = \alpha_5 = 0$. This also solves the problem of multi-collinearity. The results are in the second column of Table 1 (specification 2). On the basis of the Wald, Lagrange multiplier, likelihood-ratio and F-test, the hypothesis that $\alpha_2 = \alpha_5 = 0$ cannot be rejected. The specification explains 51% of the variation in rates. The coefficients are clearly significantly different from zero and they have the correct sign.

Table 1 Estimation results: Taylor expansion (first order) 88 observations

$$R_{ij} = \alpha_0 + \alpha_1 Q_l + \alpha_2 Q_l^2 + \alpha_3 \frac{DIST_{ij}}{Q_l} + \alpha_4 DIST_{ij} + \alpha_5 Q_l DIST_{ij}$$

Coefficient	Specification 1	Specification 2
α_0	21.94 (2.062)	20.785 (3.079)
α_1	-0.000372 (-0.613)	-0.000194 (-1.383)
α_2	3.199 E-0.9 (0.614)	0 (*)
α_3	59.543 (2.266)	79.294 (5.622)
α_4	0.00257 (0.858)	-0.000093 (-0.092)
α_5	-4.826 E-08 (-0.846)	0 (*)
R_a^2	0.503	0.510
ln £	-388.81	-389.28
Σu^2	35454.81	35841.7
F	18.63	31.1661

Notes:
* fixed
The values in brackets are t-values

On the basis of the second specification it is possible to calculate the elasticities of the cost per ton, relating to the ship size (ε_Q) and the distance (ε_{DIST}). If $\alpha_2 = \alpha_5 = 0$, then

$$\varepsilon_Q = \frac{Q}{R}\left(\alpha_1 - \alpha_3 \frac{DIST}{Q^2}\right)$$

$$\varepsilon_{DIST} = \frac{DIST}{R}\left(\frac{\alpha_3}{Q} + \alpha_4\right)$$

The cost per ton decreases at an increasing ship size, but the intensity is very much fluctuating, as is apparent from Figure 1. For some relations, the cost per ton is very sensitive to the ship size ($|\varepsilon_Q| > 1$) , while this is not at all the case for some other relations ($|\varepsilon_Q| < 1$).

The longer the distance, the higher the cost per ton, but in the majority of the cases the cost function is inelastic with respect to distance (Figure 2).

Although the results are quite acceptable, a number of problems remain unresolved. On the basis of this linear specification, it is not possible to make statements about the presence or absence of economies of scale for fuel costs. Moreover, the estimated residuals show a number of remarkable outliers (Figure 3).

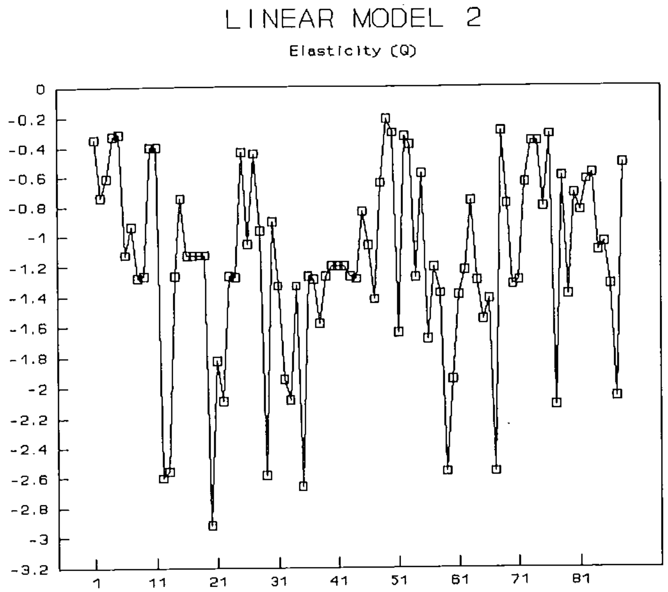

Figure 1 Elasticity of cost per ton with respect to ship size for specification 2 for each observation

