ESTIMATING INTERREGIONAL TRADES IN CHINA FOR TRANSPORT PROJECT EVALUATION BASED ON THE REGIONAL I-O FRAMEWORK AND RAILROAD NETWORK CAPACITIES

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1. INTRODUCTION

It is indispensable to carefully evaluate a project to improve transportation facilities through a feasible study, particularly when that project is to be sponsored by the international organizations or the foreign governments. We must assess beforehand how the effects of the project would distribute over the country in the sense that it promotes her growth in a spatially balanced manner. In those countries which would be possible recipients of development funds, it is likely that there would only be some insufficient regional statistics available to the researchers. Our study is aimed at establishing the way to construct a multi-regional econometric model, with which one can assess impacts of a project to improve transportation facilities with limited data requirements. While our study is intended to analyze Chinese economies in 29 provinces, it does require not much data other than the national input-output (I-O) table.

In this paper, we propose a submodel to estimate the regional I-O tables and interregional trades for assessing impacts of a project to improve transportation facilities, by means of an I-O framework. In such countries where those facilities have not been well developed, not only time costs but also capacities may be considered as the major factor to determine the generalized transport costs. Accordingly, we here discuss the way to incorporate these capacities explicitly in estimating interregional trades.

2. OVERALL CONSTRUCTION OF THE MODEL AND SOME PRELIMINARIES

2.1. Overall Construction of the Model

We illustrate, in Figure 1, the overall construction of the multi-regional econometric model considered in our study. Once a provisional project to improve transport conditions is proposed, we can calculate the transport costs reflecting the project. The population and other related economic statistics are calculated based on these costs. Combining such information, we estimate, through the multi-regional I-O framework, the interregional trades which eventually facilitate the evaluation of the particular project.

In an effort to lead to the completion of the entire model, we here concentrate on describing a part of the model which is surrounded by a broken line in Figure 1. Namely, we confine ourselves to the descriptions of the submodel to estimate regional I-O tables and

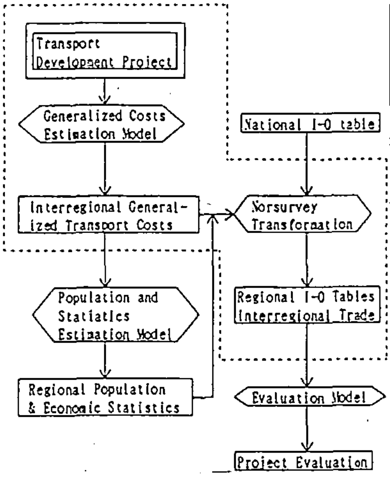
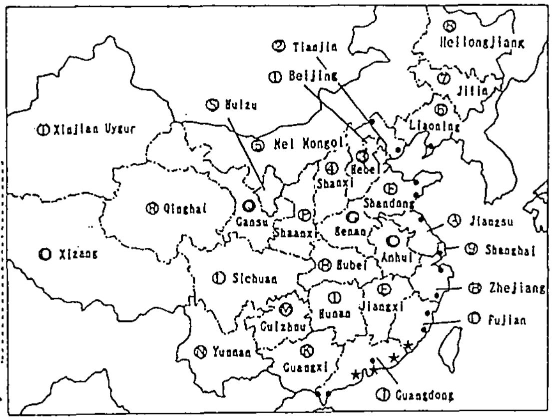


Figure 1. The multi-regional model and the scope of present analysis.



• Open City ★ Special Economic Zone

Figure 2. Geographical locations of provinces.

interregional trades based on the generalized transport costs.

2.2. Some Preliminaries

(1) There are two major sources of data available to us, i.e., a) *Statistical Yearbook of China*, published annually by Chinese National Statistics Bureau, and b) the National I-O table. The latest edition for the latter has been compiled for 1985 by the State Information Center in cooperation with the Japanese Institute of Developing Economies, and is designed to be capable to facilitating both MPS (Material Production System) and SNA (System of National Accounts). The major variables being listed in the former are summarized elsewhere.[1)]
(2) The base year of the study is set at 1985 when the latest I-O table is available after the implementation of the economic reform policies.
(3) While the nation is divided into 29 provinces, including 3 directly governed cities and 5 autonomous regions, shown in Figure 2, the industries are classified into seven sectors; 1 = agriculture, 2 = manufacturing, 3 = energy and resources, 4 = construction, 5 = transport and communication, 6 = commerce, and 7 = services.
(4) The framework of the I-O table is illustrated in Figure 3, which presumes competitive imports and is based on producer prices. The 106 sectors in the original table are aggregated to the seven sectors mentioned above.
(5) For simplicity, we here consider the railroad provides the sole mode of interregional trades. This is because the railroad virtually halves the total freight volumes in ton-kilometers with ships, but only the former serves all the provinces except Tibet.

