SOME FACTORS DETERMINING INTERNATIONAL DEPENDENCE OF NATIONAL ECONOMIES

Åke E. Andersson

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INTERNATIONAL INSTITUTE FOR APPLIED SYSTEMS ANALYSIS
A-2361 Laxenburg, Austria

PREFACE

The work on regional development at IIASA is oriented to problems of long term development of regions and systems of regions. For this purpose models of growth and development at the interregional level have been designed and implemented in a number of economies open to international trade, among others in Bulgaria and Sweden.

The design of such models as well as economic policies has to take into account the susceptibility to international trade and growth cycles. It has generally been assumed that openness is closely related to the size of the national economy. This casts serious doubts on this hypothesis. It claims that most economies, whether small or large, must incorporate the influence of international trade and factor relations in their models of planning and forecasting. The paper has been presented at the IIASA Task Force Meeting on "Problems in Long-Term Macroeconomic Planning and Forecasting in Small, Open Economies," 19-21 September, 1979.

INTRODUCTION

This paper has two objectives. The first objective is problem-oriented. It has always been assumed that openness to international disturbances must necessarily be greater for smaller economies. Neoclassical international trade theory as well as empirical evidence also seem to support such a hypothesis. It is obvious that increasing the size of an economy leads to an increase in the total diversity of factor supply. Thus the possibility of achieving optimal resource allocation through regional specialization and interregional trade would decrease the necessity to engage in international trade. Increasing returns to scale in production would also contribute to a decreasing propensity to international trade with the increasing size of the national economy. The statistical analysis in this paper casts serious doubts on validity of smallness-openness correlation in a dynamic perspective.

The second objective of this paper is to examine the relative usefulness of two different approaches to international trade and location modeling. The first approach presented is a deterministic neoclassical model of trade and location with an explicit transportation-communication sector. This model is not an equilibrium model but a model of optimal trade and location. The information necessary to support the optimum is, however, of the same nature as the pricing information of the market system. It can, therefore, be assumed that a market system can sustain the solution according to this model. The second approach to trade and location modeling is to use a stochastic trade model, based on information theory, and *a priori* information created by a dynamic input-output model. It is shown that such an integrated trade and location model can generate more easily refutable hypotheses than the neoclassical model and that it also performs statistically well at all levels of aggregation.

One general conclusion of this paper is that trade must be seen in a framework of growing and structurally changing supply and demand conditions in different parts of the world economy. The proposed theoretical framework is one alternative for such an analysis. Another conclusion is the one that susceptibility and smallness are not intrinsically tied to each other. The dominant features is now that openness increases in most economies whether small or large. One can, therefore, conclude that the creation of planning and forecasting models for open economies is a general need. Furthermore, the necessity for international coordination of economic policies seems to be equally important for small and large nations.

1. SPECIALIZATION OR TRADE DEPENDENCE OF COUNTRIES

An economic area (nation or region) can be said to be specialized if it exchanges some of its products for products from other economic areas. Trade, location of production, and specialization are thus different aspects of the same phenomenon. Ohlin (1933) has formulated this in a forceful way.

> "When...the costs of transportation within regions and countries are taken into account, there is need for a general localization theory, which considers at the same time regions and districts of many different kinds, among which are the various countries...A theory of international trade must, therefore, be founded upon the general localization theory; indeed, it consists of a localization theory which gives special attention to the circumstances arising from the existence of a number of countries ..."

The limiting case of a household is normally the most specialized unit in economics, because it produces a certain type of labor that is exchanged for almost all goods and services, which are used by the household members. The specialization is, however, never complete. Some services are mostly produced within the household, for example, food preparation and washing. At the extremely aggregate level we have the world as a whole, which is a closed system from the economic point of view and which, as a whole, is completely unspecialized. Between these spatially differentiated extremes we find all degrees of specialization and, correspondingly, all degrees of dependence on trade.

From these considerations as well as from the comparative static analysis of the next section, we would expect to find a strong relation between the size of an economy and its reliance on trade, and, thus, its specialization of production. A rough classification of developed countries also reveals a relation between size and trade reliance.

Table 1 shows that there are a few exceptions to the rule of smaller trade reliance with larger size. The Netherlands is one of the exceptions with an extremely large trade reliance (57% of GNP), although it has a larger GNP than the median for

Table 1. The relation between size of the economy (GNP, 1973) and reliance on international trade (Exports/GNP, 1973)

EXPORTS \ GNP	Above median	Below median	Sum
Above median	Netherlands Sweden 2	Iceland Austria Belgium Denmark Norway Finland Ireland Switzerland 8	10
Below median	Canada United Kingdom Germany (FRG) Italy France Australia Japan USA 8	New Zealand South Africa 2	10
Sum	10	10	20

the 20 economies included in the Table. The opposite is true for New Zealand and South Africa.

There is, however, a rather large variation within the cells of the contingency table. Japan, which is approximately the same size as the FRG, has a trade reliance of 10 per cent of GNP for the same year as the FRG has a share of exports in GNP of 20 per cent. The problem is then to find out what other factors, beside the size of the economy, are of importance for the trade dependence or specialization of an economic area.

Furthermore, it can be shown that the average degree of trade dependence is growing steadily for most advanced market economies. Table 2 shows that the vast majority of highly developed market economies had a remarkable increase in their reliance on trade and specialized production between 1950 and 1974. It shows that the only countries that have a decline in their trade reliance are those at extreme distances from the major centers of the world market. Japan and Australia are two of these distant countries that have faced a decreasing degree of specialization.

The problem is to determine if there is an optimal degree of trade reliance of a region*, and if this optimal degree of trade reliance (and specialization) can change over time in a causally systematic way.

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*Some countries, which resemble sub-regions of most other countries in terms of area and population, like Hong Kong, Singapore--and to a lesser extent, the Netherlands and Belgium--have export and import share well above half their GNPs. In the former two countries it is normally close to 100 per cent. The maximal share of exports in GNP can, incidentally, be larger than 100 per cent, because the GNP measure does not include intermediary commodity deliveries, which are included in the exports and imports.

Table 2. Exports as a percentage of GNP 1950 and 1974 in 20 developed market economies

Source: Unctad, Handbook of International Trade and Development Statistics, pp. 346-347, 1976.