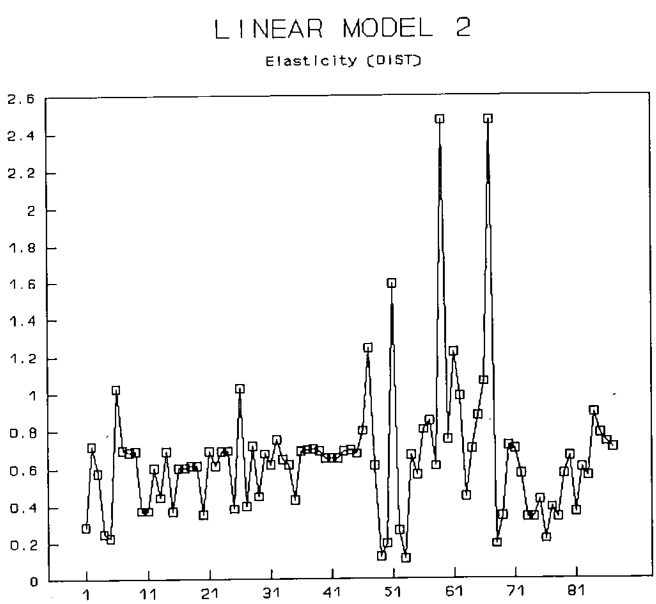

Figure 2 Elasticity of cost per ton with respect to distance for specification 2

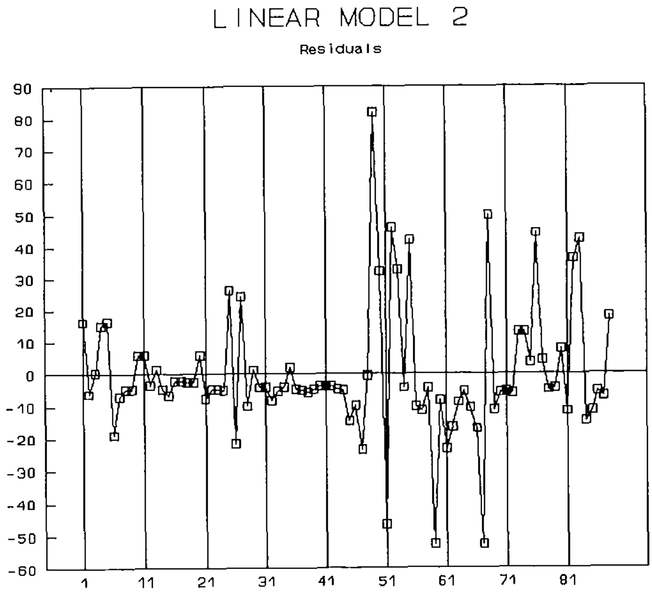

Figure 3 **Estimated residuals for specification 2**

One of the reasons for these outliers can be a misspecification of the functional form. Therefore, as an alternative for the linear approximation, we assumed that the functions f are exponential in terms of Q_l.

$$f_D(Q_l) = aQ_l^{b} \tag{14}$$

$$f_L(Q_l) = cQ_l^{d} \tag{15}$$

$$f_V(Q_l) = eQ_l^{f} \tag{16}$$

$$f_F(Q_l) = gQ_l^{h} \tag{17}$$

After substitution in (3), the cost per ton becomes:

$$R_{ij} = \alpha Q_l^{\beta} + \gamma Q_l^{\delta} DIST_{ij} + \theta Q_l^{\varphi} DIST_{ij} + u_{ij} \tag{18}$$

where $\alpha = ac$

$\beta = b + d$

$\gamma = ae$

$\delta = b + f - 1$

$\theta = g$

$\varphi = h - 1$

u_{ij} = residual term

Estimations with non-linear least squares or maximum likelihood methods failed due to convergence problems. Assumptions about economies of scale can offer a solution, because restrictions will be imposed on the coefficients.