Endogenous Transactions x_{ij}	Intermediate Demands	Private Consumption	Social Consumption	Consumption Total	Fixed Capital Formation	Net.Final Demands	Net Increase In Stocks	Exports	Domestic Exports	Final Demand Total	Total Demand	Imports (−)	Domestic Imports (−)	Productions
	U_i	Y_{i1}	Y_{i2}	$\tilde{Y}_i$	I_i	Y_i	J_i	F_i	TF_i	FDT_i	TD_i	M_i	TM_i	X_i.
Intermediate Inputs Z_j		W			I	Y	J	F	TF	FDT	TD	M	TM	X
Depreciation V_{1j}	V_1													
National Income V_{2j}	V_2													
Value Added Total VAT_j	VAT													
Productions X_j														

$U_i=\sum_j x_{ij}$, $\tilde{Y}_i=Y_{i1}+Y_{i2}$, $Y_i=\tilde{Y}_i+I_i$

$FDT_i=Y_i+J_i+F_i+TF_i$, $TD_i=U_i+FDT_i$

$X_i=TD_i-M_i-TM_i$, D_i(Net Demand) $=U_i+Y_i$

$Z_j=\sum_i x_{ij}$, $VAT_j=V_{1j}+V_{2j}$, $X_j=Z_j+VAT_j$

r, s ······· regions i, j ··············· commodities * ··········· nominal

Figure 3. The composition of an input-output table.

3. THE METHOD TO ESTIMATE THE GENERALIZED TRANSPORT COSTS

3.1. The Outline of the Method

Frictions associated with interregional transactions are commonly considered in many commercial and residential location models[2)3)] in form of the gravity type formulas. Such frictions would take the form of either time distances, monetary costs or their weighted means. As mentioned above, we here consider the physical capacities of the transport network explicitly in determining the generalized costs. Similar discussions can be found in the context of road networks. For instance, it is possible to obtain the maximum traffic flows facilitated in the network through the methods based on minimum cuts with the relative composition of OD pairs fixed.[4)] Masutani[5)] also deals with a similar case, but defines the network capacities as the maximum amounts of individual OD flows by means of the OD-cut matrix, and thus, the composition of OD pairs may be shifted from the one originally given.

In our case, the freight OD's are unknown due to the lack of regional statistics, and the railroads can be regarded as being independent of flows as far as times required are concerned. Thus we employ a rather mechanical way to assign capacities to individual OD pairs using the OD-cut and cutset matrices provided that the those of individual links are known beforehand. Once the capacities based on OD's are calculated, we can easily estimate the interregional trades using the general transport costs reflecting them. It must be noted that it is possible to revise the capacities using the estimated trade patterns while our method simply assigns an equivalent weight to each OD pair relevant to a link concerned. In that case, we might determine both capacities and interregional trades iteratively.

3.2. Interregional Transport Capacities

(1) Link capacities CL_l: A link capacity is defined as a composite function of the average distance between adjacent stations along each , link, LS_l, and the average gradient over that link, LG_l,

$$CL_l = \alpha(LS_l)^{\beta}(LG_l)^{\gamma}. \tag{1}$$

The parameters associated with eq.(1) are determined using the only regional freight data available in the *Yearbook*, viz. the total ton-.1h12
kilometers of freights carried in each province by rail, FV^r. When we denote the line length in operation in province r by TL^r, the linear density of freight volumes carried in that province is given by

$$FVT^r = FV^r/TL^r. \tag{2}$$

If the facilities are utilized efficiently, we might regard a linear density as an approximation to the link capacity. Then we can determine those parameters from the following regression concerning provincial averages.

$$CL^r = FVT^r = \alpha(LS^r)^{\beta}(LG^r)^{\gamma}, \tag{3}$$

where LS^r, LG^r are the averages over the links relevant to province r.