Country	Export value 1950	Export value 1974
Expansion of international dependence		
Austria	14 per cent of GNP	37 per cent of GNP
FR Germany	11 " " " "	29 " " " "
USA	4 " " " "	8 " " " "
Italy	12 " " " "	24 " " " "
Belgium	28 " " " "	54 " " " "
Ireland	29 " " " "	44 " " " "
Finland	20 " " " "	30 " " " "
Switzerland	25 " " " "	36 " " " "
Netherlands	41 " " " "	57 " " " "
Iceland	28 " " " "	39 " " " "
Sweden	24 " " " "	33 " " " "
Denmark	27 " " " "	36 " " " "
Norway	39 " " " "	48 " " " "
France	16 " " " "	19 " " " "
Canada	23 " " " "	26 " " " "
United Kingdom	22 " " " "	24 " " " "
Contraction of international dependence		
South Africa	31 " " " "	29 " " " "
New Zealand	31 " " " "	26 " " " "
Japan	12 " " " "	10 " " " "
Australia	29 " " " "	15 " " " "

2. NEOCLASSICAL THEORY OF TRADE AND LOCATION

We have in the former section illustrated the degree of specialization at a rather comprehensive level. The only and rather indirect measure of specialization in that section is the degree of trade dependence as reflected in the export/GNP ratios and its spatial disaggregation. The problem of the optimal pattern of location and trade of commodities is the subject of this section.

This is a problem with a long tradition in interregional and international economics. To outline the central aspects of the problem we will use a stylized optimization model that includes a simple transportation sector. Transportation is assumed to be a pure intermediary in the economic system. (See Lefeber 1958).

The model has the following basic elements:

- *Resources,*
- *Production technology,*
- *Transportation technology,*
- *Transportation needs,*
- *Consumer goods,*
- *Producing and consuming regions, and*
- *A valuation or welfare function.*

The resources are assumed to be located in regions, private in nature, but in public control. The production technology is assumed to be represented by some neo-classical production function (i.e., concave, continuous, and at least twice differentiable). Transportation needs are strictly proportional to the volume shipped between the regions with an implicit distance effect such that transportation needs increase with distance. Production of transportation is also subject to some neo-classical production functions.

It is further assumed that there exists some global continuous, concave, differentiable welfare function for the regional system as a whole, which is further assumed to be a weighted sum of the welfare levels of the constituent regions. All the weights are assumed to be strictly positive. The model now can be formulated:

$$L^r_{kT}+\sum_{s,i} L^{rs}_{ki} \leqq L^r_k \quad ; \quad \lambda^r_k \geqq 0 \quad ;$$ <u>Resource k</u> $\{r = 1,\dots,R,\ k = 1,\dots m\}$

$$X^s_i \leq F^s_i\left(\sum_r L^{rs}_{1i}, \sum_r L^{rs}_{2i},\dots,\sum_r L^{rs}_{mi}\right) \quad ; \quad \lambda^s_i \geq 0 \quad ;$$ <u>Production Technology</u> $\{i = 1,\dots,n\}$

$$\sum_q X^{sq}_i = X^s_i \quad ;$$ <u>Spatial commodity distribution</u>

$$T(X,L) \leq F^T\left(\sum_r L^r_{1T},\dots,\sum_r L^r_{mT}\right) \quad ; \quad \lambda_T \geq 0 \quad ;$$ <u>Transportation Technology</u>

$$\sum_q X^{qs}_i \leqq M^s_i \ ; \ \sigma^s_i \geqq 0 \quad ;$$ <u>Import constraint for commodity i in country i</u>

$$\sum_{q,s} X^{qs}_i - \sum_{s,q} X^{sq}_i = 0; \ \tau \ ;$$ <u>Conservation of total trade flow for commodity i (consistency-constraint</u>

$$\sum_j \alpha_j W_j\left(\sum_s X^{sj}_1,\dots,\sum_s X^{sj}_n\right) = W \quad ;$$ <u>Welfare</u>

Problem: Maximize welfare, subject to constraints; i.e.,

$$\max_{\{L,X\}} \quad G(L,X) = \sum_j \alpha_j W_j\left(\sum_s X^{sj}_1,\dots,\sum_s X^{sj}_n\right)$$

$$- \sum_{r,k} \lambda^r_k\left(L^r_{kT} + \sum_{s,i} L^{rs}_{ki} - L^r_k\right) \qquad - \sum_{s,i} \lambda^s_i\left(\sum_q X^{sq}_i - F^s_i\left(\sum_r L^{rs}_{1i},\dots,\sum_r L^{rs}_{mi}\right)\right)$$

$$- \lambda_T\left(T(X,L) - F^T\left(\sum_r L^r_{1T},\dots,\sum_r L^r_{mT}\right)\right) - \sum_{s,i} \sigma^s_i \left(\sum_q X^{qs}_i - M^s_i\right) - \tau\left(\sum_{q,s} X^{qs}_i - \sum_{s,q} X^{sq}_i\right)$$

Symbols: $L = \{L_{ki}^{rs}\}$ = amount of factor service k originating in region r to be used for production of commodty i in region s.

L_{kT}^{r} = amount of factor service k originating in region r to be used in the production of transportation services,

X_i^s = production of commodity i in region s,

$X = \{x_i^{sj}\}$ = amount of commodity i shipped from producer region s to consumer region j.

The first order conditions of a maximum can now be derived.

$$\frac{\partial G}{\partial L_{ki}^{rs}} = \underbrace{\lambda_i^s}_{\text{shadow price of commodity i in producer region s}} \cdot \underbrace{\frac{\partial F_i^s}{\partial L_{ki}}}_{\text{marginal productivity of factor k when used for production of commodity r in region s}} - \underbrace{\lambda_k^r}_{\text{shadow price of factor k emerging in region r}} - \underbrace{\lambda_T}_{\text{shadow price of transportation}} \underbrace{\frac{\partial T}{\partial L_{ki}^{rs}}}_{\text{marginal transportation need for factor k delivered from region r to region s}} \leqq 0 \; ; \quad (1a)$$

$\{r = 1,\ldots,R\}$; $\{k = 1,\ldots,m\}$
$\{s = 1,\ldots,R\}$; $\{i = 1,\ldots,n\}$:

$$\sum_{r,s,k,i} \frac{\partial G}{\partial L_{ki}^{rs}} L_{ki}^{rs} = \sum_{r,s,k,i} (\lambda_i^s \frac{\partial F_i^s}{\partial L_{ki}}) - \lambda_k^r - \lambda_T \frac{\partial T}{\partial L_{ki}^{rs}}) L_{ki}^{rs} = 0; \quad (1b)$$

$$\frac{\partial G}{x_i^{sj}} = \underbrace{\alpha_j \frac{\partial W}{\partial x_i^{sj}}}_{\text{marginal value of commodity i when delivered from region s to region j}} - \underbrace{\lambda_i^s}_{\text{see above}} - \underbrace{\lambda_T}_{\text{see above}} \cdot \underbrace{\frac{\partial T}{\partial x_i^{sj}}}_{\text{marginal transportation need for commodity i delivered from region s to region j}} - \underbrace{\sigma_i^j}_{\text{shadow custom duty for commodity i in region j}} - \tau \leqq 0; \quad (2a)$$