If we retain the assumption that there are no economies of scale for loading and unloading times and voyage time, then d = f = 0 or ß = b and δ = b - 1 = ß - 1. As a result, (18) takes the following form:

$$R_{ij} = \alpha Q_l^{\beta} + \gamma Q_l^{\beta-1} DIST_{ij} + \theta Q_l^{\varphi} DIST_{ij} + u_{ij} \quad (19)$$

The results of non-linear least squares estimations are shown in the first column of Table 2 (specification 3).

Table 2 Estimation results: exponential functions

Coefficient	Specification 3	Specification 4
α	13.317	16.830
	(0.520)	(0.348)
ß	0.027	-0.0099
	(0.143)	(-0.033)
γ	64.152	101.17
	(0.598)	(0.407)
θ	-0.27E-10	-0.000875
	(-0.062)	(-0.373)
φ	1.622	0 (*)
	(1.146)	
R_a^2	0.528	0.499
ln £	-389.159	-390.275
Σu^2	35738.3	36656.9
σ_u^2	430.581	436.391

(*) fixed; the figures in between brackets are t-values

With specification (19) it is possible to test whether there are economies of scale for the fuel costs. When these effects are absent, h = 1 or $\varphi = 0$. The results of the estimations under this restriction are to be found in the second column of Table 2 (specification 4). From the tests it is clear that we cannot reject the hypothesis that h = 1.

The elasticities relating to ship size and distance calculated on the basis of this relation, are shown in Figure 4 and Figure 5.

The fluctuations in the elasticities are less extreme than in the linear model, but point in the same direction with, however, much more tendency towards an inelastic cost with respect to ship size.

Some caution is needed here, because none of the coefficients is significantly different from zero, but they are stable. Moreover, it is also clearly visible here again that the estimated residuals include similar remarkable outliers (Figure 6) as for the linear model.

Instead of strictly keeping to the cost structure and approximating the various components by a Taylor-expansion or an exponential function, we could also consider an immediate approximation of the cost function. This is the path taken by De Borger and Nonneman (1981). The double logarithmic approximation is then:

$$\ln R_{ij} = \beta_0 + \beta_1 \ln Q_l + \beta_2 \ln DIST_{ij} \quad (20)$$

The empirical results of estimations of equation (19) with the data set mentioned above is reported in Table 3. All coefficients are significantly different from zero.

In a second approximation, De Borger and Nonneman (1981:163) took account of a few aspects from studies by Goss and Jones (1977) and Heaver (1970), who worked with engineering cost functions. This leads to:

$$R_{ij} = \gamma_0 + \gamma_1 \frac{1}{Q_l} + \gamma_2 DIST_{ij} + \gamma_3 DIST_{ij}^2 + \gamma_4 Q_l DIST_{ij} \quad (21)$$

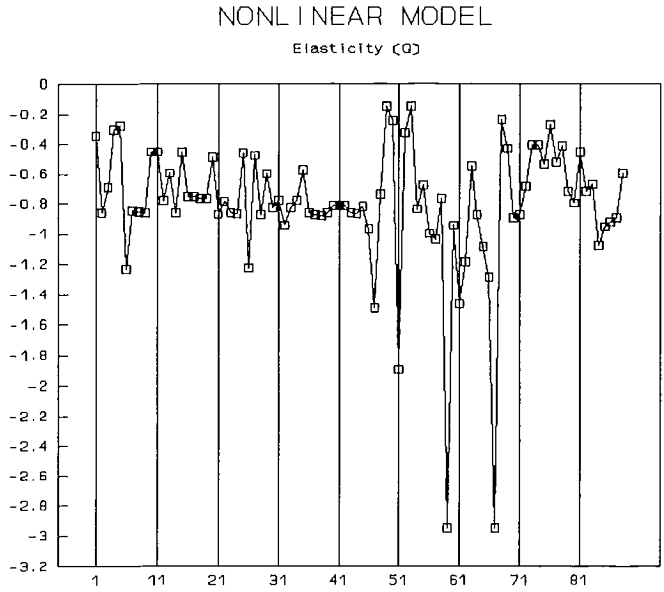

Figure 4 Elasticity of cost per ton with respect to ship size for specification 4

