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The Impact of Decreasing Border Barriers in Europe on Freight Transport By Road

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ABSTRACT

At present international freight transport flows have only a small share in total freight movements in Europe. It is to be expected however that the increasing trade between EC countries will have a strong influence on the long-term development of international freight flows. Earlier research by the authors showed the existence of barriers to the exchange of goods between countries, going far beyond actual delays experienced at border crossings. The aim of this paper is to examine the effect of the gradual integration of national economies in Europe on freight transport flows by road, by considering different scenario's for the decrease of border barriers. The methodology is based on an application of partial matrix techniques for the estimation of interregional transport flows. Originally introduced for the purpose of estimating unobserved flows in origin/destination tables, these techniques also proved to be useful for quantifying the influence of decreasing border barriers on freight transport. The presented methodology allows one to take into account these developments for strategic planning purposes. The calculations indicate a significant growth in international transport as an effect of the realization of the Internal Market.

INTRODUCTION

Along with the rapid developments in the political and economical context of European freight transport, the need for information in this field of research has been growing at the same pace. For transportation studies on a European scale, this need for information primarily concerns the flows of commodities between the regions of Europe. International transport has a share of around 3% of the total freight tonnage moved by road within Europe [1]. Despite these relatively small quantities, the economic and environmental impacts are of increasing political concern [2,3]. Due to the growing integration of Europe's national economies, a strong growth of European international transport is to be expected. The integration comprises alleviation of the existing barriers to international business activity. The costs of these barriers for the private sector in Europe were recently estimated to amount to tens of billions of dollars [4]. Physical and administrative hindrances at border crossings (e.g. customs procedures), different technical standards and fiscal regulations on national level were found to be the main impediments towards the so-called "internal market" in Europe. An attempt to quantify the impact of changes in border barriers on freight transport has, to the best of our knowledge, not been documented earlier. Rietveld and Rossera have studied the role of barriers in the demand of telecommunications services [5].

This paper describes a methodology for quantifying the long-term effects of the gradual alleviation of barriers on international freight transportation by road. In earlier research by the authors, the magnitude of present border barriers was identified [6]. For this purpose, a demand model for freight transport by road was formulated for the estimation of an origin/destination table for transport between regions of the European Community. We first describe the available data and the methodology that was developed for the estimation. Next, the estimation method is applied to estimate the influence of gradually decreasing border barriers on cross-border commodity flows. The final section of this paper discusses the results of the estimation and its applicability to strategic planning problems.

AVAILABLE DATA

In order to estimate transport flows under different scenario's a baseyear table of flows between regions, also called an origin/destination (or O/D table), is required. The table can be constructed using data on freight transport from European, national or regional statistics' offices. This process however is a costly one, if it has to be pursued for several countries in Europe. The possible incompatibility of data raises less problems in the case of O/D data already compiled for use on a European level. This compilation of transport statistics is done each year by Eurostat. The Eurostat data that are readily available for our purpose concern only tonnes transported between countries (all commodities taken together) and tonnes transported between regions of the same country (all commodities taken together). Due to the fact that the flows were not observed equally well in all countries of the European Community, our research has to be restricted to the Netherlands (6 regions), Belgium (4 regions), former West-Germany (21 regions) and France (8 regions), for a total of 39 regions in Europe. The latest information available was for the year 1989.

The difference between volumes moved in intraregional and interregional transport is remarkable. Approximately 97% of the total tonnage moved in Europe concerns national transport, of which again ± 85% concerns *intra*regional transport. Intraregional flows (within regions with a diameter up to 75 km.) largely involve transport of building materials. This rather unbalanced character of the available observations would influence the results of the estimation process. Thus we have chosen not to carry out the estimation of the intraregional flows. In fig. 1 we give an overview of the data in the partial matrix.

