VALIDITY AND APPLICABILITY OF A SPATIAL COMPUTABLE GENERAL EQUILIBRIUM MODEL

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ABSTRACT The main purpose of this paper is to examine validity and applicability of a spatial computable general equilibrium (SCGE) model by comparing the results obtained from an application of the SCGE model with the observed data, the Japanese nine-region interregional input-output table. In SCGE modeling trade models play a key role. This paper also pays a special attention to the integration of spatial and economic concepts of transport into an equilibrium framework. We show the two basic approaches to model transport sector, which generate an equivalent input-output table. After addressing a unified approach connecting these two approaches, we show the testing results of the performance of the SCGE model developed by Miyagi and Honbu.

1. INTRODUCTION

Transport infrastructure is seen as an essential prerequisite for economic development. While there is still interest in the effect of new or improved transportation systems, governments are concerned with the cost of providing and maintaining infrastructure when there are pressures to reduce public expenditure. This requires governments or planners to give rigorous explanations of the requirements of the infrastructure, which in turn implies a need for a more accurate assessment of the wider economic benefits.

Many of the traditional approaches have looked at the impact of individual infrastructure projects on the regions directly affected. However, a major change in the interregional transport system will exert an influence on national and regional economies in various ways. There are of course several models available for dealing with specific aspects of economy-wide effects of transportation. They may be classified as the multisectoral, multiregional, endogenous-price, and general equilibrium models. However, none of these approaches fully captures the sort of changes in which the spatial question affects the overall, regional or national, and multisector-performance of the economy (see, for example, Nijkamp, Rietvelt and Snickars, 1984, 1987; Rietvelt, 1989; JCJM van den Bergh *et al.*, 1996 for useful discussions and surveys.) It seems to be common knowledge amongst regional scientists that from a general economy-wide perspective, the only available approaches are *spatial computable general equilibrium* (SCGE) or *multiregional CGE*. SCGE models can consider quantity and price adjustments within a consistent multiregional accounting framework and do not suffer from any of the drawbacks of the traditional approaches.

The aim of this paper is to examine the validity and applicability of a spatial computable general equilibrium model by comparing results from an application of the SCGE model with actual data. Large-scale investment in transport lowers transport costs, thereby lowering the supply prices of various commodities and stimulating consumer demand. They in their turn change interregional trade patterns. This implies that trade models play a key role in SCGE modelling. This paper pays special attention to the integration of spatial and economic concepts of transport into an equilibrium framework. We start with a prototype model of CGE with emphasis on computational aspects, followed by two basic approaches to model the transport sector in the framework of SCGE. Then, we address a more sophisticated approach to describing the behaviour of a transport sector in order to derive a gravity type of interregional trade model. In the final section, we discuss the results of a SCGE model, where the performance of the SCGE model developed by Miyagi and Honbu (1993) is tested by using the 1985 interregional input-output data for Japan, divided into nine regions: Hokkaido, Tohoku, Kanto, Chubu, Kinki, Chugoku, Shikoku, Kyusyu and Okinawa.

2. OUTLINE OF CGE

A computable general equilibrium (CGE) is a common starting point for constructing a SCGE model. CGE and Applied General Equilibrium share the same meaning. They are operational or empirical general equilibrium models that can be used to provide quantitative analysis of economic policy problems (Dixson *et al.*, 1992; van den Bergh *et al.*, 1996). In this section we outline the basic framework of CGE with the two-good-two-factor case. The next section illustrates how this specific model can be extended to include the transportation sector. In the following, a single, representative consumer (a single household) is assumed. Much of the discussion in this section is taken from Shoven and Whalley (1992).

Consumer equilibrium

Consumer commodity demand can be derived from the first-order condition of the utility-maximization problem

$$\max\ U(C_1, C_2) \quad \text{s.t.} \ \sum_{i=1}^{2} p_i C_i = wL + rK$$

where C_i, L, K denote commodity demand and factor endowments for the consumer; P_i, w, r are the corresponding commodity and factor prices. Assuming that the utility function is strictly quasiconcave and differentiable implies that the solution to (1) is homogeneous to degree zero in prices.

Producer equilibrium

We consider two industries, each with linear homogeneous production functions

$$X_j = X_j(L_j, K_j)$$

Cost-minimisation behaviour yields factor demands

$$L_j = L_j(w, r, X_j), \quad K_j = K_j(w, r, X_j)$$

which are homogeneous to degree zero in factor prices.