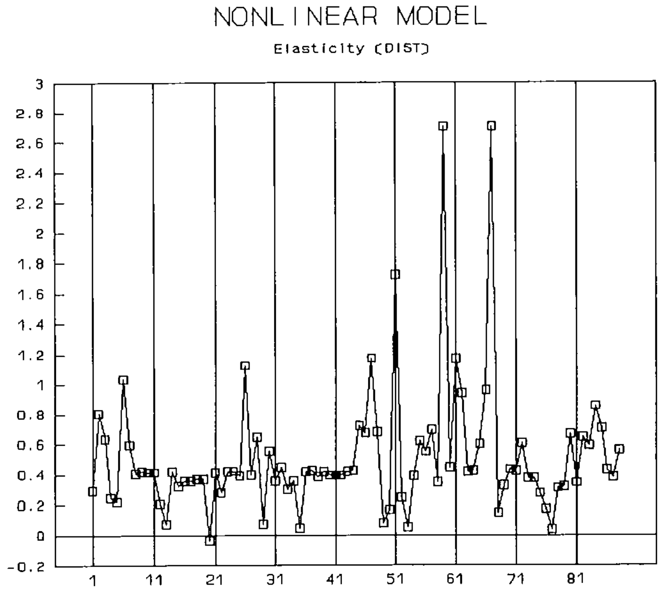

Figure 5 Elasticity of cost per ton with respect to distance for specification 4

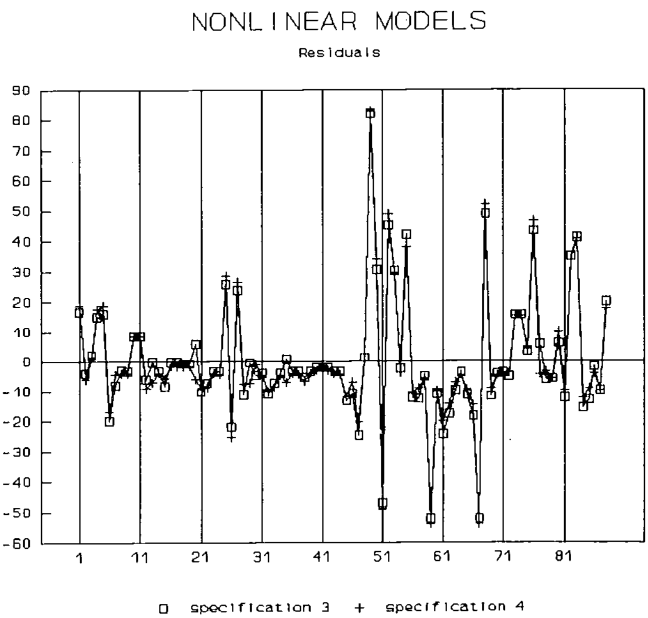

Figure 6 Estimated residuals for specification 4

Table 3 Estimation results double logarithmic specification (specification 5)

$\ln R_{ij} = \beta_0 + \beta_1 \ln Q_1 + \beta_2 \ln DIST_{ij}$		
Coefficient	**estimation**	**t-statistics**
β_0	6.500	9.122
β_1	-0.806	-11.591
β_2	0.579	6.636
R_a^2	0.604	R_a^2 (*) 0.705
ln£	-55.92	
Σu^2	18.365	
F	67.367	

(*) re-calculated for R_{ij} instead of ln R_{ij}

The estimation results can be found in Table 4. The constant factor and the coefficient linked to the variable $DIST_{ij}^2$ turn out not to be significant, whereas the other coefficients are.

As far as the economic interpretation is concerned, in every estimated equation the coefficient of the variables Q_I and $DIST_{ij}$ are significantly different from zero, and have the correct sign. Concretely, this means that a larger cargo leads to a lower freight rate per ton, and that a greater distance leads to a higher price per ton. In all this we assume that the other variables remain fixed.