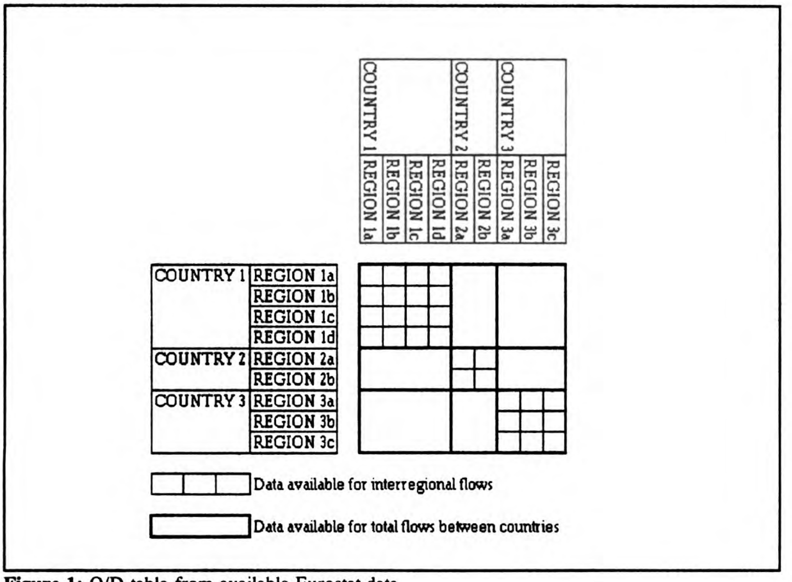

Figure 1: O/D table from available Eurostat data

Because information on interregional flows between countries is not readily available, it is necessary to estimate these flows, taking the Eurostat data as a starting point. The approach used for the estimation comprises an application of partial matrix techniques. The theoretical aspects of partial matrix techniques have been discussed in a general by Kirby [7]. Hamerslag and Immers [8] give a review of the technique and compare it to other matrix estimation methods.

ESTIMATION OF TRANSPORT FLOWS

The distribution of commodity flows, expressed in tons transported between a number of origins and destinations during a certain period, is represented in an O/D matrix consisting of I rows (origins) and J columns (destinations).

Assume that observations t_{ij} are available only for a restricted number of cells in the matrix. Call these cells single cells. Further assume that in the remaining cells of the matrix M blocks or groups of cells can be distinguished. A block or group is a number of cells, not necessarily adjacent to each other, for which only the sum of the observations is known, not the values of the individual cells. In the problem at hand, these blocks represent the groups of regions belonging to the respective countries. It is not required that the blocks cover all the remaining cells. Assume that the observations in the O/D cells are independent and

Poisson distributed, with expected value $\hat{t}_{ij}$. The problem then is to estimate the $\hat{t}_{ij}$, such that the best possible agreement with the observations is obtained.

For one particular cell with expected value $\hat{t}_{ij}$ the probability of observing t_{ij} is:

$$Pr(t_{ij} \mid \hat{t}_{ij}) = \frac{e^{-\hat{t}_{ij}} \cdot \hat{t}_{ij}^{\,t_{ij}}}{t_{ij}!}$$

If the observations for one O/D cell are Poisson distributed with expected value $\hat{t}_{ij}$, then the value for a sum of observations of O/D cells will also have a Poisson distribution. The expected value $\hat{T}_m$ for a block will be equal to the sum of the expected values of the cells the block is composed of. So the probability of observing T_m for block m is:

$$Pr(T_m \mid \hat{T}_m) = \frac{e^{-\hat{T}_m} \cdot \hat{T}_m^{\,T_m}}{T_m!}$$

$$\text{where } \hat{T}_m = \sum_{\text{cell in block } m} \hat{t}_{ij}$$

The probability of observing the given O/D matrix may now be expressed as:

$$L = \prod_{\text{single cells}} Pr(t_{ij}/\hat{t}_{ij}) \cdot \prod_{\text{blocks}} Pr(T_m/\hat{T}_m)$$

Substituting the observations in L an expression is obtained which, considered as a function of the $\hat{t}_{ij}$, is called the likelihood function of the matrix for the given observations. The most likely values for the $\hat{t}_{ij}$ are found by maximizing this function. Since the natural logarithm is a monotonic increasing function of its argument, maximizing the likelihood function is equivalent to maximizing the loglikelihood function:

$$L^* = \ln(L) \tag{1}$$

We now introduce the assumption that the values for $\hat{t}_{ij}$ in the *entire* matrix can be expressed by the gravity model:

$$\hat{t}_{ij} = p_i \cdot q_j \cdot f(c_{ij})$$

where

p_i	=	(production-)polarity of origin i,
q_j	=	(attraction-)polarity of destination j,
$f(c_{ij})$	=	deterrence function, and
c_{ij}	=	resistance (e.g. distance) between origin zone i and destination zone j.

By classifying the resistance values c_{ij} into K intervals we can transform the deterrence function into a discrete function [10]. The values of $f(c_{ij})$ are replaced by the deterrence factor r_k, when c_{ij} is in the k-th interval. The gravity model then becomes:

$$\hat{t}_{ij} = p_i \cdot q_j \cdot r_k \tag{2}$$

Substitution of (2) into the loglikelihood function (1) results in an expression for L^*, which is a function of p_i, q_j and r_k. We find the maximum of the loglikelihood function by setting the first derivatives with respect to p_i, q_j and r_k to zero. This yields a set of $I + J + K$ equations which can be solved for p_i, q_j and r_k using an iterative method. The estimation method has been implemented in a computer program. The computer program has been tested extensively. In almost all cases the iteration process converged to a stable solution in 10 to 20 iteration steps.

