"TRADE LIBERALIZATION, TRANSPORTATION AND THE ENVIRONMENT"

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This paper is an empirical study of the consequences of European trade liberalization for international transport demand and its environmental impact. The European market is broken into nine trading blocks, and trade flow equations for 29 industries are estimated for the period 1975-1985. A simulation of the change in volumes of trade by industry and the distances traded goods must move generates an estimate of the increased transport demand in each industry. Date on the modal composition of transportation in each industry then allows an aggregation of demand across industries by transport mode - truck, train, sea, and inland waterway.

The study concludes that the greatest increases will be in the demand for international transportation by sea, but that in terms of land-based transportation, there will be a large relative shift from rail to road. This will have a major adverse environmental impact which is discussed in the paper.

(I) Introduction

Those whose economic interests or protectionist instincts make them opponents of trade liberalization have found allies in the environmental community [see, for example, *The Ecologist* (1990); Ekins (1989); European Environmental Bureau (1989); Morris (1990); Ritchie (1989); Shrybman (1990)]. And while much of the criticism of free trade that has appeared in the environmental literature has focused on issues like "pollution havens" and agricultural practices in underdeveloped countries, the transport sector has also attracted environmentalists' attention. Environmentalists are not alone. The Task Force of the European Commission named transportation as the *one* sector through which liberalization of the internal EC market would have its greatest environmental impact [Commission of the European Communities (1989)]. In February 1992, it issued a "Green Paper" on the subject [Commission of the European Communities (1992)]. The OECD as well has concerned itself with the environmental implications of transport demand stimulated by the liberalization of international trade [see, for example, Barde and Button, (1990); Gabel, (1991); OECD (1991b)].

At its most basic level, the concern expressed by the EC and the OECD is that trade liberalization may so increase the level and alter the structure of economic activity that it will place insupportable demands on a transport sector which is already a major contributor to the environmental degradation of the industrialized countries.

In theory, of course, liberal international trade and environmental protection are mutually compatible policy regimes. Both have the same objective - the efficient allocation of economic (including environmental) resources. If all resources were correctly priced, free trade would allocate them to the production of an optimal set of goods and services, and it would allocate tasks to countries according to the principles of comparative advantage. Free trade would surely have environmental consequences, but those consequences would be optimal in terms of economic efficiency.

But if environmental resource prices are distorted, and if for any of several possible reasons they can not be corrected, then it is no longer clear that trade liberalization constitutes a Pareto improvement. (This is simply an example of the principal of the second best.) Since international trade policy is further along the path toward liberalization than is environmental policy along the path to correct resource pricing, the risk that expanded international trade may exacerbate the problem of environmental resource misallocation is real.

The objective of this paper is to begin to quantify the implications of EC trade liberalization for the output of international transport services and thence for environment quality. Our specific goal here is to determine quantitatively the increase in the movement of internationally traded goods of different types throughout Europe that would occur should trade barriers be eliminated, and then to translate the movements of goods into demands for the different transport modes. The final step - to translate the transportation changes into environmental damages of different types - is a prospect for future research.

Ours is not the first study of trade liberalization and trade flows [see, for example, Neven and Röller (1991a,b); Jacquemin and Sapir (1988a,b); Venables and Smith (1988)]. But previous studies, which provided the grist on which fears for the environment have fed, only looked at the volumes of goods that were to be moved. What they did not look at - but which are equally important for the output of the transport sector - are the particular goods most effected,

the changing distances those goods have to move from exporter to importer, and the implications of these changes for transportation modes. Because trade liberalization will systematically affect these, one must take empirical cognizance of the changes in the *pattern* of flows by commodity and transportation method as well as of trade *volumes*. This is what we do here.

In Section II, we examine the evidence linking the transport sector with environmental damage. Then in Section III, we argue that there will be a systematic relationship between trade liberalization and both the volume of trade flows of particular goods and the average distance that a unit of each internationally traded good must be transported from exporter to importer. These two factors together will dictate how much demand for the various modes of international transport services trade liberalization will prompt. Section IV presents an econometric model which attempts to analyze this relationship. Section V discusses the results, and a final section concludes the paper.

(II) The Transport Sector and the Environment

The transport sector is a major contributor to environmental degradation in industrialized countries [OECD (1991a)]. In terms of air pollution, transportation causes about 70% of all carbon monoxide (CO) and 50% of all nitrogen oxide (NO_x) emissions into the atmosphere. Along with sulfur dioxide (SO_2) which is emitted by diesel (but not gasoline) engines, NO_x accounts for about one-third of all acid rain depositions. Transportation causes 50% of all hydrocarbon (HC) emissions in urban areas. Some of these figures are presented in Table 1.