Excess demands

$$C_j(p, w, r) - X_j \leq 0$$

$$\sum_{j=1}^{2} K_j(w, r, X_j) - K \leq 0$$

$$\sum_{j=1}^{2} L_j(w, r, X_j) - L \leq 0$$

Efficient market pricing

If the output of industry j is positive then a zero-profit condition prevails; that is,

$$p_j C_j = wL_j(w, r, X_j) + rK_j(w, r, X_j)$$

Walras' law

$$\sum_{j=1}^{2} p_j(X_j - C_j) + w(\sum_{j=1}^{2} L_j - L) + r(\sum_{j=1}^{2} K_j - K)$$

The dimensionality of the solution space in this model can be reduced to the number of factors of production. The steps involved are as follows:

1. Determine the cost-minimising factor demands per unit of output j given factor prices,

$$\frac{L_j}{X_j} = \alpha_j(w, r, 1), \quad \frac{K_j}{X_j} = \beta_j(w, r, 1) \; ; \quad j = 1, 2$$

2. Compute commodity prices as functions of r and w using the zero-profit conditions:

$$p_j = w\alpha_j(w, r, 1) + r\beta_j(w, r, 1) \; ; \quad j = 1, 2$$

3. Individual commodity demands can be given as:

$$C_j = X_j(p_1(w, r), p_2(w, r)); \quad j = 1, 2$$

4. Calculate output quantities that meet market demands

$$X_j(w, r) = C_j(w, r); \quad j = 1, 2$$

and calculate derived factor demands as

$$L_j(w, r) = \alpha_j(w, r) X_j(w, r); \quad j = 1, 2$$

$$K_j(w, r) = \beta_j(w, r) X_j(w, r); \quad j = 1, 2$$

5. Aggregate excess factor demands are given as

$$Z_L = \sum_{j=1}^{2} L_j(w, r) - L$$
$$Z_K = \sum_{j=1}^{2} K_j(w, r) - K$$

6. In comparing equilibria an aggregate measure of welfare, Hicksian equivalent variation, *EV*, is used.

$$EV = Y^1 - Y^0 - [E(p^1, U^1) - E(p^0, U^1)]$$

where Y^0, Y^1 denote the income of consumers in period 0 and 1, respectively, and $E(p,U)$ the expenditure function.

A variety of applications of CGF is illustrated in Shoven and Whalley (1992) and Whalley (1985). Ichikawa (1991), Kuroda (1989) and others demonstrate its application to the Japanese economy.

3. SIMPLE PROTOTYPE SCGE MODELS: THE INTEGRATION OF SPATIAL AND ECONOMIC CONCEPTS OF TRANSPORT

3.1 Two Basic Approaches

Differences in market prices between any pair of destinations reflect differences in transport costs. If local producers do not take market prices as given, price differences may also reflect some degree of price discrimination. In this case, market prices increase more or less proportionally to transport costs, as the distance from the producer's location grows (Greenhut, Norman and Hung, 1987).

Spatial price discrimination can be interpreted in either of two (effectively equivalent) ways. It occurs either as freight absorption by the producing sector or, equivalently, as the producer changing different production prices to consumers at different locations. The first approach may be called the horse truck model (or the so-called iceberg model). von Thunen (1842) illustrates this type of primitive transportation technology by a horse truck example where a farmer ships his agricultural products from the firm to the CBD by horse while the horse eats some of the load. In electrical and hydraulic circuits the same phenomenon is observed, flows encounter "resistance" which requires the expenditure of "energy" (the associated cost). Therefore, an additional amount of product must be sent to demand sites to meet the demand there. The second interpretation is the so-called supply and demand pool concept where all flows of a particular commodity are treated as being routed via a supply pool in the region of production and a pool in the region of absorption (Moses,1955; Chenery,1953): No direct link exists between producers and consumers (intermediate or final users of a specific commodity). This pooling approach explicitly recognises that products of the same sector from different regions are likely to be more readily substitutable for each other than are products of different sectors, and corresponds to the Armington assumption. We show a trade model based on the second approach in the next subsection.