To be able to apply the estimation method, both statistics on transport flows and data on transport resistance are needed. For the resistance factor in the deterrence function we use the geographical distance between the regions. If we assume a more or less constant speed of the truck traffic this resistance factor is practically proportional to the time cost of travel. We have classified the distances into intervals of 75 kilometers each. Using a European road network the transport distances can be determined by a shortest route calculation. We used a transport information system developed at Delft University of Technology [10], which contains the network used for the main transport routes through the European Community, to calculate the shortest routes. The method has been validated by using the national transport data for former West-Germany [6].

BORDER BARRIERS

Existing border barriers

The estimation method was used to estimate transport flows between 39 regions in Europe. In the first calculation no border resistances were taken into account. It was found that the estimated commodity flows between countries were much higher than the observations indicated. This result was expected, because the computation is dominated by data referring only to commodity flows between regions of a single country.

We then introduced border resistances between countries by raising the distance class between the regions of these countries. The amount by which the distances are raised thus act as a proxy for the actual border barriers. Only one value is adopted for a relation between countries, even if on a particular journey more border-crossings would occur. We now repeated the computation several times, each time increasing the border resistances systematically, until a satifactory agreement was reached between the estimated commodity flows between countries and the observed ones. Increasing the border resistance was done in steps of one distance class.

The results of the estimation are shown in Table 1. It appears that the resistance to commodity flows between two countries equals about 2 to 4 distance classes (150 to 300 kilometers). It is of interest to note that the values for the resistance are equal for both directions on a certain relation. It is also interesting to see that the border resistance between the Netherlands and Belgium is smaller than the resistance between other countries. This might be explained on the one hand by the longstanding cooperation between these countries within the framework of the Benelux-union (Belgium, Netherlands, Luxembourg), and on the other hand by the relatively small differences in language and culture.

TABLE 1

Border Resistances (In Equivalent Distance Classes of 75 km.)

	NL	*D*	*B*	*F*
NL		3	2	4
D	3		3	4
B	2	4		3
F	4	4	3	

where NL = the Netherlands, D = Germany,
B = Belgium, F = France

Figure 2 shows the deterrent effect of distance (which now is the sum of geographical distance and the distance equivalent of border barriers) on transport flows. This deterrence function was calculated using discrete distance classes; the smooth shape of the the function shows that using a continuous deterrence function for the demand model in (2) would be appropriate.

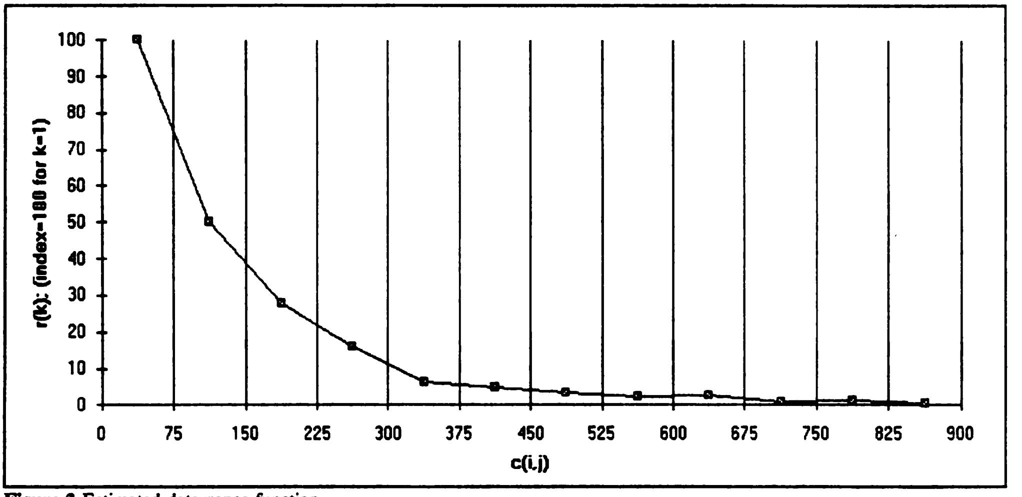

Figure 2 Estimated deterrence function

The impact of decreasing border resistances

Knowing the border resistances at present (i.e. in the year of the available observations, 1989), the following question becomes imminent: in what way will decreasing border resistances affect international transport flows? The first application of the estimation method showed that international transport is strongly overestimated (relative to the observed flows) if no additional resistance is introduced. In order to obtain a satisfactory agreement between estimated and observed cross-border flows, we had to increase the border resitances between countries.

