DEVELOPMENT OF INTERNATIONAL TRADE MODEL TAKING ACCOUNT OF OCEAN CARRIERS' BEHAVIOR

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Abstract: Many previous spatial computable general equilibrium (SCGE) models cannot be applied for the evaluation of transport policies such as port development and tax/subsidy policy against transportation sectors, since they do not deal ocean freight rate and ocean carriers explicitly in the model. The model proposed here considers the behavior of ocean carriers and ocean freight rate. Input structure and sales amount of interregional transportation sector are estimated and new way to represent ocean freight rate is suggested. Multi-level function composed of CES and Leontief function is adopted for getting reliable parameters of production function for many industries. The model is applied to four major economic regions, they are Japan, USA, EU and Asia, and stability of the model is confirmed by numerical experiment.

Key Words: carriers' behavior, ocean freight rate, SCGE theory, trade estimation

1. INTRODUCTION

Traditional regional trade models, such as the input-output and economic based models and econometric models, can hardly contain detailed actual situations. Those models assume perfectly elastic supply and fixed prices. All results derive from exogenous change in demand. Alternatively, the spatial computable general equilibrium (SCGE) model, which is based on neoclassical theory, has been applied to regional analysis. It is distinguished by less than perfectly elastic supply and flexible prices. Strict assumptions can be relaxed. Many researcher pointed out fixed price models can be viewed as limiting cased of the more general equilibrium system.

According as the rapid growing of ocean carriers, they are getting more power to control the world trade. Using the international input-output tables in different time period, a growing path of ocean carriers is examined in the viewpoint of technical coefficient. Since major carriers are still growing, relatively small carriers will be kicked out from the field of worldwide trade in near future. Large carriers are very sensitive to the amount of transport demand and change their freight rate frequently. Carriers' surroundings are changing, for example, facilities of ports in the world are improved rapidly. In view above, when we forecast future world trade amount, following matters should be considered. Behavior of international carriers has to be regarded as one of the important active economic units. And then ocean freight rate, which reflects carrier's inputs exactly, should be taken into the model. Previous studies on SCGE model, however, are still poor to incorporate behavior of transportation firm and improvement of transportation facilities.

This study formulates a SCGE model including active behavior of ocean shipping carrier and applies it to estimation of trade amount among four major economic regions that are Japan, USA, EU and Asia. Input structure and sales amount of interregional transportation sector are estimated and new way to represent ocean freight rate is suggested. In section 2 the previous studies on trade prediction are introduced. In section 3 the SCGE model which includes behavior of carriers and their agreed freight rate is formulated. In section 4 the benchmark equilibrium data and the parameter values are described. In section 5 the model are applied to four major economic regions and influence of competitiveness among carriers and change of operational cost are discussed. Finally, section 6 is devoted to concluding remarks and the summary of remaining problems for future study.

2. OVERVIEW OF INTER-REGIONAL TRADE MODEL

2.1 Gravity Model

Gravity model represents flow by regional potential and distance between regions. Carey (1877) was the earliest study on gravity model. Zipf (1949) and Isard *et al.* (1960) improved the formulation and Wilson (1970) formulates the entropy model as a reform of it. Gravity model can easily predict flow in future by scarce data.

2.2 Input-Output Model

Isard (1951) composed inter-regional input-output table by input-output table in several interactive regions. Isard *et al.* (1960) and Leontief *et al.* (1963) improve inter-regional input-output analysis. Gravity model was integrated as an inter-regional trade factor. Polenske (1970) and Batten (1983) also improved the model. Oosterhaven (1984) introduced rectangular input-output table into inter-regional trade analysis in order to solve product-mix, which had been pointed as an important problem of input-output analysis. These models are consistent with a short-run Keynesian economy containing excess supplies of capital and labor. Technical coefficients and trade coefficients are to be fixed and interaction between income and consumption is not clarified in these models. Some econometric improvements should be introduced at a long-run analysis.

2.3 Spatial Price Equilibrium Model

Spatial price equilibrium model was developed by Samuelson (1952) and Takayama *et al.* (1964, 1971). Transportation cost is introduced into regional microeconomic model include demand function and supply function. Inter-regional trade amount is not well predicted compared with demand, supply and price. Since inter-regional demand and supply are calculated founded on price deterministically, intra-industry trade can not be represented. Batten *et al.* (1985) and Harker (1988) developed dispersed spatial price equilibrium models which include spatial interaction model such as gravity model and entropy model. Relationship between these models and behavioral theory, however, still is not clear. Miyagi (1990) introduce random utility theory consistent with behavioral theory into the model.