$\{s = 1,\ldots,R\}$; $\{i = 1,\ldots,n\}$.
$\{j = 1,\ldots,R\}$

(2b)

$$\sum_{s,j,i} \frac{\partial G}{\partial X_i^{sj}} X_i^{sj} = \sum_{s,j,i} (\alpha_j \frac{\partial W}{\partial X_i^{sj}} - \lambda_i^s - \lambda_T \frac{\partial T}{\partial X_i^{sj}}) - \sigma_i^j - \tau) X_i^{sj} = 0; \quad (2b)$$

$$\frac{\partial G}{\partial L_{kT}^r} = \underbrace{-\lambda_k^r}_{\text{see above}} + \underbrace{\lambda_T}_{\text{see above}} \underbrace{\frac{\partial F^T}{\partial L_{kT}}}_{\substack{\text{marginal}\\ \text{productivity}\\ \text{of factor k}\\ \text{from region r}\\ \text{used for pro-}\\ \text{duction of}\\ \text{transportation}}} \leqq 0 , \quad (3a)$$

$$\sum_{r,k} \frac{\partial G}{\partial L_{kT}^r} L_{kT}^r = \sum_{r,k} (-\lambda_k^r + \lambda_T \frac{\partial F^T}{\partial L_{kT}}) L_{kT}^r = 0 . \quad (3b)$$

$$\frac{\partial G}{\partial \lambda_i^s} \geqq 0 \quad (4a);$$

$$\left\{ \begin{array}{l} s = 1,\dots,R \\ i = 1,\dots,n \end{array} \right\}$$

$$\sum_{s,i} \lambda_i^s \frac{\partial G}{\partial \lambda_i^s} = \sum_{s,i} \lambda_i^s (\sum_q X_i^{sq} - F_i^s (\sum_r L_{1i}^{rs},\dots, \sum_r L_{mi}^{rs})) = 0 , \quad (4b)$$

$$\frac{\partial G}{\partial \lambda_k^r} \geqq 0 \quad ; \quad (5a)$$

$$\left\{ \begin{array}{l} r = 1,\dots,R \ ; \\ k = 1,\dots,m \ ; \\ T = 1 \end{array} \right\}$$

$$\sum_{r,k} \lambda_k^r \frac{\partial G}{\partial \lambda_k^r} = \sum_{r,k} \lambda_k^r (L_{kT}^r + \sum_{s,i} L_{ki}^{rs} - L_k^r) = 0 , \quad (5b)$$

$$\frac{\partial G}{\partial \lambda_T} \geqq 0 \quad (6a) , \quad (6a)$$

$$\lambda^T \frac{\partial G}{\partial \lambda^T} = \lambda^T (T(X,L) - F^T (\sum_r L_{1T}^r,\dots, \sum_r L_{mT}^r)) = 0 . \quad (6b)$$

The first interpretation can be illustrated. If the i-th good condition is standardized with the numeraire good (*), we can illustrate equation (2) as in Figure 1.

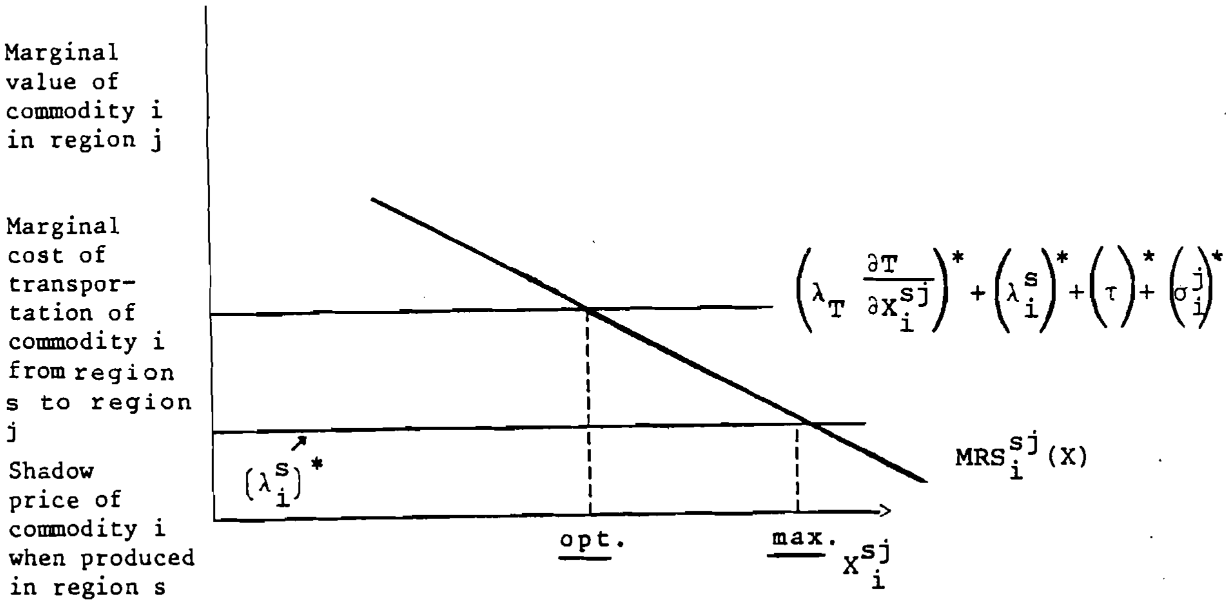

Figure 1. Illustration of optimality conditions for commodity trade

Figure 1 indicates the maximally optimal trade of commodity i from region s to region j. It is clear that this maximum can only occur in a frictionless economy (where $\lambda_T = 0$) without custom duties.

Opt. indicates the best degree of trade relation for an economy with the assumed transportation frictions. This optimum point is determined at the intersection of the marginal value curve and the sum of the FOB-price and the marginal cost of transportation. It is clear that the further apart are the regions, the less is traded of each one of the commodities and, thus, also of the sum ($\partial T/\partial X_i^{sj}$ increases with distance).

The optimum trade point (assumed to be binding) might shift to the right as a consequence of six different ceteris paribus changes:

a) The taste for commodity i produced in region s increases,
b) Marginal productivity in production of i increases in region s,
c) Transportation need per unit of commodity i decreases, i.e., by more efficient packaging, etc.,
d) Marginal productivity in production of transportation services increases,
e) The availability of resources used in the production of commodity i increases.
f) The shadow custom duty decreases as a consequence of decreasing import constraints.