Also here, the residuals show peaks, as appears from Figure 7. So that we can conclude that this pattern in the residuals is not due to a misspecification of the functional form because every specification estimated in this paper leads to a similar pattern in the estimated residuals This implies that one or more factors not included may have additional explanatory power. Beside the cost structure these factors contribute to the determination of the freight rate, R_{ij}.

Table 4 Estimation results mixed approximation (specification 6)

$$R_{ij} = \gamma_0 + \gamma_1 \frac{1}{Q_1} + \gamma_2 DIST_{ij} + \gamma_3 DIST_{ij}^2 + \gamma_4 Q_1 DIST_{ij}$$

Coefficient	estimation	t-statistics
γ_0	-5.359	-0.391
γ_1	226118	3.189
γ_2	0.010	2.455
γ_3	-2.421 E-07	-0.698
γ_4	-9.774 E-08	-4.294
R_a^2	0.476	
ln £	-391.696	
Σu^2	37860	
F	20759	

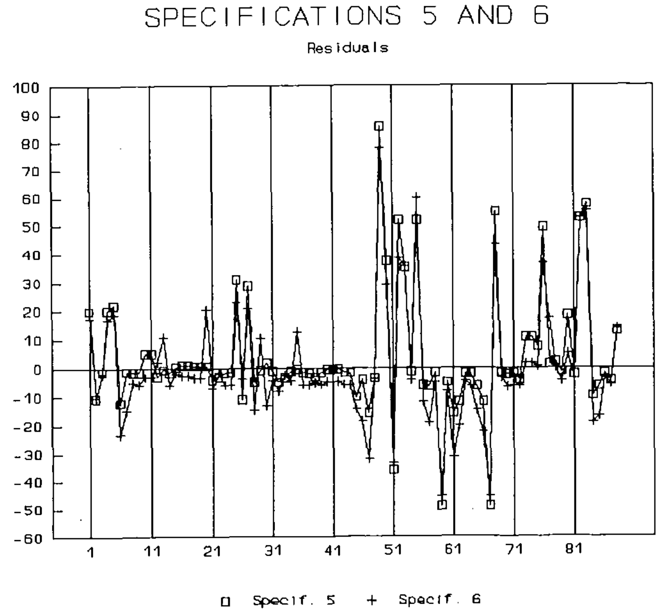

Figure 7 **Estimated residuals for specifications 5 and 6**

One possibility could be to include route-specific elements. Consider this example: the grain transport to Europe stands a better chance of a return freight than transport to Japan. The demand for seaborne grain transport, split up geographically, is not only a function of the world grain production, but certainly also of the imbalances in production of and/or demand for grain. Apart from this, there is also the fact that the time spent in ports may be different from port to port, and this may be a consequence of the available port superstructure, productivity, etc.

FREIGHT RATES AND COMPETITION

In its simplest approximation, it could be said that the freight rates are determined as the mark-up on costs. As we are dealing with a single moment in time, this mark-up could even be negative. In the long term, of course, this is not a viable situation.

As such we get:

$$R_{ij} = (1+m)GK_{ij} = GK_{ij} + mGK_{ij} \tag{22}$$

The latter term (mGK_{ij}) is, as it were, comprised in the residuals, u_{ij}, of the estimated equations from the previous specifications. If m>0 (m<0), then the price will be higher (lower) than the average cost and $u_{ij}>0$ ($u_{ij}<0$). A positive mark-up means that a profit can be made on the origin-destination (ij) relation from i to j. In the opposite case, one is (temporarily) willing to incur a loss, for whatever reason.

An additional question is then how the mark up is determined. Two factors are obviously playing an important part here, namely capacity utilization and market situation. If demand is sufficiently high, and the capacity utilization is very high, this could result in an upward pressure on rates. Clients will be prepared to pay a higher rate to ensure that the cargo is still transported. When the capacity utilization is lower, the rate may be lowered to ensure a partial coverage of the fixed costs.

Perhaps even more important than the capacity utilization is the market situation. When the competition is fierce, this will lead to 'sharp' prices that are very close to the average costs and may even go below that. In the latter case, there is a negative mark-up and this will mean that $u_{ij}<0$. If the competition is not so strong, the rates will differ much more from the average costs, because then there will be an opportunity to make larger profits. This situation can be recognized by m>0 and $u_{ij}>0$.