(2) Cut capacities Q_m: Suppose the cutset matrix of the network is denoted by an (M×L) matrix C, whose element C_{ml} is defined as follows.

C_{ml} = 1 when cut m includes link l, or 0 otherwise.

Then the capacity of the cuts can be calculated from the link capacities CL_l calculated by eq.(1).

$$Q = [Q_1 \cdots Q_M]^T = [\ C_{ml}\ ][CL_1 \cdots CL_L]^T = C \cdot CL \tag{4}$$

(3) Cut capacities of assigned to relevant OD pairs CP_{mn}: To understand the nature of the problem, it must be noted that those cuts are directly related with the OD's in the sense that a cut applies to some OD pairs, but not to others, and it has to intersect all the paths associated with the relevant OD pairs. For example, cut A in Figure 4 applies to only the pair (1,2), while cut B to (1,3). When the cut flows by OD pairs are concerned, the flow intersecting cut A is given by q_1, and is equal to the OD volume for pair (1,2). As for the

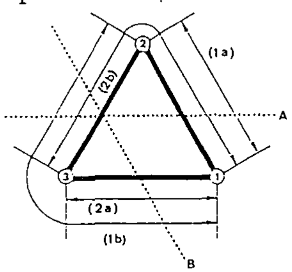


Figure 4. An illustration of cuts and paths in a simple network.

Table 1. An illustration of cut flows in Figure 4.

OD pairs		(1-2)		(1-3)		total
OD flows		q_1		q_2		
path		(1a)	(1b)	(2a)	(2b)	
path flows		αq_1	$(1-\alpha)q_1$	βq_2	$(1-\beta)q_2$	q_1+q_2
cut A	cut flows by OD pairs	αq_1	$(1-\alpha)q_1$	0	0	q_1
	cut flows re.capacity	αq_1	$(1-\alpha)q_1$	0	$2(1-\beta)q_2$	$q_1+2(1-\beta)q_2$
cut B	cut flows by OD pairs	0	0	βq_2	$(1-\beta)q_2$	q_2
	cut flows re.capacity	0	$2(1-\alpha)q_1$	βq_2	$(1-\beta)q_2$	$2(1-\alpha)q_1+q_2$

Note: $0 \leqq \alpha,\ \beta \leqq 1$

capacity at the cut, we must also account for the path 2b associated with the pair (1,3). This is why we consider the twice of a part of the OD volumes associated with the latter pair, $(1-\beta)q_2$, as illustrated in Table 1, where α and β are the proportions of the OD volumes assigned to the shortest paths.

To formalize the problem, we denote the OD-cut matrix by K, which is an (MXN) matrix with N reflecting the number of OD pairs. Its element K_{mn} gives the volume of traffic passing through the m-th cut and attributable to the n-th OD pair. If S_{mn} represents the share of the capacity associated with the m-th cut assigned to the n-th OD, the matrix S comprising S_{mn} is given by

$$S = [S_{mn}] = [\mathrm{diag}(K1)^{-1}]K, \tag{5}$$

where 1 is a column vector of size M whose elements are unity. And with this matrix, the (MXN) matrix CP comprising of CP_{mn} can easily be written as

$$CP = [CP_{mn}] = [Q_m S_{mn}] = \mathrm{diag}\ Q\cdot S \tag{6}$$

It must be noted that we here consider only the shortest path for each OD pair. Further, we disregard the difference in magnitudes of respective OD flows as there is no a priori information about the freight OD distributions. In terms of the example in Figure 4, such simplification is equivalent to assume α = B = 1 and $q_1 = q_2$ in Table 1. In such a case, S_{mn} stands for the number of times the path associated with the n-th OD pair intersects the m-th cut. Incidentally, the latter simplification could be eased by introducing an iterative procedure where the resulting OD patterns are utilized as the a priori information at the succeeding step.

(4) Capacities assigned to OD pairs CP^{rs}: Each column of matrix CP represents the cut capacity assigned to an OD pair. Thus the minimum element in each column gives the actual capacity for the relevant OD pair; $CP_n = [\min_m CP_{mn}]$. When we rewrite the n-th OD pair with its origin and destination (r,s), this is nothing but what we need, CP^{rs}.