For the factor mobility part of the conditions we can also draw some qualitative conclusions. One equilibrium condition is:

$$\lambda_k^r = \frac{\partial F^T}{\partial L_{kT}} \cdot \lambda_T = \lambda_k^s \quad , \qquad \text{for any r and s.}$$

This implies that for factors used in production of transportation, there should be factor price equalization. Otherwise, this is generally not true.

The same kind of illustration can be given for inequality equation (1)), see Figure 2.

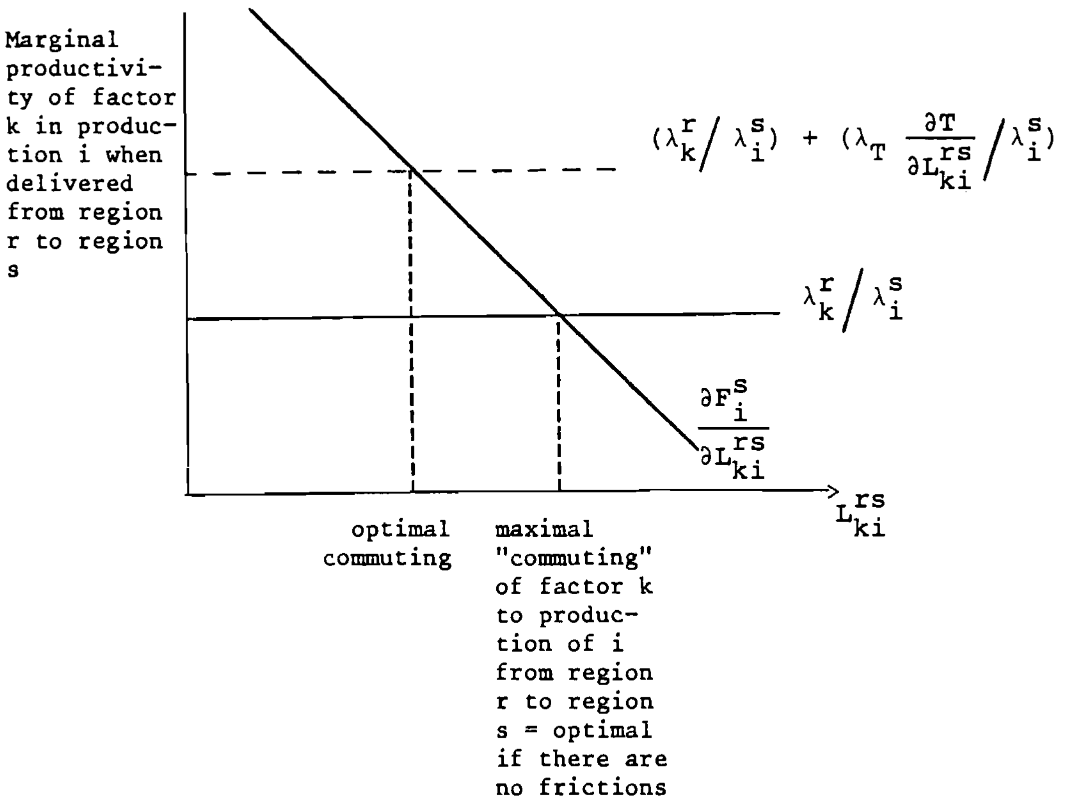

Figure 2. Illustration of optimality conditions for factor mobility

The optimum "commuting" point for factor k might shift to the right for the following four ceteris paribus changes in relative terms:

a) The valuation of commodity i increases,
b) The availability of factor k in location r increases,
c) The marginal physical productivity of factor k used in production of commodity i in region s increases,
d) The need for transportation per unit of distance of factor k per unit of factor service decreases.

We can conclude that changes in the transportation and generally the communication sectors is of importance for the trade in goods and factor services and thus for the optimal degree of specialization of an economy. With the secularly decreasing relative cost of transportation over the long term, an increasing reliance on trade and factor exchange should be expected. It is also obvious that a forced or natural scarcity of energy in the future with a corresponding increase in energy prices and increase in transportation prices should lead to a decline in trade and specialization. With this construction of the model, the prediction is clear. Any smooth decrease in availability of energy will lead to smooth declines in international and interregional trade and commuting of factors.

Some non-neoclassical studies of this specialization issue have indicated that a smooth change in availability of energy for transportation might not give rise to smooth responses in terms of decreasing degrees of specialization. The consequence might very well be "catastrophic". (See Alistair Mees, 1976.)

We have also shown that the relative regional differentials in availability of resources, technology of production, and valuation of the commodities produced can trigger off changes in the level of specialization and thus reliance on trade. It is clear from the analysis that the commodity structure of production and trade depends on <u>all</u> the parameters of the problem. However, very little can be said on this more specific issue without a structurally much more specified model than the one used above.

These long-term sectorial issues cannot be handled within the neoclassical comparative static model used above. Such an analysis needs a specification of a dynamic interregional input-output model consistent with the general non-spatial form proposed by Leontief or von Neumann. An interregional growth model suited to such a dynamic specialization analysis is presented in a forthcoming paper to be published as a IIASA Research Report. A version of this model is briefly discussed in the last section of this paper.

SOME EMPIRICAL MEASUREMENTS BASED ON NEOCLASSICAL TRADE AND LOCATION THEORY

According to the neoclassial theory of trade and location, three circumstances are of primary importance for specialization of production and trade dependence. These factors are:

- -factor supply,
- -transportation and communication costs, and
- -institutional constraints on the flows.

Surprisingly enough, very few empirical measurements of total trade dependence have been made . International trade economists have been much more interested in questions such as commodity structure of trade and similar issues. (See, for example, Baldwin, 1971; Bhagwati and Bharawaj, 1967; Branson W.H. and Monoyois, 1977; Keesing, 1966; and Leontief, 1956.)

One of the few econometric studies oriented to explaining total trade dependence (total import value in relation to GNP) has been done by Balassa (1977). (However, see also Chenery 1960.) His measurements are based on an implicit assumption that total diversity of factor supply increases with the size of the economy as reflected in national product and population size. He also introduced custom duties, measured as the average rate of tariffs on manufactured goods.