Now we show two basic approaches to integrate the transport sector into the framework of SCGE. In the first approach, the transport sector is not explicitly treated, being based on the iceberg assumption. The second approach recognises the transport sector and takes its behaviour into account. We show that in spite of different starting points, the two approaches reach the same conclusion.

Kanemoto and Mera (1985) propose a simple general-equilibrium model (called the KM model) linked to the iceberg concept, to examine several economic issues associated with the benefit evaluation of a large transportation project. They formulate a two-region model where each region specialises in the production of one type of commodity. The production in the other region is used as an intermediate input and as one of the consumption goods. Factors of production are assumed to be fixed and suppressed in the production function. Although one region produces only one commodity, it is assumed that each region consumes both commodities. The second approach is the one proposed by van den Bergh and Nijkamp (1996) (called the BN model). In the BN model a further factor is introduced; a single household consumes two commodities; the first commodity production sector is located in the same place as the household sector, thus, no transportation is required to move a final good from sector 1 to the household sector. Another difference between these two models is that while the mill pricing is supposed in the KM model, the BN model assumes the CIF pricing.

We start with the BN model, but the transport cost assumption is slightly changed from the original to make for an easier comparison of the two approaches.

Table 1. Input-Output Relation in the BN Model (Quantity Base)

	Region 1	Region 2	Transport	Consumption	Production
Region 1		M_2		C_1	X_1
Region 2	M_1			C_2	X_2
(Transport)	(M_1)	(M_2)		(C_2)	$(M_1+M_2+C_2)$
Factor Input	L_1	L_2	L_T		

Table 1 shows the quantitative input-output relation corresponding to the BN model. Notice that since the transport sector only moves goods from one place to another, there is no contribution to the real production of goods.

The general equilibrium systems in the BN model are described as follows:

Consumer equilibrium

$$\max\ U(C_1, C_2) \quad \text{s.t.}\ \sum_{i=1}^{2} q_i C_i = Y \tag{1}$$

Here q_i denotes the CIF price of final goods i paid after transportation.

Producer equilibrium

$$\max\ \Pi_i = p_i X_i - w L_i - p_{M_i} M_i \quad \text{s.t.}\ X_i = X_i(L_i, M_i) \tag{2}$$

where M_i, $X_i(L_i, M_i)$ $(i = 1, 2)$ represent intermediate goods imported from the other region, and p_{M_i} the CIF price upon delivery of intermediate inputs. Assuming a linear transportation cost function[1], we can write the transportation costs of exports from region i to region j as $(t_i - 1)M_j$ $(j \neq i)$, where $(t_i - 1)$ is the transportation cost per unit quantity and t_i is called the transportation factor. For region j $(j \neq i)$ to obtain M_j region i must send $t_i M_j$ of the goods, since $(t_i - 1)M_j$ disappears in the process of transportation. Thus, the CIF prices of intermediate goods M_i and the final goods C_2 are represented by

$$\begin{aligned} p_{M_i} &= p_j + p_j(t_j - 1) = p_j t_j \quad (j \neq i) \\ q_2 &= p_2 + p_2(t_2 - 1) = p_2 t_2 \end{aligned} \tag{3}$$

Transportation sector

$$\max\ \Pi_T = \sum_{i=1}^{2} \sum_{j=i}^{2} (p_{M_i} - p_j) M_i + (q_2 - p_2) C_2 - w L_T \quad \text{s.t.}\ \sum_{i=1}^{2} M_i + C_2 = X_T(L_T) \tag{4}$$

where $X_T(L_T)$ is the production tunction of the transport sector with L_T being an input, labour factor.

Market clearing conditions

$$C_1 + M_2 = X_1,\quad C_2 + M_1 = X_2,\quad L_1 + L_2 + L_T = L \tag{5}$$

All earnings flow to the single household. Thus, the income of the household can be described as:

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[1] In the original paper by Bergh and Nijkamp (1996), a uniform transportation cost is assumed and SPE conditions in transport costs are imposed on equilibrium conditions: Delivered prices are equal to the sum of producer prices and transport costs. In the present context, SPE conditions are $p_{M_i} = p_j + p_T$, $q_2 = p_2 + p_T$, where p_T denotes transport cost.