3.3 The Generalized Transport Costs Incorporating Capacities

The generalized transport cost DC_i^{rs} for the i-th commodity associated with shipment between regions r and s is formulated as a Cobb-Douglas type function.

$$DC_i^{rs} = \alpha_i (d^{rs})^{\beta_i} (CP^{rs})^{-\gamma_i}, \tag{7}$$

where d^{rs} and CP^{rs} are the interregional time cost and capacity, respectively. The parameters α_i, β_i and γ_i are to be determined through the non-survey procedure to generate regional I-O tables from the national one discussed in Section 4.2.

4. ESTIMATING INTERREGIONAL TRADES

4.1. Overview of the Procedure

The extensive surveys on the evolvement of the procedures to estimate interregional trades, including the possible future extensions, can be found in Batten.[4] He classifies the existing literature into four categories; 1 = gravity and entropy models, 2 = interregional I-O models, 3 = spatial price equilibrium models, and 4 = interregional CGE models. Our method belong to the second category in his context.

Where sufficient regional statistics are not available, it would be a possible way to determine the interregional trades simultaneously through a non-survey transformation to adapt the national I-O table to the regional configurations. One reasoning is that the interregional trades would result from the economic interdependencies among regions, and cannot be obtained independent of the levels of regional economies. (See Round[5] for surveys covering the non-survey transformations.) Ando and Sakai[6] propose an iterative method to modify a regional table to meet the configurations of a subregion contained in the region. The method allows the transfers between the endogenous and final demand sectors, and explicitly considers the cross-hauling within the region. While the present method resembles to the former in the sense that the modification is mainly based on the balance equations along the rows of the I-O table, it differs in the following respects. That is, the amounts of domestic imports and exports are determined separately in each region, and the spatial disaggregation of the national table is made to maintain its additive consistency. In addition, the modifications along the columns are jointly used to estimate the surrogate market prices to adjust the interregional price differentials. As a detailed description of the procedure can be found elsewhere,[7] it would suffice to provide its rough sketch as depicted in Figure 5.

4.2. Estimating Regional I-O Tables

(1) The regional variables required: Some of the values in the 1985 national I-O table, including the productions X_i, value added V_j, itemized consumptions W_j and investments I_i, must be distributed in advance using the regional statistics available in the *Yearbook*.

(2) Endogenous sectors: The inter-sectorial transactions x^r_{ij} in region r are calculated provided that the national input coefficients *in real terms* are applicable everywhere. The intermediate demands U^r_i and inputs Z^r_j can then be calculated accordingly.

(3) The regional consumptions $\tilde{Y}^r_i$: The commodity composition of a net

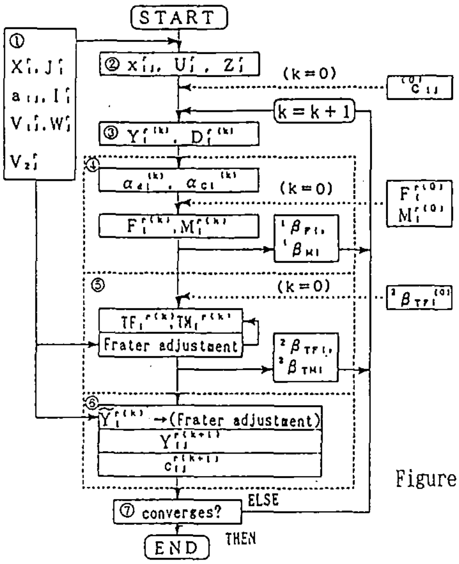


Figure 5. The process of non-survey modification of the national table.

final demand item j is given as the consumption converters c^r_{ij}. The initial approximation to the consumptions can easily be obtained from multiplying the itemized consumption by these converters;

$$\tilde{Y}^r_i = \Sigma_j c^r_{ij} W^r_j. \tag{8}$$

(4) The imports M^r_i and exports F^r_i by commodities: The national values in the I-O table are distributed through a potential model based on the regional productions and net demands, X^r_i and D^r_i, and the generalized transport costs, DC^{rs}.