Table 1
Percentage Share of Transport Emissions in Total Emissions

emission	North America	OECD Europe	all OECD
NO_x	43	60	49
CO	67	78	71
HC	33	50	39
SO_x	4	4	4

Source: OECD (1991a)

One quarter of all carbon dioxide (CO_2) emissions are the product of transportation. To a lesser extent, chlorofluorocarbons (CFCs) are released from automobile air conditioning units and insulating foams. Diesel engines are significant contributors to airborne particulate pollution, especially in Europe where such engines are relatively common in both automobiles and trucks.

In addition to its contribution to air pollution, the transport sector is the largest single source of noise pollution - in particular from road traffic and aircraft around congested urban and suburban areas. In 1988, there were 120 million OECD residents exposed to noise levels exceeding 65dB (an

"unacceptable" level in OECD words), and 50% of the OECD population was exposed to more than 55dB (an "unsatisfactory" level) - all caused by transportation activities. Transportation is a major contributor to solid waste accumulation in the form of abandoned vehicles, non-recyclable materials such as automobile and truck tires, and earth and rubble from infrastructure construction.

The numbers of deaths and injuries and the property damage of automobile accidents are enormous. Accidents from truck, rail, and water transport are a significant cause of toxic or otherwise environmentally damaging spills - in particularly of oil and chemicals. Purposeful oil discharge from ships is a major cause of marine pollution.

Finally, the third-party effects of congestion on motorways and around airports is a serious and growing environmental problem. Efforts to increase infrastructure capacity to alleviate this congestion only exacerbate the environmental damage of the infrastructure construction, and they frequently and frustratingly fail to reduce the congestion.

In an effort to estimate the cost of the environmental damage done by the transport sector, Quinet (1990) surveyed existing estimates of land-based transport and concluded with the figures shown in Table 2.

Table 2
Social Costs of Transport

type of cost	cost as a percent of GDP
noise	0.1
air pollution	0.4
accidents	2.0
lost time	6.8

Source: Quinet (1990)

Although land-based transport, especially the automobile, is the biggest single contributor to the environmental damage caused by the sector, aircraft are also implicated. They cause between 1% and 2% of the emissions of CO_2, SO_2, and NO_x, and they consume 2% to 3% of the world's oil resources. The NO_x emissions are especially harmful because they occur in the troposphere where they may cause greenhouse warming.

Trends that are taking place in the transport sector are important to understand because these trends are to a dominant degree driven by growth in output and in per capita incomes - the very objectives of international trade liberalization. Several trends are especially significant. One is the increase in passenger cars and commercial vehicles of all types. From 1970 to 1987, the number of passenger cars in use increased by 88% in the OECD and 110% world-wide and the number of commercial vehicles by 126% in the OECD and 130% world-wide. And despite a decline in average vehicle annual mileage (actual passenger car traffic only increased by 74% and goods vehicular

traffic by 131%), there was an increase in the total distance travelled annually. Total road traffic in the OECD rose by 93% from 1970 to 1989.

Offsetting the increase in vehicle-miles travelled, the effluents emitted per vehicle-mile have declined for two reasons. One is the rising average fuel efficiency of the vehicle stock. Despite the 93% increase in miles travelled in the OECD in the last two decades, the fuel consumed by road transport increased only 60%. The other offset is the declining emissions per unit of fuel burned due to emission standards put into place by the OECD countries. These standards, based in most countries on catalytic converters, have significantly reduced the emissions of NO_x, HC, and CO per fuel unit. Catalytic converters can eliminate 90% of these harmful exhaust emissions, and since they require lead-free gasoline, they indirectly take credit for reduced lead emissions. Lead emissions in the US have fallen 68% between 1975 and 1983.

Another significant trend is an inter-modal shift to roadway vehicles and aircraft - the fastest growing portions of the transport sector. Between 1970 and 1988 in the OECD countries, road passenger transport increased by 68% while rail increased by only 38%. For freight, road rose 84% while rail rose 21%. Between 1978 and 1988, the volume of traffic (passengers and freight in ton-kilometers) on international scheduled airlines doubled, increasing on average by 7.7% annually. (By comparison, GDP in the developed countries increased by only 2.6% annually in that period.) Air cargo services expanded on average by 9.3% annually in the last decade - more rapidly than any other category of air transport service. Air transport is expected to increase half again more rapidly in the next two decades with volumes doubling every ten years.

The significance of this is that inter-modal shifts in the past are in the direction of the transport media that are the most damaging environmentally - especially road transport. Table 3 shows modes of international transport for selected European countries and Table 4 shows various estimates of the external costs of some of these modes.