The function used was the following:

$$\log M = 1.03 + 0.76 \log Y - 0.13 \log P - 0.45 \log T; \quad n = 21 \text{ countries}$$

t-values	7.7	9.7	2.8	year: 1970

where M = total import value in US dollars
Y = gross national product "
P = population
T = rate of tariffs

This function has not been derived in any explicit way from theory and there is thus no explanation of the choice of functional form. I suspect that the form was chosen for ease of interpretation.

The effect of size is clear in this estimation. The average dependence on trade decreases by 24 per cent with an increase of GNP of 100 per cent. (Cet.Par.) The influence of size is also clearly indicated in the population elasticity. The tariff (and thus the price) elasticity is rather high and of the expected sign. Balassa:

> "The protection variable itself has the expected negative sign and it is significantly different from zero at the 1 per cent level. The relevance of the protection variable for intercountry differences in imports can further be indicated by calculating from the regression equation hypothetical values of imports at different levels of protection.
>
> For a country with a per capita income of $2241 and population of 35.6 million, corresponding to mean values in the 21 country sample, estimated import values are $35.7 billion for a zero tariff on manufactured goods, $12.6 billion for a tariff level of 10 per cent, $9.3 billion for a tariff level of 20 per cent, and $7.7 billion for a tariff level of 30 per cent. For the same tariff levels, the ratios of estimated imports to the gross national product are 36.8 per cent, 9.6 per cent, and 7.9 per cent, respectively. These figures compare to average imports of $10.3 billion and an average import share of 10.6 per cent in the sample."

Balassa omits the distance factor with the spurious argument that the price of transportation of commodities has fallen. He does not recognize that this development may have influenced the international location of production and thus may have also influenced trade. Furthermore, he forgets the great and unchanged or even increased importance of other forms of communication and its effect on trade dependence. The reason for the exclusion of transportation and communication friction from the estimation equation is possibly also of a methodological nature. Distances are measures of relations between pairs of countries; overall measures of distances can only be computed as <u>indexes</u> with all the errors that can be associated with such entities.

The following sections are devoted to an approach to international trade analysis that can accommodate distance effects together with any deductive findings from neoclassical theory within a stochastic framework.

TRADE, TRANSPORTATION AND COMMUNICATION - A STOCHASTIC APPROACH

The neoclassical theory of international trade is a good starting point for qualitative, prescriptive analysis. It is, however, doubtful if it can serve as an equally good starting point for explanatory and empirical analysis. Most of the hypotheses of the neoclassical theory of trade and location are such that they are difficult to refute. For instance, it can always be claimed that if this theory is refuted at the level of aggregation used in the test, the reason for the error lies in insufficient disaggregation rather than in the flaws of the theory. In the following section, I attempt to formulate a theory of international trade, which is more suitable for empirical tests and yet preserves many of the basic assumptions of the neoclassical theory of trade. Some of the procedures proposed below have implicit similarities to procedures used by Linnemann, Tinbergen, Pöyhönen and Nyhus, to name a few.

One basic idea of this approach is that natural resource abundance is of minor importance for specialization of production and trade. Rather, it is the assumption that production specialization is determined by national policies of capital accumulation, education, research and development and by <u>trade patterns</u> tying the allocation of policies of one country to allocation policies of all other countries. Growth of production and development of trade patterns are thus tied to each other in a dynamic theory of location and trade. This idea also forms the basis of Leontief's projections in "The Future of the World Economy".

In most theoretical studies of trade, there is no explicit consideration of the spatial dimension. One notable exception is Lefeber (1958). In his approach, used as a basis of the preceding section of this paper, a discrete network for transportation is assumed to be given exogenously. The structure and capacity of this network is assumed to be of importance for the structure of trade. Some of the implications, given above, are intuitively appealing. Others are more disputable. With deterministic assumptions as a basis of the analysis, the conclusion is that no crosshauling can occur in the system. This conclusion is obviously at odds with any empirically observed structure of trade and it casts serious doubts on the usefulness of such trade equilibrium conditions.

Linear programming approaches to the same problem employing transportation and other trade cost minimization objectives give the same no-crosshauling conditions. It does not seem to be the objectives as such but rather the deterministic approach that gives this result. With the deterministic approach also goes an implicit assumption of perfect information on trading and production conditions.

An economic theory based on the assumption of perfect information is almost a self-contradiction in a spatial context. We know from many empirical studies (with the pioneering work of Hägerstrand in the 1950s) that diffusion of information is very much dependent on spatial relations. Thus, trade must rely on incomplete information. This introduces a random element both in the coupling of buyers to sellers and in the choice of transportation services. In the presence of uncertainties, it can also be assumed that the contracts between buyers and sellers are not based on a strict optimization principle, but that in fact, calculated risks are taken into account. Hence, portfolio solutions can influence the outcome of the spatial relations.

The above arguments indicate the necessity of using a stochastic, rather than a deterministic, model to describe and predict patterns of trade. Another, more technical problem adds to this picture, namely the problem of aggregation. Aggregation over space obviously makes the trade problem less dominant (that is, if intraregional spatial variations can be neglected). Other types of aggregation of activities, goods and overtime make the role of crosshauling more apparent. Even at a very fine level of aggregation, small differences of quality, say cars of the same make but of different colors, are enough to induce crosshauling over great distances. Temporal variations of, for example, stocks, may have the same effect.

The main non-optimization approaches belong to the class of information based models, and such a model will be the focus of interest in this paper. However, first some other thoughts that are of potential interest in transportation should be mentioned - location modeling.

Recently, much research in this field has concentrated on the handling of information. It has been argued that the changing role of transportation is a key feature of post-industrial society. The relative importance of the transportation of goods is diminishing (at least as long as no drastic rise in energy prices takes place) and the relative importance of information processing and transfer are becoming greater. Information which is transferred by face-to-face contact thus becomes a crucial factor in determining the transportation pattern. This is particularly so since transfer of material and information often appear in combination. The effect of the personal contact system cannot be described simply as a cost-minimization or profit-maximization process. Empirical evidence shows that social norms, attitudes, and habits, as well as legislation have an impact on how contacts are made. This is demonstrated particularly well in studies of firms that have moved from one region to another and that have kept contacts with their former subcontractors, etc., more or less intact in spite of the possibility of establishing new, closer ones. Obviously, ownership and other legal arrangements put restrictions on transportation and trade that cannot be derived from spatial considerations. Conversely, transportation flows that take place within a firm but between units at different locations cannot alway be analyzed, since they are not registered in trading accounts.