Table 2. Input-Output Table in the BN Model

	Region 1	Region 2	Transport	Consumption	Production
Region 1		p_1M_2		q_1C_1	p_1X_1
Region 2	p_2M_1			q_2C_2	p_2X_2
Transport	$p_2(t_2\text{-}1)M_1$	$p_1(t_1\text{-}1)M_2$		$p_2(t_2\text{-}1)C_2$	$P_T^{\#}$
Factor Input	wL_1	wL_2	wL_T		

#: $P_T = p_2(t_2-1)M_1 + p_1(t_1-1)M_2 + p_2(t_2-1)C_2$

$$Y = w(L_1 + L_2 + L_T) + \Pi_1 + \Pi_2 + \Pi_T \tag{6}$$

The resultant input-output table is shown in Table 2. It ensures that Walras' law holds. Walras' law is an important basic check on any equilibrium system: if it does not hold, a misspecification is usually present since the model of the economy in question violates the sum of individual budget constraints (Shoven and Whalley, 1992).

The KM model does not explicitly take the transport sector into account. The market clearing conditions of the KM model are given as:

$$C_1 + t_1M_2 = X_1, \quad t_2C_2 + t_2M_1 = X_2 \tag{7}$$

The equation (7) is rewritten in the well-known linear system of input-output equations:

$$\begin{bmatrix} X_1 \\ X_2 \end{bmatrix} = \begin{bmatrix} t_1 & 0 \\ 0 & t_2 \end{bmatrix} \begin{bmatrix} 0 & a_{12} \\ a_{21} & 0 \end{bmatrix} \begin{bmatrix} X_1 \\ X_2 \end{bmatrix} + \begin{bmatrix} 1 & 0 \\ 0 & t_2 \end{bmatrix} \begin{bmatrix} C_1 \\ C_2 \end{bmatrix}$$

or

$$\boldsymbol{X} = \boldsymbol{T_I A X} + \boldsymbol{T_C C} \tag{8}$$

where $\boldsymbol{T_I}$, $\boldsymbol{T_C}$ are the transportation factors of intermediate goods and of the final goods, respectively, and $\boldsymbol{A}$ is the technology coefficient matrix with elements defined by $\{a_{ij}\} = \{M_j / X_j\}$, $(j \neq i)$. The market clearing conditions in the KM model are summarised in Table 3. Since each region's production sector creates a burden for the transportation of its own production, the exportation of goods from region 1 to region 2, and vice versa, includes transport itself.

Table 3. Input-Output Relations in the KM Model (Quantity Base)

	Region 1	Region 2	Consumption	Production
Region 1		t_1M_2	C_1	X_1
Region 2	t_2M_1		t_2C_2	X_2
Factor Input	L_1	L_2		

Table 4. Input-Output Relation with Segrated Transport Sector in the KM Model

	Region 1	Region 2	Transport	Consumption	Production
Region 1		t_1M_2		C_1	X_1
Region 2	t_2M_1			t_2C_2	X_2
Transport	$(t_2\text{-}1)M_1$	$(t_1\text{-}1)M_2$		$(t_2\text{-}1)C_2$	$T^{\#}$
Factor Input	L_1	L_2	L_T		

#: $T = (t_2-1)M_1 + (t_1-1)M_2 + (t_2-1)C_2$

If the transport sector is segregated, the input-output relation must be changed as shown in Table 4. Taking the price system into account, we have the same table as the one depicted in Table 2. Thus, the KM model calculates a similar economic equilibrium as the one described by the BN model. However, it must be emphasised that in the KM model (equivalently, the iceberg model) the transport sector is not explicitly treated as one of the economic profit-making sectors.

The computation procedure stated in the previous section can be used to obtain equilibrium prices and quantities in the BM model, by changing steps 2 and 4. These steps may be modified to reflect the multiregional CGE character as follows:

2. Compute commodity prices:

$$p_j = w\,\alpha_j(w,1) + t_i p_i a_{ij}\ ; \quad j = 1,2,\ i = 1,2\ (i \neq j)$$

4. Calculate output quantities that meet market demands

$$\boldsymbol{X} = \boldsymbol{T_I A X} + \boldsymbol{T_C C}$$

3.2 An Interregional Trade Model

The horse truck or iceberg model cannot provide any information on the structure of the transportation factors because it is not based on any economic perspective of the transport sector's behaviour. Therefore it cannot measure the impact of improvements in transportation services or technology. The national CGE models almost invariably employ the Armington specification for modelling foreign trade. The idea has been generalised in a straightforward fashion in the multi-regional or multinational CGE models. The Armington specification is based on the heterogeneity of goods from different origins, and results in a kind of logistic (or gravity-type) model which realises cross-hauling trade. Miyagi and Honbu (1993, 1996) propose an interregional trade model utilising a CES production function which is consistent with the BN model described by the profit maximisation problem (4). The interregional trade model in the MH (Miyagi-Honbu) model is outlined as follows.