Table 3
Mode of Surface Transport for International Goods for Selected European Economies, 1986 (percentages)

country	rail	road	inland waterway	sea
Belgium*	6	21	19	37
Denmark	5	16	-	79
France	5	22	5	68
W. Germany*	10	16	26	24
Greece	2	15	-	83
Netherlands	1	14	12	72
Spain	1	7	-	93
Sweden	6	11	-	82
U.K.	-	1	-	99

Source: GATT (1989)
*Percentages do not total 100 in the source.

Table 4
Estimates of the External Costs of Different Modes of Transport (in billions of DM)

type of damage	road	rail	truck	road	rail
air pollution	15.0	0.2	7.3	10.0	0.4
noise	15.0	2.1	14.5	2.0	0.2
land use	-	-	2.2	1.6	0.1
buildings and investments	-	-	10.3	19.7	12.9
accidents	-	-	13.3	46.2	0.5
resource depletion	57.0	1.3	-	-	-
tailback costs	-	-	3.0	-	-
water pollution	-	-	10.0	-	-

Source: Bennett, *et.al.* The first two columns are estimates of the IEEP, the third column is an estimate of the UPI-Bericht, LKW-Verkehr, the fourth and fifth columns are estimates of the Grupp ISI.

The external costs for road are many times those of rail, and the trend toward road travel, already dominant, is expected to continue. The EC predicts that road's share of freight haulage, which increased from 56% of the market in 1970 to 73% in 1988, will grow to 82% by 2010 [Commission of the European Communities (1992)].

(III) International Trade Liberalization and Transport Distances to Market

International trade liberalization should increase geographical specialization and concentration of production either due to the exploitation of comparative advantage (in inter-industry trade) or exploitation of economies of scale or experience (in intra-industry trade). At the same time, consumption should disperse geographically as falling import barriers, lower product prices, higher per capita incomes, and lower transport costs widen markets internationally. This should increase average distances from points of production to points of consumption.

As an example, complete liberalization of agricultural commodity markets will have little impact on total world-wide production but a significant impact on the location of that production - shifting it in relative terms from Japan, the US, and the developed countries of Europe (where most of it is consumed) to the developing countries of South America, Sub-Saharan Africa, and to China [Anderson (1991); Anderson and Tyers (1992)]. The international trade created will require substantially more transport inputs than that which was displaced. In some cases, the displaced trade may be domestic; in others, it may be international but between proximate countries (between European

countries, for example). Furthermore, as international trade expands and firms and industries "globalize", individual final products will embody inputs derived from or processed in many more countries. Examples are easily cited of sophisticated products like automobiles and consumer electronics in which components are sourced from around the world for assembly in specific countries and then exported world-wide.

Inter-industry trade is more likely to increase average transport distance than will intra-industry trade because the source of trade gains - factor endowment differences - is to a great extent geographically determined. For example, inter-industry trade is more likely to be from Northern to Southern hemisphere than is intra-industry trade. And inter-industry trade is more likely to be transport-intensive because it is trade in undifferentiated bulk commodities like agricultural products and raw materials rather than in highly differentiated and highly valued manufactured goods. In 1987, dependence on the export of basic commodities other than petroleum averaged 35% of recorded visible export earnings of African countries and 46% of Latin American countries. In the least developed countries, it averaged 70% or more. In terms of specific industries, 80% of world exports of tin, 60% of copper, and 40% of iron ores originate in developing countries. All these cases are of inter-industry trade involving long distances and high relative transportation costs.

Additional evidence to support the argument that expanded inter-industry trade between developed and developing countries might disproportionately increase transport is found in the relatively high transport intensity of developing countries' trade. Developing countries account for one-fourth of the world-wide value of imports plus exports of goods, the transport of which generates about one-half of the world-wide freight bill. In addition to the inherent bulk of developing countries' export trade, the low density of routes, unbalanced trade flows, and long distances are further partial explanations of the high transport intensity of that trade.

This prediction of increased distances to market is hedged for several reasons. First, the examples of trade between the US and Mexico and the US and Canada indicate that neighboring countries can have quite different factor endowments. Furthermore, if trade between two neighboring countries with a long common border is liberalized, it is possible that trade across that border will entail on average *shorter* routes than trade internal to each country. As an example, east-west trade entirely within Canada and similar east-west trade entirely within the US may require more transport than north-south trade across the border which would be created by liberalization between the two countries.

It is also possible that the liberalization of Western European trade with the former Communist countries of Central Europe will displace those countries' trade with the ex-Soviet Union republics to the east, all with a reduction in average transport distances. And to the extent that liberalization within trading blocks diverts rather than creates trade, again geography will determine average distances to market. Trade liberalized between the EC and EFTA countries may well shorten trade distances if that trade is diverted from Southern European countries.