It is possible to avoid some difficulties in working with causal relations between location and transportation on the microlevel by using a statistical or information theory approach. The problem can typically be posed in the following way. Certain flow conditions are given exogenously by economic theory, for example, by supply-demand constraints in different regions. Sometimes some empirical observations of interregional flows are also at hand. The problem becomes one of estimating the complete transportation-trade pattern and of predicting this pattern in future situations. The tools are provided by information theory. A standard example of this approach is the derivation of gravity models for travel flows. The distribution of trips derived is the maximum likelihood solution of a probability distribution constrained by a set of statistics on origins, destinations, and on the total cost (or distance) or trips. A weakness of this simple approach is that no a priori information about existing flows is taken into account. However, as shown by Snickars and Weibull (1977), it is possible to define the microstates of the statistical distribution in such a way that a priori information of that kind can be incorporated. This so-called minimum information principle has been shown by Hobson (1971) to provide a generalization of the Shannon-Weaver entropy measure.

In the following analysis, I will use the term "region" in the place of nation, because the analysis is assumed to cover trade between locations, irrespective of their political status. To obtain estimates of transportation flows of goods between regions, a similar statistical approach can be applied. Let a_{ij} denote the usual Leontief input coefficient, that is, to produce an amount x_j of goods j an input $a_{ij}x_j$ is needed of goods i. a_{ij} is a technological coefficient that is assumed to be independent of volumes and prices (no scale effect, no substitution) and that remains constant over time. It seems to be a natural step to generalize this input-output notion in a spatial context and to introduce a regional input-output relation a_{ij}^{rs}, where rs denotes deliveries from region r to region s. However, as will be clear from the sequel, it is not possible to express the regional input-output relations as a linear function of production volumes x, and hence the definition of a_{ij}^{rs} cannot be made unambiguous.

In the case where spatial separation between regions r and s can be totally ignored, an unbiased assumption of deliveries to production, x_j^s from sector i in region r, would be

$$x_{ij}^{rs} = \frac{x_i^r a_{ij} x_j^s}{\sum\limits_r x_i^r} \quad , \tag{7}$$

that is, each unit of production i contributes with the same amount or with the same <u>probability</u>. If the number of delivering regions is r=1, the expression above is reduced to the usual input-output relations:

$$x_{ij}^{rs} = a_{ij}x_j^s \text{ , where } x_j^s \text{ is production of commodity j in region s.} \tag{8}$$

In no other cases can the quadratic expression for flows x_{ij}^{rs} be reduced to linear relationships. There is no reason to assume that the introduction of a distance factor or other frictions would upset this observation. The flows x_{ij}^{rs} are subject to the following general conditions:

$$\sum_r x_{ij}^{rs} = a_{ij}x_j^s, \text{ input constraint } i,\ j = 1,\ldots,s = 1, \tag{9}$$

$$\sum_j \sum_s x_{ij}^{rs} = x_i^r \ , \quad \text{output constraint } i = 1,\ldots,r = 1, \tag{10}$$

(making the simplifying assumption that no deliveries go to capital and labor, and that final demand is treated as endogenous).

It is evident that the maximum likelihood estimate of x_{ij}^{rs}, taking the two constraints above into account, leads to the formula for unbiased transportation flows given above.

Equation (9) can be generalized to include investment flows. According to the acceleration principle of capital formation, the investment terms can be expressed as a linear function of the change of production Δx_j^s. Thus

$$\Sigma x_{ij}^{rs} = a_{ij} x_j^s + b_{ij} \Delta x_j^s \,. \tag{11}$$

This formulation corresponds to the dynamic version of Leontief's input-output model. The distinction between flows and stocks is a relative one. It can be expressed in terms of durability, that is, the time span during which a certain commodity is utilized. This provides an alternative formulation, whereby durabilities τ_i for capital i can be used to link input-output coefficients a_{ij} to capital-output coefficients b_{ij}:

$$\tau_i a_{ij} = b_{ij} \,. \tag{12}$$

In its simplest form the costs (c) of transportation of goods x_{ij}^{rs} can be expressed as a linear function of unit costs :

$$c = x_{ij}^{rs} \,.\, t^i \,.\, d^{rs} \,, \tag{13}$$

where t^i denotes the cost per value of goods i per kilometer and d^{rs} denoted the distance in kilometers.

It is fairly obvious that information networks can be included in the same way to represent the a priori constraints of information capacity of the trading system. The information about transportation costs can be used in various ways to constrain the set of feasible transportation flows and hence to effect the most probable distribution of flows. For example, if the capacity in terms of total transportation costs between each pair of regions is known, then the cost constraints read

$$\sum_{ij}\sum x_{ij}^{rs} t^i d^{rs} = c^{rs} \quad . \tag{14}$$

Together with the two previous constraints (10) and (11) the maximum likelihood solution becomes

$$x_{ij}^{rs} = A_i^r x_i^r B_{ij}^s (a_{ij} x_j^s + b_{ij} \Delta x_j^s) \exp(-\gamma_{rs} t^i d^{rs}) \quad . \tag{15}$$

A_i^r and B_{ij}^s are balancing factors that are implicitly defined by the first two constraints. They depend on the whole trade pattern

$$B_{ij}^s = \frac{1}{\sum_r A_i^r x_i^r \exp(\gamma_{rs} t^i d^{rs})} \quad , \tag{16}$$

$$A_i^r = \frac{1}{\sum_{js}\sum B_{ij}^s (a_{ij} x_j^s + b_{ij} \Delta x_j^s) \exp(-\gamma_{rs} t^i d^{rs})} \quad . \tag{17}$$

The cost constraint can be defined in other ways, for example, in terms of total cost or total cost per type of goods. The corresponding changes of parameters in the formula for x_{ij}^{rs} are obvious and will not be derived here.

As noted above, there are methods to improve the estimate of the flow matrix (x_{ij}^{rs}) by using a priori information according to the minimum information principle (Snickars and Weibull, 1977). Historical data of flows x_{ij}^{rs} together with actual data (observed or exogenously determined) related to the demand and supply constraints (C) can be used to ensure an "effective" statistical estimate (that is, with the lowest information content),

$$\min - \Sigma x_{ij}^{rs} \log \frac{x_{ij}^{rs}}{\hat{x}_{ij}^{rs}} \text{, subject to (C).} \tag{18}$$

A Taylor-expansion of log $\frac{x_{ij}^{rs}}{\hat{x}_{ij}^{rs}}$ in the neighborhood of $x_{ij}^{rs} = \hat{x}_{ij}^{rs}$ shows that the expression above can be approximated with a measure of quadratic deviation (Kádas and Klafszky, 1976):

$$\min - \Sigma \frac{1}{\hat{x}_{ij}^{rs}} (\hat{x}_{ij}^{rs} - x_{ij}^{rs})^2 \tag{19}$$

In many cases, the a priori information cannot be given in the form of a complete historical interregional flow table. Regional trade information is often available only for certain branches and regions. However, a flow matrix can be completed by using the same information theoretical argument as above. Hence, the matrix x_{ij}^{rs} is derived from the formula

$$\min - \sum_{x \notin K} x_{ij}^{rs} \log x_{ij}^{rs} - \sum_{x \in K} x_{ij}^{rs} \log \frac{x_{ij}^{rs}}{\bar{x}_{ij}^{rs}} \; . \tag{20}$$

(This corresponds to the assumption that for $x \notin K$ all micro-events are assumed to be equally probable.) It should be noted that a priori information $\hat{x}_{ij}^{rs}$ derived from a maximum likelihood estimation of a subset of the constraints does not add any new information. In that case, we can put $\hat{x}_{ij}^{rs}$ equal to a constant.