For the purpose of simplicity, we consider only one commodity which is sent from various locations, say, r = 1,2,...,R to a specific location s, where it is first merged into a demand pool, and then delivered to intermediate or final users. For comparison with the previous specification, we assume that intermediate good M_s is required in location s to produce X_s. The precise choice of locational goods X_{rs} is determined by profit maximisation subject to CES production technology for transportation:

$$\max \Pi_T(X) = p_{M_s}M_s - \sum_r q_{rs}X_{rs} \qquad \text{s.t. } M_s = X_s(X) = \left[\sum_r b_r X_{rs}^{\rho}\right]^{1/\rho} \tag{9}$$

where q_{rs} denotes the user price of X_{rs} and ρ the substitution parameter. Typical examples of the user price are defined by

$$q_{rs} = p_r \exp(\eta_{rs}) = p_r(1+\eta_{rs}) \tag{10}$$

so that the resultant cost function is leaner and more homogeneous with respect to commodity prices. Parameters η_{rs} denote *ad valorem* rates of transport costs or margins. Given the $\{p_{M_s}, M_s\}$, maximisation problem (9) is transformed into a minimisation problem.[2]

The behavioural model formulated above generates the following transport demand and cost functions for one unit of production in region s by putting $M_s = 1$ in (9):

$$X_{rs} = \frac{\theta_r q_{rs}^{-\sigma}}{\sum_r \theta_r q_{rs}^{1-\sigma}} p_{M_s} \tag{11a}$$

or

$$X_{rs} = \theta_r \exp(-\sigma\eta_{rs})\left[\frac{p_{M_s}}{p_r}\right]^{\sigma} \tag{11b}$$

and

$$p_{M_s} = \left[\sum_r \theta_r q_{rs}^{1-\sigma}\right]^{\frac{1}{1-\sigma}} \tag{12}$$

where $\sigma = 1/(1-\rho)$ and θ_r denote the elasticity of substitution for importing regions and calibration parameters, respectively. Equation (11a) provides us with an adaptable form for the statistical estimation of the elasticity of transport σ. Since the so-called trade conditions between regions r and s, p_{M_s}/p_r can be assumed to be constants for the interregional I-O data available, a regression analysis can be used to estimate σ. Putting a unit price p_{M_s} on the composite goods by a unit-cost function $c(q_{1s}, q_{2s}, \cdots, q_{rs}, \cdots, q_{Rs}, 1)$ enables demand for locational goods to be obtained by differentiating $c(q, 1)$ with respect to the price of the commodity in

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2 When the constraints are replaced by the total supply and demand at each location, this problem becomes the well-known Hichcock-Koopmans transportation problem, which induces the SPE equilibrium condition. The solution to these problems, however, leads to a rather unrealistic outcome: each location can only either import or export, and even then, only with a few other locations. Kim (1990) introduced the entropy constraint to represent the level of regional commodity flow crosshauling.

region r: [3]

$$t_{rs} = \frac{\partial c(q,1)}{\partial p_r} = \frac{\theta_r (q_{rs})^{1-\sigma}}{\sum_{r=1}^{R} \theta_r (q_{rs})^{1-\sigma}} \frac{p_{M_s}}{p_r} \tag{13}$$