(5) The domestic imports TM^r_i and exports TF^r_i: Suppose ρ^r_i denote the share of the regional supplies to fill in the intra-regional demand. Then the domestic export can be obtained from

$$TF^r_i = (X^r_i - F^r_i)(1 - \rho^r_i). \tag{9}$$

The domestic import, on the other hand, has to be determined to satisfy the following two conditions. That is, the national total of domestic imports and exports must coincide with each other, and the balance equation has to be satisfied in each region;

$$\Sigma_r TF^r_i = \Sigma_r TM^r_i \quad \text{and} \quad TF^r_i - TM^r_i = V^r_1 + V^r_2 - \tilde{Y}^r_i - I^r_i - J^r_i - F^r_i + M^r_i. \tag{10}$$

(6) Simultaneous modifications of consumptions and converters: There are two alternative ways to determine consumptions, viz. through eqs.(8) and (10), but there is no guarantee for these two results to coincide. Thus we employ the averages of them as the new

approximations of the consumptions. Applying the Fratar method in three dimensions, viz. w.r.t. regions, commodities and items, we can determine the consumption converters for the next step.
(7) The convergence criterion: We repeat steps (3) through (6) until the consumption converters satisfy the following criterion.

$$\Sigma_r \Sigma_i \Sigma_j |c_{ij}^{r} - c_{ij}^{r(-1)}| < \varepsilon \tag{11}$$

Once the convergence is reached, the consumptions, imports and exports, both external and domestic, along with a number of unknown parameters including those associated with eq.(7) are determined simultaneously. Consequently, we can obtain the regional renditions of the I-O tables.

4.3. The Interregional Trades

When we denote the trade of the i-th commodity between regions r and s by T_i^{rs}, it can be calculated through a doubly constrained gravity model based on the regional domestic import and export, TM_i^r and TF_i^r, obtained from the above procedure.

$$T_i^{rs} = A_i^r B_i^s TF_i^r TM_i^r (d^{rs})^{-\beta_i} (CP^{rs})^{\gamma_i}, \tag{12}$$

where A_i^r and B_i^r are the adjustment factors to satisfy the demand and supply constraints, and the parameters β_i and γ_i are given as the estimators in eq.(7).

5. THE RAILROAD TRANSPORTATION AND INTERREGIONAL TRADES IN CHINA

5.1. The Conditions of Chinese Railroad

The line length of Chinese railroad in operation amounts to 52,800 km in 1988, which stretches over all the provinces but Tibet. However, merely 22.3% are double-tracked, and electrification covers only 10.9 % of the total length. The shares carried by rail reaches 52.5 % in passenger-kilometers and 41.5 % in ton-kilometers. On the other hand, the highway carries 40.7 % of passengers and 13.5% of freights, and the same figures are 3.3 % and 42.3 %, respectively, for on-water transportation. The average trip lengths for freights range from 1128km for ships to 44 km for trucks. While the former could serve only a limited number of provinces, railroad carries as far as 681 km on the average, and covers all but one provinces. In this regard, the railroad still plays a major role in Chinese long-haul freight transportation.

5.2. Transport Capacities in China

(1) Link transport capacities: First we construct the link map for the Chinese rail system comprising 132 nodes and 167 links using the railroad timetable (1989 edition). We further calculate the average distance between adjacent stations along each link and the average gradient over that link from the maps. When the link is double-

tracked, the former is replaced by 1km, which halves the approximate length of two consecutive track blockades as the capacity is to be assessed on the bi-directional basis. Using those data, we estimate the parameters in eq.(3) as summarized in Table 2, and with these parameters we can calculate the link capacities through eq.(1).

(2) Interregional transport capacities: We further aggregate the link capacities obtained from the above link map in a way of adding up those of links across each provincial border. This inter-provincial link map possesses 29 nodes, corresponding to the respective provincial capitals, and 42 links, representing the borders between provinces. Such a convention is required from the computational feasibility. From this aggregated link map, we could obtain the sum of 911 cuts which are meaningful in evaluating the interregional capacities according to the procedure as described in Section 3.2. That is, the interregional capacities, CP^{rs}, are calculated from the OD-cut matrix, where a simplification measure is employed to limit the inter-provincial paths to the shortest ones between respective pairs of provinces for simplicity.