The assumption that inter-industry trade involves trade between more distant countries than does intra-industry trade has exceptions, too. Much intra-industry trade is between the US, Western Europe, and Japan, with what are obviously long transport distances. But even here, trade liberalization could well mean dramatically increased transport distances. For example, with trade

liberalization, imports of automobiles from Japan will displace auto production and trade within the EC. This would increase transport in a process the opposite of what has recently been experienced. Restrictive trade policy in this sector in the US and now in the EC has resulted in Japanese direct investment in "transplants" in those countries. As these investments have grown, they have displaced both exports from Japan and the production of native firms. (Ironically, these Japanese greenfield plants are approximately as efficient as plants in Japan, which implies that protectionism in this instance has shortened trade distances with no long term efficiency loss.)

The ultimate result of trade liberalization for international transport demand is the empirical question to which we now turn.

(IV) An Econometric Analysis of Trade Flows

In order to analyze trade flows and their changes when non-tariff barriers are removed, we specify a model which is similar to Neven and Röller (1991a). Our model is a semi-logarithmic specification of the form

$$\ln Y_{ijkt} = a_{ij} + b_{ij} X_{ijkt} + e_{ijkt} \qquad (1)$$

where Y_{ijkt} is the import volume of country i from country j in industry k at time t. Twelve explanatory variables (the vector **X**) were selected to represent factors customarily associated with inter and intra-industry trade as well as measures of trade barriers. The parameter vector $\mathbf{b}_{ij}$ (of dimension twelve) is allowed to vary across importing as well as exporting countries. This flexible parameterization allows us to analyze changes in trade flow patterns specific to a country pair. However, we do not allow these elasticities to vary across time and industries.

Our panel data set consists of twenty-nine ISIC three-digit manufacturing industries for the eleven years from 1975 to 1985. Details on variables and their sources are presented in the Appendix.

The importing countries include France, the UK, Italy, and the former West Germany. Exporting countries or blocks of countries include the same four major EC member states plus the former COMECON countries (the former East Germany, Poland, Bulgaria, Albania, Czechoslovakia, Hungary, Rumania, Yugoslavia, and the former USSR), Benelux (Belgium, the Netherlands, and Luxembourg), Iberia (Spain and Portugal), Scandinavia (Norway, Sweden, Finland, and Denmark), Greece, and Central European countries (Austria and Switzerland).

The additive stochastic term e_{ijkt} is assumed to be temporally uncorrelated in all instances but contemporaneously correlated for each importing country across exporting countries. That is,

$$E\,[e_{ijkt}\, e_{iskt}] \neq 0 \qquad \text{for } j \neq s$$

and

$$E\,[e_{ijkt}\, e_{sjkt}] = 0 \qquad \text{for } i \neq s$$

We estimate expression (1) via a system of nine equations using seemingly unrelated regression techniques for each of the four importing countries.

Of the twelve independent variables, ten represent determinants of inter and intra-industry trade. They include economy size, proxies for the intensity of human and physical capital in production, research and development intensity, a measure of economies of scale, a measure of product differentiation, the rate of growth of demand, and a measure of transportation costs.

Two independent variables account for trade barriers. For non-tariff barriers, we made extensive use of the work of Buigues and Ilzkovitz (1988) which summarized the evidence collected by the European Commission. They constructed an ordinal variable (ranging from 0 (none) to 3 (maximum)) to represent the importance of non-tariff barriers at the industry level. Of the twenty-nine industries in our study, fifteen have no non-tariff barriers.

It should be emphasized that the data on non-tariff barriers were derived for intra-EC trade. Yet it is very likely that they also apply to EC member states' imports from the rest of the world. For example, technical standards and public procurement policies presumably block both intra and extra-EC trade equally. It should be clear, however, that our measure does not include non-tariff barriers that are specifically directed towards imports from non-EC countries (like the Multifibre Agreement).

A second variable measures the EC common external tariff. The trade policy of the EC with the rest of the world is difficult to capture given the complex system of preferences across EC trading partners which determines the import duties effectively imposed on any particular product according to its origin [see Sapir (1990)]. In principle, it would be desirable to estimate the degree of protection by computing a weighted average of import duties with weights representing the proportion of world supply. This exercise is hardly feasible, and we simply introduced the "standard level" of the Community common external tariff applicable to all countries. But because our non-EC trade groups are composed of EFTA countries (with which there is no tariff) with the sole exception of the COMECON countries, we do not analyze elimination of the common external tariff in the work that follows.

(V) Results and Interpretation

Estimation of the four systems of nine equations each by seemingly unrelated regression techniques yielded 36 sets of regression results. Those regression results for the non-tariff variable are reported in Table 5.