The value of the residuals can thus be used as an indication of the market situation. Indeed, it is interesting to know

(1) in which routes there is strong competition, and in which there is not;

(2) whether the market situation in the relations remains the same across time;

(3) whether the market situation is the same for all goods categories.

At this moment in the study, the answer to the first question can be derived from the analysis of the residuals. Destinations with extreme positive residuals and hence rates which are higher than average cost are Tunisia, Durban, Casablanca, Aqaba, Port Sudan, Sri Lanka and Paramaribo. This would imply no or very small competitive pressure on these lines. Dar-Es-Salaam, Djibouti and Massawa have high pressure and hence freight rates below average costs. For South Africa and Tunisia the situation is somewhat mixed.

CONCLUSION AND SUGGESTIONS FOR FURTHER RESEARCH

This paper could be seen as a methodological paper, with an empirical application: for one type of transport (voyage fixtures), for only one goods category (grain), for departure from the same port of origin (New Orleans), at one moment in time (September 1992).

In itself, the empirical material presented in this contribution teaches us quite a lot. First of all, we now have an interpretation of the effect of the separate variables and a test for the presence of scale effects. Economies of scale are clearly present in the day costs. Equally interesting are the conclusions on the calculated elasticities relating to the ship size and distance. The cost per ton decreases at increasing ship sizes, but the intensity fluctuates considerably per relation. The greater the distance, the higher the cost per ton, but in the majority of the cases the elasticity is lower than 1. Further, we have also analyzed the estimated residuals as an indicator of the market situation.

On the basis of this empirical work, we can compute the effect of ship size and distance variables on the rate variable, under the hypothesis that the other variables are fixed. Eventually, this will give us some information on aspects that can influence the structural competitiveness of ports. If we assume that a larger vessel type can call at a port, what kind of effect does this have on the freight rate per ton? What advantage is this to the various parties, taking account of the fact that they also need storage in larger quantities, hence for a longer time, and also implying a higher storage cost. Is the disadvantage of a higher maritime transport cost resulting from a port location further inland not outweighed by the doubtlessly smaller inland transport cost?

In itself, the empirical work thus yielded interesting results, but interpreting this we have to remain aware of the circumstantial factors. In the end, the empirical work only applies to a very limited part of the global bulk transport.

A next step in this kind of research requires empirical work for other subfields of bulk transport (eg long term charters), for other commodity groups (eg crude oil, coal, bauxite,...) and for different moments in time. At that point, one could analyze to what extent the relation between rates on the one hand, and load size and distance on the other hand are different per commodity. Conversely, it could be examined how the coefficients differ through time, comparing for instance periods of high average rates with periods of low average rates. That evolution in rates can be the consequence of changes in the growth of the world economy and its concomitant trade, and also of the potential tonnage overcapacity.

At the same time, more work is needed to refine the methodology. The empirical results presented in this paper have clearly shown that there are obviously other factors, not included in our specification, which could have an impact on freight rates. This could be port specific factors, but certainly factors representing the degree of market pressure. A more detailed analysis could give us more definite information in this area. Finally, we have to examine where and in which form the output of this kind of model could serve as input, for instance in cost benefit analysis of port investment.

REFERENCES

Beenstock, M. and Vergottis, A. (1993) *Econometric Modelling of World Shipping*. Chapman and Hall, London.

Benford, H. (1985) Ships'capital costs: the approach of economists, naval architects and business managers. *Maritime Policy and Management* 12, 9-26.

Blauwens, G. and Van de Voorde, E. (1991) Port renovation and optimal ship size: the case of bulk transport. In W. Winkelmans (ed.), *Shipping and Port in the National Economy. Economic Relations and Models*. Maritime Transport Economics Institute Gdansk and Department of Transport Economics (Ruca), Antwerp.

Branch, A.E. (1988) *Economics of Shipping Practice and Management*. Chapman and Hall, London.