Equation (13) may be called a trade function, which is different from the usual trade coefficient in the sense that it is a function of both transport costs and production prices. It should be noted that while (11) describes transport demands in terms of quantity, (13) represents them in monetary terms. Therefore, applying the expressions in (10) we get the following relations:

$$t_{rs} = \exp(\eta_{rs}) X_{rs} \text{ or } t_{rs} = (1 + \eta_{rs}) X_{rs}$$

Given that in the previous section the transport factor t_i is defined as corresponding to a coefficient $(1 + \eta_{rs})$ or a trade coefficient t_{rs} with a unit-importing good. It follows from (13) that

$$\sum_{r=1}^{R} p_r t_{rs} = p_{M_s}$$

This implies that p_{M_s} is a unit price of the composite good including transport costs. Interregional trades M_{rs} are given by

$$M_{rs} = t_{rs} X_s$$

In matrix form,

$$\boldsymbol{M} = \boldsymbol{T}[\boldsymbol{AX} + \boldsymbol{C}]$$

This corresponds to equation (8) in the case of $\boldsymbol{T}_I = \boldsymbol{T}_C = \boldsymbol{T}$. We can see that the behavioural model for the transport sector can be easily extended to include multi-commodity and multi-destinations as well.

4. APPLICATION RESULTS OF THE SCGE MODEL

4.1 Various SCGE Models

The Multiregional Variable Input-Output model proposed by Liew and Liew (1984) may be one of the first examples of CGE modelling at regional level.

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[3] The entropy production function proposed by Miyagi (1994) also generates the logistic type of the trade coefficient when it is applied to (9).

However, their approach has several weaknesses, such as inconsistencies between transport costs, activity levels in transport industries and final demand (Sasaki *et al.*, 1987; Roson, 1992). Miyagi (1995, 1996) proposed a SCGE model, paying special attention to the interactions between transportation, housing services and economic activities. This model is able not only to predict the changes in economic demand for freight and passenger transportation, and housing services, but also to measure the benefits arising from such changes. The SCGE model is based on the SCGE model developed by Miyagi and Honbu (1993) (called the MH model hereafter), which has essentially the same structure as the world trade model (Shoven and Whalley,1984; Whalley, 1985). Other SCGE models have been developed by Brocker (1992), Roson and Vianelli (1993), Roson (1995) and Mizokami (1996). All of those models except for Mizokami, adopt the Armington specification to realise multiregional cross-hauling trade. Mizokami uses the logit type of trade model. Both the MH and Brocker's models use nested CES functions (Sato, 1967) in a two-stage production process and utility function, and they both develop a similar computation procedure based on the sequential Newton-Raphson method. Roson use a two-stage substitution mechanism: the first level includes domestic and imported goods within the same industry (modelled by a CES function) and the second level includes all of the inputs of each industrial production process (modelled by a CRESH function). The Johanson method is used in the computation of equilibrium systems. All of the models assume that congested transportation systems do not affect the choice of final destination for the goods, either by the householder or the exporter/importer. This assumption simplifies the overall model structure and allows us to build a sequential approach to SCGE with joint modal split/traffic assignment models.

Miyagi (1996) propose a hierarchical structure where both interregional freight and passenger flows, being outputs of the SCGE model in the upper scheme, are assumed to effect changes in the share of transportation modes and the level of congestion, hence their use in shipping routes. When we try to model the interdependency of SCGE and transport congestion in a consistent way, variational inequality formulation is required. In that case a large amount of computation effort is inevitable.

4.2 Testing the MH model

The essential assumptions of the MH model are:

1. Each firm located in a certain region uses labour and capital only from that region. The model does not permit interregional labour migration or capital reallocation.
2. Walras' law holds in each region.
3. Workers move to high-wage firms within the region.

The technical merits of the SCGE model are that, unlike econometric models, it does not require the collection of a large amount of data and it can be applied to regions divided into arbitrary sizes. A collection of regions for which an input-output account is available is divided into several regions. Regional parameters for industrial production and household utilities can be identified by calibration