Now assume that we do not introduce any additional border resistances. The problem is now to determine how high the observed cross-border flows (which are used as an input to the calculation) will have to be, in order for the estimation method to reproduce them to a satisfactory degree. The process of adapting "observed" cross-border flows and performing an estimation of the O/D table is repeated until the "observed" flows are equal to the calculated flows. The cross-border transport flows obtained this way can be regarded as estimates of international commodity flows that would result as a consequence of zero additional border resistance. The process described converges rapidly; input and output flows showing approximately 5% divergence after a maximum of 8 iterations. It can be repeated for any value of the border resistances. Using this principle, in addition to the scenario where no border resistances were taken as a starting point, a second estimation was performed assuming all border resistances being the equivalent of two distance classes. As we have seen, this is the case at present for commodity flows between the Netherlands and Belgium. This may constitute a more realistic assumption with respect to the changes in border barriers that can be expected.

The first case, in which border barriers are assumed to disappear completely, indicates an effect on international traffic of between +300% and +500% (table 2). In the case that border barriers will decrease up to the level of the present Benelux union, international freight flows would experience a relatively lower growth (table 3).

TABLE 2

Estimated Growth Factor For International Transport; No Border Barriers

	NL	*D*	*B*	*F*
NL		4.5	3.6	4.3
D	4.1		6.2	5.7
B	3.4	5.6		3.3
F	5.4	4.9	4.5	

where NL = the Netherlands, D = Germany,
B = Belgium, F = France

TABLE 3

Estimated Growth Factor for International Transport; Border Barriers Equal 2 Distance Classes

	NL	*D*	*B*	*F*
NL		1.6	1.1	1.8
D	1.4		2.2	2.1
B	1.1	2.2		1.5
F	2.3	1.9	1.8	

where NL = the Netherlands, D = Germany,
B = Belgium, F = France

EVALUATION

This study has shown that, on an aggregate level, freight transport can be modeled with a gravity model. The results are particularly useful for purposes of transportation planning or transportation policy analysis on a strategic level, i.e. regarding long term developments within a European scope. The described methodology allows us to take into account the effects of a growing integration of Europe's national economies. It is assumed that transport resistances will decrease in the future; this assumption is supported by the low border resistance that was found within the Benelux Union. It would be possible to improve the estimates, taking into account the following aspects of the described approach:

- The aggregation level adopted for this estimation (European regions) allows for inaccuracies in the distance estimates of approximately 10 to 50 km., arising from the fact that the patterns of industry location are not as ideally centralized as assumed in the present regionalization. The smaller the regions, the more accurate the distance estimates will be.
- As the statistics provided by Eurostat on interregional and national freight transport are not broken down by commodity type, the estimation has been completed for one virtual commodity group only (i.e. all commodities taken together).
- The national statistics' agencies have to supply information to Eurostat on a yearly basis. The necessary additional aggregations made at Eurostat make it difficult to link these data to the original data from the individual national agencies. We expect that more accurate estimates can be made using the original data for national transport flows. As a tentative exercise, we replaced the Eurostat data for the 21 German regions by the original data from the German Statistisches Bundesamt. The results of the estimation clearly improved.
- One general feature of transport statistics is that the observed origins and destinations do not necessarily match the endpoints of the door-to-door transport chain, i.e. the actual sender and receiver. Border resistances will be weighed differently by shippers and/or carriers if, say, the good originates from the city of Rotterdam itself, or from the port of Rotterdam, being shipped within a transcontinental transport chain.

CONCLUSIONS

- A method is presented which enables transportation planners to take into account the existence and gradual alleviation of border barriers in building scenario's for forecasting.
- Border resistances for international freight transport by road in Europe are at present equivalent to a distance of between 150 and 300 km.
- If border barriers would be completely abolished in the future, international road transport could be expected to grow by between 4 to 6 times its present volume.
- It is conceivable, however, that border barriers will only be alleviated to a certain level, e.g. as existing at present within the Benelux-Union. This

scenario indicates a less radical growth of cross-border freight transport by road, up to about twice its present volume.

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LIST OF SYMBOLS

I	=	number of rows O/D table (number of origin zones)
J	=	number of columns O/D table (number of destinationzones)
K	=	number of resistance value intervals
M	=	number of blocks (groups of O/D cells)
$\hat{t}_{ij}$	=	expected value assumed Poisson distribution for an O/D cell

t_{ij}	=	observed value O/D cell
$\hat{T}_m$	=	expected value of the sum of a block of O/D cells
T_m	=	observed sum of a block of O/D cells
L	=	likelihood function
L^*	=	log-likelihood function
p_i	=	polarity origin zone i
q_j	=	polarity destination zone j
r_k	=	deterrence-factor for resistance interval k
c_{ij}	=	resistance between origin i and destination j
$f(c)$	=	deterrence-function

ENDNOTES

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