Buxton, I.L. (1985) Fuel costs and their relationship with capital and operation costs. *Maritime Policy and Management* 12, 47-54.

Chrzanowski, I. (1985) *An Introduction to Shipping Economics*. Fairplay Publications, London.

De Borger, B. and Nonneman, W. (1981) Statistical cost functions for dry bulk carriers. *Journal of Transport Economics and Policy* 15, 155-165.

Evans, J.J. (1994) An analysis of efficiency of the bulk shipping markets. *Maritime Policy and Management* 21, 311-329.

Goss, R.O. and Jones, C.D. (1977) The economies of size in dry bulk carriers. In R.O. Goss (ed.), *Advances in Maritime Economics*. Cambridge University Press, 90-137.

Heaver, T.D. (1970) The cost of large vessels. *An examination of the sensitivity of total vessel costs to certain operating conditions*. Research and Technical Bulletin 7, National Ports Council, 342-356.

Heaver, T.D. (1985) The treatment of ships'operating costs. *Maritime Policy and Management* 12, 35-46.

Jansson, J.O. and Shneerson, D. (1982) *Port Economics*. The MIT Press, Cambridge, Massachusetts.

Kendall, P.M.H. (1972) A theory of optimum ship size. *Journal of Transport Economics and Policy* 6, 128-146.

Magatsuka, S. (1986) The demand and supply of grain in the world and its impact on shipping. *Jamri report 15*. Japan Maritime Research Institute, Tokyo.

Moreby, D.H. (1985) Crew costs. *Maritime Policy and Management* 12, 55-60.

Stopford, M. (1988) *Maritime Economics*. Unwin Hyman, London.

Verhoeff, J.M. (1987) *De aard van zeehavenconcurrentie*. Ipo-conferentie, Universiteit van Antwerpen, Belgium.

APPENDIX

List with ports of destination

1	PUERTO QUETZAL	45	JAMAICA
2	PUERTO QUETZAL	46	DURBAN
3	GUYANA	47	DAR-ES-SALAAM
4	PUERTO QUETZAL	48	GUYANA
5	PUERTO QUETZAL	49	DURBAN
6	SOUTH AFRICA	50	CASABLANCA
7	SOUTH AFRICA	51	DJIBOUTI
8	JAPAN	52	AQABA
9	JAPAN	53	CASABLANCA
10	JAMAICA	54	JAPAN
11	JAMAICA	55	PORT SUDAN
12	LISBON	56	BARCELONA
13	HOLLAND	57	SOUTH AFRICA
14	JAPAN	58	BLACK SEA
15	LA GUAIRA	59	TUNISIA
16	JAPAN	60	ANTWERP-HAMBURG
17	JAPAN	61	BEIRA
18	JAPAN	62	IRELAND
19	JAPAN	63	VENEZUELA
20	HOLLAND	64	JAPAN
21	LISBON	65	SOUTH AFRICA
22	HOLLAND	66	STAVANGER
23	JAPAN	67	TUNISIA
24	JAPAN	68	SOUTH AFRICA
25	TUNISIA	69	VERACRUZ
26	MASSAWA	70	JAPAN
27	TUNISIA	71	JAPAN
28	ALGERIA	72	CORINTO
29	HOLLAND	73	JAMAICA
30	RUSSIA	74	JAMAICA
31	SOUTH AFRICA	75	SOUTH AFRICA
32	BELGIUM	76	SOUTH AFRICA
33	HAMBURG	77	RUSSIA
34	SOUTH AFRICA	78	BUENAVENTURA
35	AMSTERDAM	79	RUSSIA
36	JAPAN	80	SRI LANKA
37	JAPAN	81	EC MEXICO
38	SOUTH AFRICA	82	SRI LANKA
39	JAPAN	83	SRI LANKA
40	JAPAN	84	ALGERIA
41	JAPAN	85	TUNISIA
42	JAPAN	86	TAIWAN
43	JAPAN	87	ROTTERDAM
44	JAPAN	88	PARAMARIBO