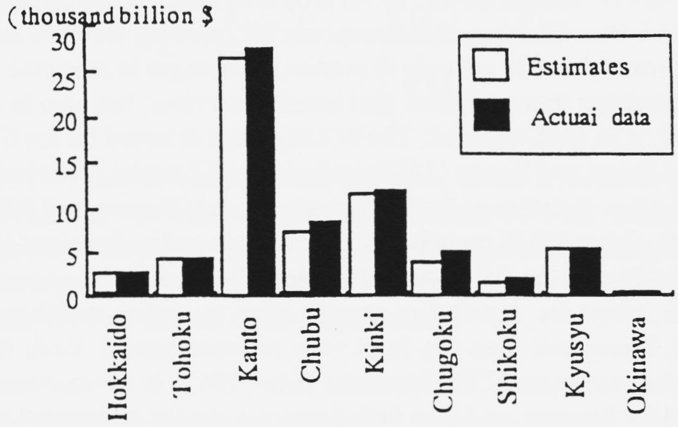

Figure 1. Comparison Between Estimated and Survey Results in Regional Production

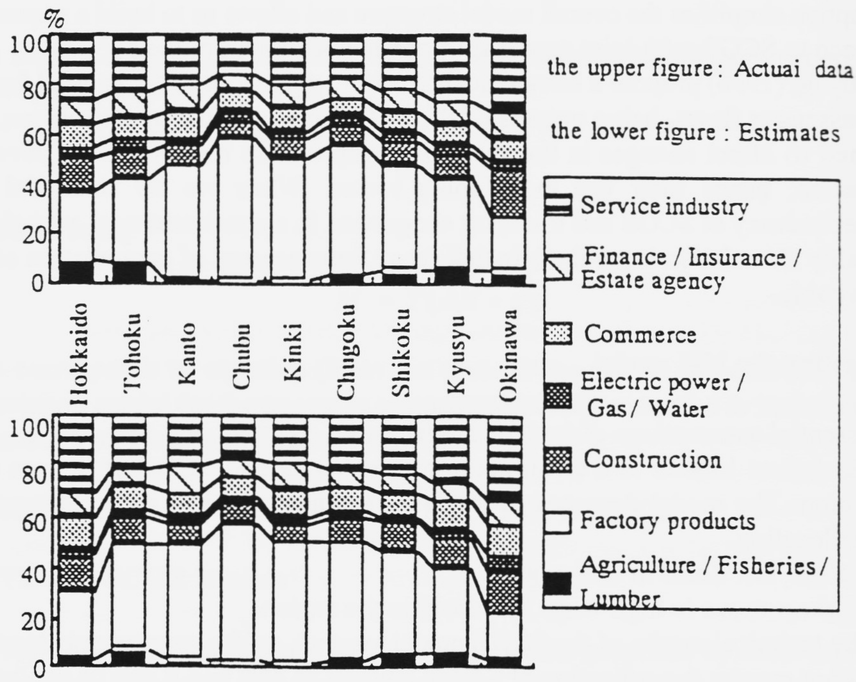

Figure 2. Comparison Between Estimated and Survey Results by Each Industrial Classification Regional Production

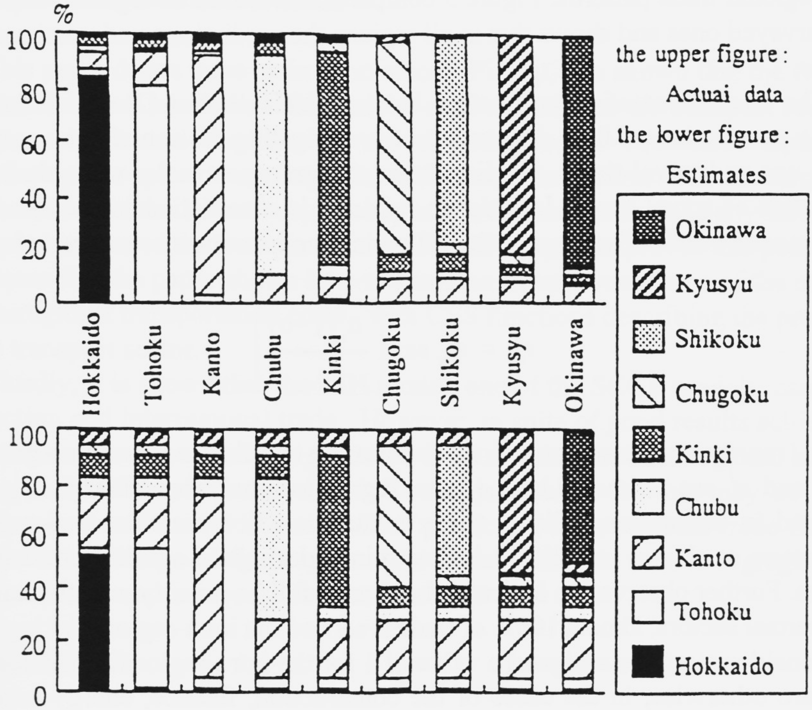

Figure 3. Comparison Between Estimated and Survey Results in Regional Exports

techniques in order to deduce the benchmark equilibrium data for the region in question. Parameters included in production, utility functions and trade coefficients are determined by calibration techniques.