5.3. Interregional Trades

We explicitly consider the capacities as well as the time costs as to constitute the generalized transport costs, with which the regional domestic imports and exports are estimated through non-survey modifications of the national table. Table 3 compares those regional imports and exports in two cases, viz. the case 1 where only the time costs are considered, and the case 2 where both components of the generalized costs are considered. Due to lack in sufficient regional statistics as mentioned earlier, the comparisons here are made in terms of RMSE's and MAPE's. Table 3 also lists the parameters associated with eq.(7).

The RMSE's averaged over the sectors are about 0.6 billion yuan for domestic imports and 1 billion yuan for exports. The differences

Table 2. The parameters associated with link capacities.

	α	β	γ	
Parameters (t-values)	28.438	-0.6437 (5.36)	-0.0783 (1.51)	R^2=0.6513 (df=18)

Note: The t-values listed are the absolute values.

Table 3. Comparisons of domestic exports and imports in 1985 associated with cases 1 and 2.

Sector	Productions (Million Yuan)	Domestic Imports(Exports)		RMSE(Million Yuan), (ρ(%))		MAPE(%)		Parameters(case. 2)	
		case. 1	case. 2	Domestic Imports	Domestic Exports	Domestic Imports	Domestic Exports	$\alpha_{\cdot 1}$	$\alpha_{\cdot 2}$
Agriculture	362,734.8	23,280.0	23,439.7	58.2(0.3)	83.4(0.4)	55.1	40.2	0.5281	0.2985
Manufacturing	847,272.4	60,062.0	72,308.2	558.2(0.9)	1,020.9(1.7)	36.7	42.1	0.8339	0.4767
Energy & Resources	124,227.5	15,535.9	15,296.2	65.2(0.4)	44.7(0.3)	38.3	50.2	0.6190	0.4904
Construction	165,600.0	0.0	0.0	—	—	—	—	0.5182	0.3711
Transport & Communication	54,942.9	2,481.6	2,439.6	33.1(1.3)	23.2(0.9)	58.7	35.1	0.6270	0.4261
Commerce	121,578.0	7,150.1	7,090.9	52.3(0.7)	45.2(0.6)	26.5	45.2	0.5952	0.3464
Services	206,291.5	5,610.3	5,536.5	64.1(1.1)	54.6(1.0)	38.2	38.3	0.5121	0.3429
Total	1,882,647.1	114,119.9	126,201.2	550.7(0.5)	1,025.1(0.9)	17.5	11.6	—	—

■ TF_1, TM_1 : case. 1 TF_2, TM_2 : case. 2 ■ $\rho(\%) = (RMSE / \Sigma TF'_i) \times 100$ ■ $MAPE(\%) = (\Sigma(|TF'_i - TF_i| / TF'_i) \times 100/29$

■ $RMSE = SQR(\Sigma [TF'_i - TF_i])^2 / 29$

between two cases are fairly limited in the sense that these errors correspond to 0.5 % and 0.9 % of the total domestic imports and exports, respectively. On the other hand, the errors evaluated in MAPE's are relatively large as the average MAPE's amount to 18 % for imports and 12 % for exports, respectively. This observation corresponds to the nature of the index that the errors in the regions where the observed values are small tend to contribute to result in greater values.

When we look at those indices regarding three major industries, sectors 1 through 3, which jointly produce 70 % of the total national productions, we realize that the manufacturing sector is among the most sensitive to capacities. This could be understood that as the remainig two sectors are strongly bound to the local conditions, and thus, there is little room for capacities to affect their product distributions.

Next we estimate the interregional trades T_i^{rs} for respective commoditiesusing eq.(12), where the trades are evaluated on the monetary bases. Figure 6 illustrates the outstanding trade flows for the manufactured commodities. We can identify a major concentration of the supply sites for those commodities around the North-East and the coastal provinces to the East. In particular, the three provinces comprising Shanghai(9), Jiangsu(A) and Zhejiang(B), which produce 25% of the national manufacturing outputs, are quite active in exporting those commodities to various parts of the country. And those shipments are mainly received by the industrial and agricultural regions in the Inland area and the energy producing regions in the North-East.