Table 5
Non-Tariff Barrier Regression Coefficients

to / from	France NTB (t-stat)	France R^2	Germany NTB (t-stat)	Germany R^2	Italy NTB (t-stat)	Italy R^2	UK NTB (t-stat)	UK R^2
France	*	*	-.28 (-3.72)	0.63	.01 (.20)	0.73	-.51 (-6.33)	0.63
Germany	-0.24 (-3.10)	0.64	*	*	.13 (1.72)	0.77	-.33 (-3.91)	0.68
Italy	-0.40 (-6.32)	0.56	-.27 (-3.88)	0.52	*	*	-.61 (-8.80)	0.67
UK	-0.22 (-2.57)	0.61	-.35 (-4.44)	0.66	-.17 (-1.78)	0.61	*	*
Benelux	-0.02 (-0.27)	0.65	-.23 (-2.89)	0.65	.16 (1.69)	0.72	-.37 (-4.39)	0.67
Iberia	-0.20 (-3.08)	0.61	-.15 (-1.55)	0.40	-.17 (-1.78)	0.58	-.45 (-4.43)	0.38
Scand.	0.23 (1.94)	0.51	.13 (1.29)	0.48	0.70 (5.65)	0.56	-.06 (-.60)	0.63
COMECON	-0.51 (-5.12)	0.58	-.29 (-2.73)	0.42	0.22 (2.03)	0.55	-.66 (-5.78)	0.30
Center	0.07 (0.63)	0.47	-.002 (-.03)	0.57	.65 (6.45)	0.60	-.14 (-1.26)	0.52
Greece	-0.46 (-2.36)	0.37	-0.34 (-1.92)	0.39	-.11 (-.68)	0.57	-.80 (-5.40)	0.49

Having estimated the model, we then set the non-tariff trade barriers to zero for those fourteen industries having such barriers, and we predicted import volumes. These were then aggregated across all nine exporting countries (or blocks) for each of the four importing country, then aggregated across the four importing countries. This gave us the total trade volume by industry under conditions of no non-tariff barriers. (To repeat, we did not estimate the impact of eliminating the common external tariff because it was only relevant to the single COMECON block.) The final step was to compare that trade volume to the original trade volume to determine by what percent the trade expanded with liberalization. Denoting the predicted trade flows by $\hat{Y}_{ijkt}$ and the

predicted trade flows should the non-tariff barriers be eliminated by $\hat{Y}^{o}_{ijkt}$, the above procedure amounts to calculating

$$\frac{\sum_i \sum_j \hat{Y}^{o}_{ijkt}}{\sum_i \sum_j \hat{Y}_{ijkt}} - 1$$

Averaging the expression above over time gave us the results by industry reported in Table 6. As the table shows, we also decomposed these results into intra-EC trade and imports from outside.

Table 6
Percentage Increase in Trade Volumes after Elimination of Non-Tariff Barriers

industry	all countries	intra-EC trade	exports to EC from non-EC
foodstuffs	18	22	1
foodstuffs-other	24	27	2
beverages	26	30	4
tobacco	27	30	10
wood	22	32	3
wood-furniture	30	34	10
paper	20	28	9
printing-publishing	27	31	5
pharmaceuticals	16	22	-6
stone and non-metallic mineral products	35	56	-17
tools and finished metal goods	22	29	0
electrical machinery	133	150	66
motor vehicles, railway, aerospace	26	28	8
surgical, optical instruments	27	32	5

The elimination of non-tariff barriers protecting the EC member states has the predicted qualitative consequences. Aggregate trade volumes increase in all industries (Table 6). Intra-EC trade volumes increase in all industries as well, as do exports into the EC from outside (with the exception of pharmaceuticals and stone and non-metallic mineral products). Trade volumes do not necessarily increase between all country pairs, however. While most of the positive regression coefficients in Table 5 fail a test of statistical significance, one would expect that the rearrangement of trade patterns with the elimination of trade barriers could divert trade from one origin to another. (For an explanation and interpretation of the other regression coefficients, see Neven and Röller (1991b)).

Our results are generally consistent with other studies in the literature. Venables and Smith (1988) in a calibration exercise obtain results similar to those reported in Table 6. They find inter-EC trade increases ranging from as low as 0.8% to as high as 21.8% and even larger increases for intra-EC trade flows. When comparing empirical findings, one should note that the methodologies and set of industries are different. Also, Venables and Smith model the effect of integration largely through the direct cost savings of the removal of border measures, whereas our work can be interpreted as including all types of non-tariff barriers. This might help explain the somewhat larger trade increases in our study.