Another possibility is to subtract the given $\bar{x}_{ij}^{rs}$ from the matrix and the constraints and then treat the residual problem as a standard entropy maximizing problem without a priori information. However, this method fails to take into account information about the total distribution contained in the given $\bar{x}_{ij}^{rs}$. The discrepancy can be shown to depend on the relative size of K and $\bar{K}$. The influence of the entropy distribution on $x \in K$ can be expressed as an exponential factor $\alpha x = \alpha \bar{x}$, which tends to one, $\alpha \to 1$ when

$$\text{Prob}\ (\sum_{x \in K} \bar{x}) \to 1. \tag{21}$$

We have thus generated a set of equations that can be used to determine international trade flows resulting from locational choices and different frictions on trade flows. This approach can easily be extended to more general situations. The nature of this theory is that all prior information in the form of theoretical conditions, summation, and other consistency constraints can be easily accommodated and the goal function is only there to give a stochastically determined solution. It is consequently an easy theoretical matter to include constraints on the minimal welfare level of the participants of the trading system, resource constraints, economic block formations constraints, and so on. The consequence of each such constraint is to add prior theoretical determination of the flows and to leave less and less room for stochastic elements. There is one observation to be made at this stage. The consistency requirement will enter the reduced form, corresponding to equation (15), in a multipicative way, while all the deterrents to trade enter the reduced form in an exponential way.

EMPIRICAL MEASUREMENTS BASED ON STOCHASTIC THEORY OF INTERNATIONAL TRADE

Within the framework of the theoretically limited neoclassical trade and location model, we have shown that the optimal exchange of commodities decreases with distance between the trade partners. This distance decay effect is--with some exceptions, such as Linnemann, Poyhonen, Pulliainen, and Tinbergen--mostly overlooked in the international trade literature. It must be stressed that distance affects not only the cost of goods transportation but also other forms of frictions on human communication of importance in establishing and maintaining business relations. There are also other non-distance frictions on trade, created by the political and institutional systems as well as cultural and language differences. We also have shown that trade frictions are a natural part of stochastic trade theory. All these trade friction factors are treated in a symmetric way in the following statistically estimated world trade equation, which in its form is consistent with the stochastic theory of international trade. Beside these barriers to trade, the effect of the size of the importing and exporting countries is also included in the equation.

The equation used for testing has the following specification:

$$x_{ij}=\alpha_o(S_i)^{\alpha_1}(D_j)^{\alpha_2}e^{\alpha_3 d_{ij}}e^{\alpha_4 N_i N_j+\alpha_5 E_i E_j+\alpha_6 F_i F_j+\alpha_7 R_i R_j +\alpha_8 G_i G_j+\alpha_9 t_i t_j+\alpha_{10}\varepsilon_i\varepsilon_j} \quad (22)$$

where

x_{ij} = exports from country i to country j ;

S_i = GDP_i + total imports to country i ;

D_j = GDP_j + total exports from country j ;

$N_i = \begin{cases} 1 \text{ if Nordic country ,} \\ 0 \text{ otherwise ;} \end{cases}$

$E_i = \begin{cases} 1 \text{ if EEC country ,} \\ 0 \text{ otherwise ;} \end{cases}$

$F_i = \begin{cases} 1 \text{ if EFTA country ,} \\ 0 \text{ otherwise ;} \end{cases}$

$R_i = \begin{cases} 1 \text{ if country in which Roman language spoken,} \\ 0 \text{ otherwise ;} \end{cases}$

$G_i = \begin{cases} 1 \text{ if country in which Germanic language spoken,} \\ 0 \text{ otherwise ;} \end{cases}$

$t_i = \begin{cases} 1 \text{ if country in which German spoken,} \\ 0 \text{ otherwise ;} \end{cases}$

$\varepsilon_i = \begin{cases} 1 \text{ if country in which English spoken,} \\ 0 \text{ otherwise ;} \end{cases}$

d_{ij} = distance (shortest route) in 1000 km from country i to country j.

This equation has been estimated on world trade matrices for 1965, 1970, and 1975 (see appendix for table of 1975). The results for a set of 960 pairs of countries are:

$$x_{ij} = e^{-9} (S_i)^{0.69} (D_j)^{0.65} e^{-0.023 d_{ij}} e^{1.2 N_i + 0.9 E_i E_j + 0.9 t_i t_j + 0.9 \varepsilon_i \varepsilon_j} \quad . \qquad \begin{matrix} (23) \\ (1965) \end{matrix}$$

All other coefficients are not significant at the 5% level.

This equation shows that in 1965 there was a significant marginal decline in exports with an increase in the size of the exporting countries or increase in the size of the importing countries. There were only a few significant preference factors in trade. The Nordic countries have the strongest interactions, despite the fact that these countries have a rather limited system of formal trade agreements. This points to the fact that cultural and language similarity is often very important for the emergence of clustering of trade interdependency.

The effect of the European Common Market is markedly lower. It amounts to a multiplicative factor of approximately 2.5. The interpretation of a parameter value 0.9 can thus be that exports between two countries belonging to the Common Market is approximately 250% of the exports between a Common Market country and a non-Common Market country of similar economic structure. There is also a clear language effect for the German-speaking countries: Germany, Austria, and Switzerland. For Germany, the language similarity has just as strong an effect on trade as that of Common Market ties. A significant effect of similarity in language is also evident among English-speaking nations. This is approximately the same as for the German-speaking country trade preference. It is rather surprising that there is no corresponding effect for the Roman-language-speaking countries.