Miyagi *et al.* (1996) applied the MH model to the Japanese interregional input-output tables consisting of nine major regions. The national figures were taken as the benchmark equilibrium data. Each region in the study is large enough to make the assumptions of the MH model a sensible proposition. In the study the original twenty-nine sectors are aggregated into the following: 1. Primary, 2. Manufacturing, 3. Construction, 4. Finance, 5. Energy-related Industries, 6. Commerce, 7. Services.

Parameters related to the elasticity of substitution used in CES production functions, CES utility functions and trade functions are quoted from the estimated results of Ogawa *et al.* (1992). Our estimates were highly compatible with the data provided by the survey. Figures 1 and 2 show the comparisons between the estimated and surveyed results in both regional production and industrial classification. All of the correlation coefficients show values of more than 0.99. To estimate interregional trade flows, it is necessary to deduce the relationship between transport make-up and interregional travel-time (or distance).

We first assumed that transport make-ups are proportional to interregional travel-times; however, we later found that the assumption failed to capture actual interregional trade patterns. Figure 3 compares the estimated regional exports with the surveyed ones and shows that in all regions the predictions underestimate actual values.

The coefficient of determination between estimated and actual interregional trade was very low, 0.012. As a result of investigating the actual data on transport make-ups and travel-times, we discovered that transport make-ups are almost flat regardless of travel-times. In order to reflect this observation in the interregional trade model, we finally adopted the following model with a new parameter α_s^i

$$t_{rs}^{i} = \varphi_{rs}^{i} \exp\left(\frac{\alpha_s^i(1-\sigma)}{c_{rs}}\right) \tag{14}$$

where i represents the sector and c_{rs} denotes the travel time between regions r and s. φ_{rs}^i and α_s^i are estimated by the usual regression analysis, although, φ_{rs}^i itself is not used in estimation. Since φ_{rs}^i is related to price variables and calibration parameters as shown in (11b), it is determined during the equilibrium calculation process. Further observation indicates that except for the primary, manufacturing and commercial sectors, almost 100% of trade is carried out intra-region. Taking this fact into consideration, we assigned a value of 1 for the intra-regional trade coefficient and zero otherwise, in the cases of the construction, finance, energy-related and service industries. The improved results are summarised in Table 5, where a coefficient of determination corresponding to each term is calculated for each commodity by each region. A value in parenthesis for interregional trades indicates the result when given values of intra-regional trades are included in the calculation of a coefficient of determination.

In contrast with the traditional belief that the CGE model cannot be used for forecasting purposes, these results seem to indicate that the CGE model can be an effective tool for estimating multiregional trade flow. When measuring the effects of transport improvements, the following expression was used:

$$t_{rs}^{i} = \varphi_{rs}^{i} \exp\left(\frac{\alpha_s^i(1-\sigma)}{c_{rs}}\left(\frac{c_{rs}^{/}}{c_{rs}}\right)\right)$$

where $c_{rs}^{/}$ represents the interregional travel times after improvements.

Table 5. Estimation Results by the MH Model

Commodity Group	Coefficient of Determination R^2
Production	0.994
Intermediate Goods	0.989
Final Demands	0.991
Gross Value Added	0.992
Interregional Trades	0.780 (0.970)

6. CONCLUDING REMARKS

This paper draws three main conclusions. Firstly, it is shown that the two basic approaches (the KM and the BN models) used to integrate the transport sector into the general economic equilibrium model both produce equivalent input-output relationships in spite of starting from different assumptions. The iceberg model, which is used in the KM model, is simple but, it does not include any information on the behaviour of the transport sector. The BN model improves this point.

Secondly, the paper shows how to combine travel-times - one of the measures of interregional transportation costs - with CES functions describing the production of the transport sector.

Thirdly, it is shown that the NIH model, one of the SCGE models, can predict production and interregional trade. However, in spite of good results achieved for production and value-added, the goodness-of-fit measure for inter-regional trades has not yet reached a satisfactory level. The major reason for this may be that the gravity-type trade model is incapable of predicting intra-regional trade flows. To improve the goodness-of-fit measure of the trade model, we need to segregate it into two parts; intra and inter-regional models.

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