The magnitude of the percentage increases in trade volumes (Table 6, first column) is significant in every industry, ranging from a minimum of 16% in pharmaceuticals to a maximum of 133% in electrical machinery, the industry with the highest non-tariff barrier in the sample. In every industry, the percentage increase in trade volume within the EC is greater than the aggregate, implying as the figures show that in relative terms, intra-EC trade has supplanted imports from outside (even though, as noted previously, the non-tariff barrier is applicable to member state imports irrespective of their origins).

The procedure described above gives the percentage increase in international trade volumes due to the elimination of non-tariff barriers protecting individual EC member countries. But as was explained in Section III, this will not indicate the percentage increase in goods movement - i.e., the percentage increase of transport. The reason is that it ignores the changes in the originating locations of each country's imports. If the proportion of each country's imports from each exporting country were unchanged, there would be no problem. But subject to some idiosyncratic exceptions as discussed in Section III, one would expect the average distance a unit of a tradeable good moves from exporter to importer to increase with trade liberalization.

To capture the combined effect of the increase in trade volumes (measured in units) and the change in distances these volumes move, we repeated the procedure described above but with the following modification. The trade volumes between each country pair were multiplied by the distance between the two countries to get unit-kilometers as the unit of comparison. That is, we computed

$$\frac{\sum_i \sum_j \hat{Y}^o_{ijkt}\, r_{ij}}{\sum_i \sum_j \hat{Y}_{ijkt}\, r_{ij}} - 1$$

where r_{ij} is distance between countries i and j.

We again average the expression above over time to generate the results reported in Table 7. Table 8 then compares the results of Tables 6 and 7 to show by how much more transport demand will rise because of the increase in average distances moved compared to just the increase in the volume of international trade.

Table 7
Percentage Increase in Trade Flows (unit-kms) after Elimination of Non-Tariff Barriers

industry	all countries	intra-EC trade	exports to EC from non-EC
foodstuffs	23	20	25
foodstuffs-other	28	25	32
beverages	26	29	39
tobacco	25	28	11
wood	34	33	35
wood-furniture	39	35	43
paper	28	28	28
printing-publishing	35	32	39
pharmaceuticals	17	17	18
stone and non-metallic mineral products	35	50	22
tools and finished metal goods	28	31	25
electrical machinery	160	150	181
motor vehicles, railway, aerospace	32	26	42
surgical, optical instruments	34	32	37

One sees in Table 7 that again there is a large increase for all industries and all locations. The switch in signs for EC imports of pharmaceuticals and stone and non-metallic mineral products from outside the EC (Table 6 vs. 7, final column) indicates that although the volume of the trade in units has dropped, the remaining trade moves a greater distance from exporter to importer - enough greater to offset the decline in units traded.

This interpretation of a sign change is the same interpretation to be given to the fact that in comparing Tables 6 and 7 generally, one sees that while intra-EC trade has risen most in the former, it is usually imports from outside the EC that has risen most in the latter. It is the increase in distances that causes this.

Finally, Table 8 shows clearly what was hypothesized previously in the paper. Trade liberalization dramatically increases the unit volumes of trade and thus justifies the concerns expressed in many quarters that transport outputs and their associated environmental damages will increase enormously. But this understates the magnitude of the threat! Not only do the unit volumes increase, but on average, each unit must move farther from producer to consumer. And this extra spur to transport outputs is not *de minimus*. At its maximum, in the electrical equipment industry, there is a 27 percentage point increase in the transport requirement due to the inclusion of the distance factor. In only four industries does distance add less than four percentage points to the percentage increase in traded units.

Table 8
Difference Between Table 7 and Table 6 Entries

industry	all countries	intra-EC trade	exports to EC from non-EC
foodstuffs	5	-2	24
foodstuffs-other	4	-2	30
beverages	0	-1	35
tobacco	-2	-2	1
wood	12	1	32
wood-furniture	9	1	33
paper	8	0	19
printing-publishing	8	1	34
pharmaceuticals	1	-5	24
stone and non-metallic mineral products	0	-6	39
tools and finished metal goods	6	2	25
electrical machinery	27	0	115
motor vehicles, railway, aerospace	6	-2	34
surgical, optical instruments	7	0	32

The cause of the dramatic increase in the distances that internationally traded goods must moved is found in the exports into the EC from outside. If one were to look just at the intra-EC trade (Table 8, middle column), one sees that average distances do not noticeably increase; they fall in exactly half the industries. Yet the EC's imports from outside, which did not rise much relatively in terms of units, rise enormously in terms of unit-kilometers.

To convert the figures of Table 7 into the additional demands to be placed on the transport sector by mode of transportation, we disaggregated each figure in the Table into its modal percentage and then reaggregated by mode. The results are presented in Tables 9 and 10. As the tables show, we preserved the three-way separation of the results - total for all countries, intra-EC, and imports into the EC from outside.