The same equation has been estimated for 1970 and 1975.

$$x_{ij}=e^{-12}(S_i)^{0.84}(D_j)^{0.77}e^{-0.023d_{ij}}e^{1.6N_iN_j+0.8E_iE_j+0.96t_it_j+0.9\varepsilon_i\varepsilon_j} \qquad (24)\ (1970)$$

$$x_{ij}=e^{-14}(S_i)^{0.92}(D_j)^{0.83}e^{-0.023d_{ij}}e^{1.8N_iN_j+0.8E_iE_j+0.9t_it_j+0.8\varepsilon_i\varepsilon_j} \qquad (25)\ (1975)$$

The two trade equations for the 1970s indicate an interesting development. The supply and demand elasticities are, by 1975, significantly higher than in 1965. This means that world trade has become more oriented to larger countries. Such a development can be interpreted in a number of ways. The interpretation most close at hand concerns specialization of the economies. The ever-increasing number of differentiated commodities, combined with increasing returns to scale, means that all countries must increase their degree of specialization in order to reap the benefits of technological development. This hypothesis implies that all countries, and even the largest ones, will be specialized in a relatively limited number of important products, being dependent on imports for the majority of products used in the country.

Another interesting result is the extreme robustness of the transportation and communication factors. Despite the fact that the 1975 equation reflects trade patterns after the large increase in oil prices, there is no increasing distance friction in the estimate. This indicates that there will not be any fundamental re-arrangement of international trade patterns as a consequence of the rise in energy prices already witnessed. This robustness of the trading pattern to increases in energy prices must result from the fact that energy costs form a rather minor part of total transportation costs.

The estimates of the world trade equation indicate that the formation of trading blocks is important for the volume and direction of trade and thus for the achievement of a higher degree of specialization and production. We can now conclude this brief empirical section with the following observations:

- Specialization in terms of trade dependence is generally increasing in the world economy.
- The size of the economy is still a factor that is negatively related to specialization and trade dependence.
- The importance of size has, however, been declining from the mid-sixties to the mid-seventies. The largest economies are approaching the smaller, developed economies in terms of trade dependence.
- Japan and Australia have in international comparisons, a low degree of specialization. This means that many sectors exposed to international competition in developed European economies have a national character in these countries.
- Trading blocks have been formed.
- Similarity of language--and possibly also other cultural similarities--can be an important factor determining the degree of specialization and exchange of goods between two economies.

Similar estimates for individual commodity groups substantiate the findings of the aggregate level. Size plays a trade deterrent role also at the disaggregated level but this size deterrence elasticity is not far from 1 in most sectors and for most countries involved. It thus seems to be the case that smallness and dependence of the international economy will not be as closely tied to each other as they have traditionally been.

LOCATION OF PRODUCTION, TRADE, AND COMMUNICATION IN A DYNAMIC CONTEXT

The approach to trade analysis presented above is very suitable for empirical measurements both at the macrolevel and at more disaggregated levels. The estimation of trading coefficients - a_{ij}^{rs} and b_{ij}^{rs} - is straightforward, as described in section 4. It is obvious from this analysis that in order to predict trade flows, the location of production in countries must be known. Thus, a determination of trade flows between nations requires that location be known, but the determination of locations requires that the a_{ij}^{rs} and b_{ij}^{rs} coefficients, reflecting trade relations, must also be known.

A consistent theory involving the proposed model of trade must, therefore, determine jointly trade and location patterns. The problem is conveniently presented in Figure 3.

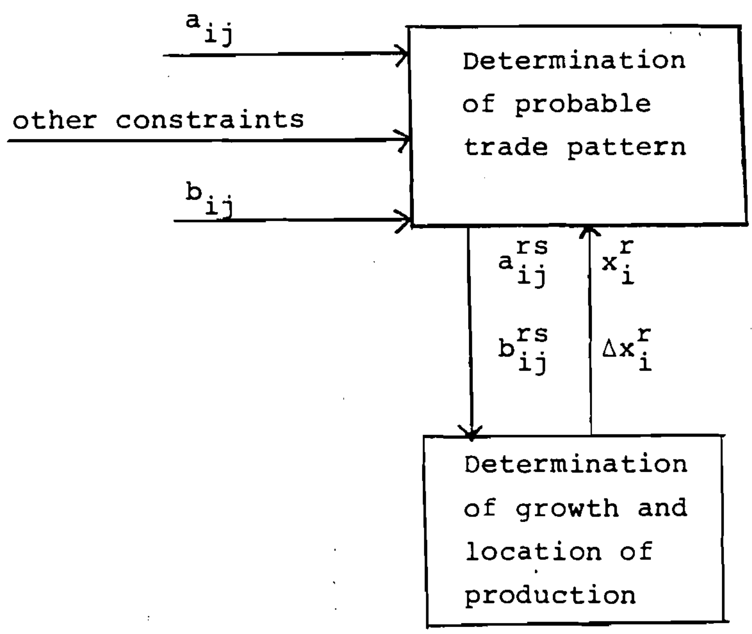

Figure 3. Determination of trade and patterns of location of production.

It has been shown in section 4 that the flow of commodities between nations is governed by equation (26)

$$x_{ij}^{rs} = x_i^r h_{ij}^{rs}(\bar{x},T)(a_{ij} + b_{ij}\, g_j^s) x_j^s \quad , \tag{26}$$

where

$h_{ij}^{rs}(\bar{x},T)$ = a parameter representing the influence of the correction factors and trade deterring variables,

$g_j^s x_j^s = \Delta x_j^s$,

T = a representation of transportation and communication networks.

This means that trade flows are determined in a quadratic way.

If these quadratic trade equations are used in a growth framework of the Leontief closed model of economic growth, that growth model must also be quadratic.

We thus have the growth model:

$$x \geqq x \; Q_1 x + x \; Q_2 \; x \; , \qquad 27)$$

where

$$Q_1 = \{h_{ij}^{rs}(\bar{x},T)\, a_{ij}\}, \text{ and}$$

$$Q_2 = \{h_{ij}^{rs}(\bar{x},T)\, b_{ij} \; g_j^s\} \; .$$

A general growth equilibrium can be defined as a state in which

$$x = x \; Q_1 \; x + \lambda x \; Q_2 x \; , \qquad (28)$$

where λ is the equilibrium rate of growth, with $\lambda = g_j^s$, for all s,j. This is a non-linear eigenvalue problem for which an economically meaningful $(x>0, \lambda>0)$ equilibrium solution exists. (See Nikaido, 1968; Andersson A.E. and Persson M., 1979).

This analysis shows that it is possible to formulate a consistent general equilibrium theory of location, growth, and trade. This approach has also been tested with numerical methods and has yielded consistent solutions to the simultaneous location-trade problem when representative sets of data were used.