From the interregional trades T_i^{rs} and the capacities CP^{rs}, we can calculate a kind of "location quotient",

$$\sigma_i^{rs} = (T_i^{rs}/\Sigma_{r,s}T_i^{rs})/(CP^{rs}/\Sigma_{r,s}CP^{rs}). \qquad (13)$$

The quotient identifies how a particular OD is specialized in the

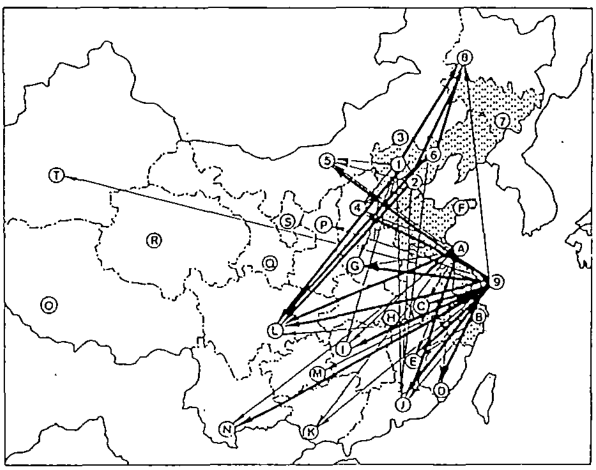


Figure 6. Major trade flows of manufactured commodities.

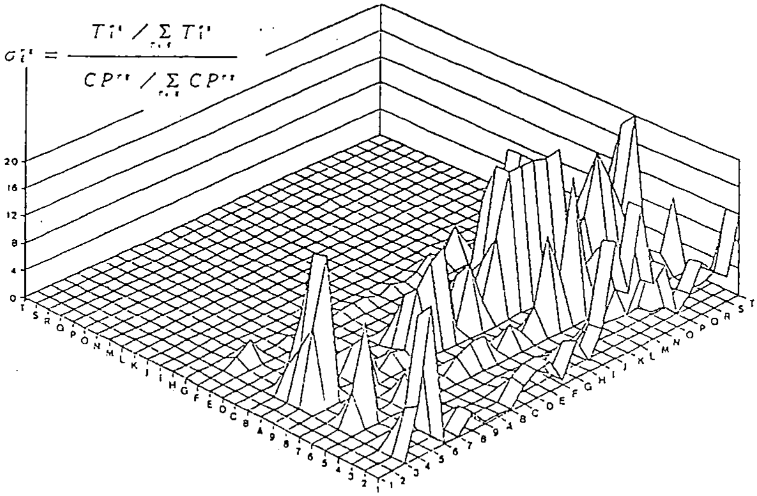


Figure 7. Location quotients of manufactured commodities.

shipment of a particular commodity. Figure 7 depicts those quotients over the region by region matrix for manufactured commodities.

We can confirm from this figure our observations concerning Figure 6. That is, the OD flows linking from Shanghai, Jiangsu and Zhejiang to the Central-South and West-South regions are specialized in those commodities. However, it is not easy to identify whether the capacities of those links are in short or not, as those capacities are to be shared with the shipments of other commodities.

It would become necessary to compare the interregional trades obtained above with the capacities when we need to clarify the problems associated with the present transport network. As the above quotients are based on the unique path corresponding to each OD pair, the immediate way to scrutinize our results would be to consider more than one path for each pair. In addition, it would also be possible to introduce some conversion ratios between weights and monetary values. Then we might compare the capacities and tonnages of freights more directly.

6. CONCLUDING REMARKS

The information concerning the interregional trades is indispensable in evaluating impacts associated with the improvements in the transportation facilities. In this article, we have discussed the way to estimate those trades using the I-O framework case without much rely upon such information. We apply the method to China, and manage to obtain some reasonable outcomes. In this regard, our method might be useful as a part of the multi-regional model designed to evaluate a project to improve transportation facilities as it explicitly considers the network capacities.

So far we have discussed a submodel to jointly determine the regional I-O tables and interregional trades. The multi-regional model implied in the study is designed to find and evaluate the alternatives concerning transport improvements. For that purpose, it is necessary to estimate the change in spatial allocations of productions and demands. In particular, as trades are partly caused by price differentials among regions, regional prices, which are determined endogenously in our model, would be of importance. Accordingly, the next step would be to complete the multi-regional model by formulating allocations of various stocks, and to establish the way to evaluate the outcomes of the model which would involve many economic indices.

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