Table 9 shows the percentage increase in international transport demand by both mode of transport and industry. The industry aggregation is different from that of Tables 6 to 8 because of data limitations as noted in the Appendix. The results indicate that the greatest increase by all modes is in machinery, transport equipment, and manufactured articles. These were the industries where trade barriers were greatest. Across transport mode, this increase is concentrated on sea and inland waterway. The notable increase in intra-EC trade by sea in these industries is due to the high proportion of sea-borne trade with the UK. The results also indicate that the increases in modal demands are different from industry to industry. For example, the increase in

transport demand emanating from metal products is relatively more intensive in rail as opposed to road than is the case for food products. This is intuitively reasonable; the food distribution system requires truck delivery into urban centers which is less necessary for metal products.

Finally, Table 10 aggregates the figures in Table 9 across industries to give single percentage increases by mode of transport. Several observations are notable. First, there is a large increase for all modes. Thus, concern that trade liberalization will have a major impact on the transport system is merited. Second, that increase is more than twice as great for road than rail. This was expected, and indicates that the inter-modal trend towards the more environmentally damaging road travel and away from rail will be exacerbated by the issue studied here. Unexpectedly, however, the greatest increase in transport demand appears in sea and inland waterway. While this does not mitigate the environmental problems that will be created on the road networks in the future, it does provide at least some solace in the knowledge that the environmental impact of trade liberalization would be even worse were this intermodal shift not to occur. Finally, it appears that increase in import flows into the EC from outside is relatively intensive in land transportation (evenly distributed between road and rail) while for trade within the EC, water is relatively more significant (and between land-based modes, road gains market share from rail).

Table 9
Percentage Increase in Demand for International Transport by Mode and Industry

industry by mode	all countries	intra-EC trade	exports to EC from non-EC
by sea			
food products	29	30	21
metal products	43	48	25
chemicals	35	32	18
machinery, trans. equip., mfg. articles, misc.	119	133	54
by road			
food products	20	17	25
metal products	24	28	15
chemicals	11	11	13
machinery, trans. equip., mfg. articles, misc.	49	43	73
by rail			
food products	2	5	29
metal products	20	23	27
chemicals	4	5	26
machinery, trans. equip., mfg. articles, misc.	24	21	80
by inland waterway			
food products	32	33	31
metal products	27	32	31
chemicals	24	31	17
machinery, trans. equip., mfg. articles, misc.	62	72	81

Table 10
Percentage Increase in Demand for International Transport by Mode

mode	all countries	intra-EC trade	exports to EC from non-EC
sea	77	87	36
road	38	34	55
rail	18	18	60
inland waterway	32	36	35

(V) Conclusion

We find that with a reduction of trade barriers in Europe, the quantities of traded goods will increase substantially. Because the units of quantity are not consistent across industries, we cannot say in aggregate how much that increase will be, but the minimum (pharmaceuticals) is 16% and the maximum (electrical machinery) is 133%. These results are broadly similar to those of earlier studies, and they justify policy concern that trade liberalization will cause a major increase in demand for international transportation and a major increase in the environmental damage done by transportation.

Yet we find evidence that this increase in traded quantities understates the increased demand for transportation because it fails to consider changes in the locations of production and consumption. These changes will in general increase the distance that representative traded goods must be shipped. This is particularly true when one considers trade between EC countries and countries outside of the Community. Because of this factor, previous estimates of the environmental damage that trade liberalization will do via the induced increase in transportation are likely to be too low.

We also find that there will be a pronounced inter-modal shift caused by trade liberalization. Although all modes show large increases, in relative terms the inter-modal shift will be from land-based transportation to water-based; as between land-based modes, it will be from rail to road. The land-to-water shift is desirable both because water-based transport is more energy efficient than land-based and because little infrastructure investment is necessary to accommodate a demand increase. However, the rail-to-road shift, increasing the existing dominance of road over rail, will exacerbate environmental damage because road transport is many times more harmful than is rail. This damage will appear in either or both congestion of the road network and expansion of that network.

As a final conclusion, we would have to agree with the EC Task Force when it stated that the liberalization of the transport sector *per se*, the stimulus to growth in incomes and trade, and such factors as the decline in automobile prices and the removal of barriers at national borders, might increase transfrontier truck traffic by between 30% and 50% [Commission of the European Communities (1989)]. In fact, this estimate might be low. Our figures are in this range, and they ignore several of the factors cited by the Task Force. Whatever the increase in traffic on the major transport corridors, they will wreck indelible damage to proximate communities. This will be exacerbated by the development of the infrastructure of roads (as well as airports) which will reduce the amount of open lands.

It does not follow from this conclusion that trade liberalization should be abandoned as an objective of the European Community or the international community of nations. It could well be argued that the damage done to the environment will be outweighed by the good that expanded international trade will bring. Yet a better conclusion to draw is that international trade liberalization must be accompanied by ever more rigorous environmental policies and enforcement to ensure that a balance is struck between the benefits that accrue from trade and the inevitable impact that trade, like any human activity, has on the environment within which all human activity must take place.

Appendix

Data Overview

The analysis spans the years 1975 to 1985. Industries are classified according to the International Standard Industrial Classification System (ISIC, United Nations Statistical Studies Series M #4/Rev.2, 1969). Aggregation is to the ISIC three-digit level for the manufacturing sector which comprises 29 industries. Industrial data from other sources were matched to the ISIC three-digit level. All financial data are converted into constant 1980 ECUs.

List of Industries

ISIC	industry
311	foodstuffs
312	foodstuffs-other
313	beverages
314	tobacco
321	textiles
322	textiles-clothing
323	leather-fur
324	leather-footwear
331	wood
332	wood-furniture
341	paper
342	printing-publishing
351	chemicals
352	pharmaceuticals
353	oil refineries
354	products derived from petroleum
355	rubber
356	rubber-other
361	ceramic goods
362	glass and glassware
369	stone and non metallic mineral products
371	steel
372	production and transformation of non-ferrous metals
381	tools and finished metal goods
382	mechanical machinery
383	electrical machinery
384	motor vehicles, railway, aerospace
385	surgical, optical instruments
390	other manufacturing

Measurement of Variables and Sources of Data

dependent variable

Imports to and exports from individual countries were obtained from the OECD; National Economics, Statistics, and National Accounts Division, magnetic tape, extracted from the International Trade by Products System. Imports are expressed CIF (cost, insurance and freight) and exports are expressed FOB (free on board). The currency used was thousands of dollars which was converted (conversion rate tables - Eurostat - EC) to thousands of ECUs and deflated to constant 1980 ECUs with an unpublished deflator obtained at the Statistical Office of the European Communities (SOEC) in Luxembourg.

independent variables

Apparent consumption was calculated as production value plus imports minus exports. Production values (value added taxes excluded) were obtained from the SOEC, magnetic tape, extracted from Domaine:Inde:Enquete Industrielle Annuelle, Collection:01, Donnees Globales (Luxembourg:SOEC 06/07/88). The NACE three-digit classification used there was converted to the ISIC three-digit classification. We have deflated the data into constant 1980 ECUs using the SOEC deflators.

Human capital was measured in deviation of industry wages from the country mean wage. Gross wages (converted into ISIC and 1980 ECUs as before) are available from the same source at the SOEC.

Investment was measured by total expenditures on investment, available through the SOEC. Data were converted to the ISIC classification and constant 1980 ECUs.

Research and development expenditures were obtained from unpublished OECD sources. It was made available to us by the Administrator of the Scientific, Technological, and Industrial Indicators Division in Paris. Some data points were added. When no data were available for a given year, the previous year was used. When several years were missing, an average of the other countries was used. In addition, the ISIC four-digit classification was converted to the ISIC three-digit classification.

Economies of scale were measured by the relative size of the mid-point plant for the German industry [Scherer (1980)]. The SYPRO four-digit classification used there was first converted into NACE three-digit and then into ISIC three-digit classification. A simple time trend regression model was estimated and the predicted values were used to obtain data for the years 1975, 1976, 1977, and 1985.

The non-tariff barrier variable for each sector was created from Buigues and Ilzkovitz (1988). The NACE three-digit classification used there was converted to the ISIC three-digit classification. Industrial sectors are classified into zero, low, medium, and high intra-EC non-tariff barriers, i.e., the variable takes values of 0-3.

The tariff variable is the EC common external tariff obtained from the Bulletin International des Douanes of the European Community for the years 1987-1988 (International Customs Tariffs Bureau - Brussels). Averages were created within industries for the ISIC three-digit classification.

Product differentiation is proxied by a dummy of 1 for the consumer goods industries and 0 otherwise.

Demand growth is computed as the percentage growth in apparent consumption.

Transportation costs are proxied by the reciprocal of the price per kilogram of Belgium imports available from the Belgium Ministry of Foreign Trade and the distance between trading countries.

Information on transport modes comes from Eurostat, External Trade by Mode of Transport, Series Accounts, Surveys and Statistics, Luxembourg, 1992. These data are aggregated into four industries - food products; metal products;

chemicals; and machinery, transportation equipment, manufactured articles, and miscellaneous articles. The source provides data on intra-EC trade and imports into the EC from all our source countries except Switzerland and Austria. For these two countries, we assumed that the transport mode for imports was identical to that for intra-EC trade.

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