2.4 Spatial Computable General Equilibrium Model

SCGE model is based on a microeconomic general equilibrium framework. Production, consumption, prices of goods and factors, and quantities of goods transported are calculated endogenously. Firms are assumed to maximize profits, with product and factor markets typically assumed to be perfectly competitive. Profit maximization dictates that firms minimize costs, with factor demands generally responsive to factor prices. Households are assumed to maximize utility in their consumption decision, responding to price differences across goods. Finally, prices adjust in goods and factor markets to equate demands and supplies. This framework is theoretically consistent. SCGE model is the most proper to analyze influences of transportation environment change on international trade.

General equilibrium framework was theoretical until Scarf (1967, 1973) solved general equilibrium model computationally. Applications of CGE models to regional economics are started within a couple of decades because of the paucity of regional data. CGE models are data intensive. Liew *et al.* (1984), one of the pioneers of SCGE, evaluated a river improvement plan from the viewpoint of reduction of waterborne transportation cost. It is pointed out that relationship between behavior of transportation firm and transportation cost is inconsistent.

3. DEVELOPMENT OF SCGE MODEL

3.1 Framework

SCGE trade model developed here mainly refers to Whalley (1985). Ocean carrier sector, which takes charge of interregional transportation, is newly introduced. The model is developed based on following assumption.

- Revenue of interregional transport sector is composed of freight rate and insurance.
- Input structure of interregional transport sector is not stated in the input-output table. If it is assumed that the structure is involved in export amount, the structure is calculated by following process. Total output of interregional transport sector is distributed according to the input structure of transport sector, which is stated in the table.
- Each region has only one port. All trade goods are transported through the port.
- Production factors are capital and labor. Both are regionally immobile. Capital is not transferable across sectors. Labor can move to other sector in same region and it is assumed that wage rate is identical in the region.
- Firms, households and regional government exist in each region.
- Regional government levy direct and indirect taxes and all of them are to be fund of government expenditure.
- Goods that is classified to same commodity produced in different regions are regarded different goods. This is well-known Armington assumption.
- Only one interregional transport firm exists and its demand is derived demand of goods. Freight rate is suggested by interregional transport firm.
- Freight rate of each transport link is calculated considering competition. Interregional transportation freight rate roles numeraire.
- Intra-regional transportation freight rate is decided while profit of interregional transport firm is set to be zero.
- Final demand is composed of households' consumption, government consumption, fixed capital formation and increase in stocks.
- Indirect taxes and increase in stocks are given exogenously.
- Price of products in the rest of the world (ROW) is 1.

3.2 Production

CES and Leontief technology is adopted as a production function of industry j in region s, mainly due to the data availability. Each industry in each region has a CES value added function with capital and labor as substitutable primary input, and has fixed coefficient intermediate requirements in terms of composite goods. Fixed requirements of composites can be met by a substitutable mix of comparable domestic and imported goods. CES functions are used at choice of produced region for each fixed composite requirement. Value added function and production function are expressed as follows.

$$V_j^s = \nu_j^s \left[\varphi_j^s (K_j^s)^{(\sigma_j^s-1)/\sigma_j^s} + (1-\varphi_j^s)(L_j^s)^{(\sigma_j^s-1)/\sigma_j^s} \right]^{\sigma_j^s/(\sigma_j^s-1)} \tag{1}$$

$$X_j^s = \min\left(\frac{V_j^s}{a_{VAj}^s}, \frac{x_{1j}^s}{a_{1j}^s}, \ldots, \frac{x_{ij}^s}{a_{ij}^s}, \ldots, \frac{x_{Nj}^s}{a_{Nj}^s} \right) \tag{2}$$

$$X_j^s = \sum_i a_{ij}^s X_j^s + y_j^s \tag{3}$$

$$x_{ij}^s = a_{ij}^s X_j^s \tag{4}$$

$$a_{ij}^s = \left[\sum_r \beta_{ij}^{rs} (a_{ij}^{rs})^{(\theta_j^s-1)/\theta_j^s} \right]^{\theta_j^s/(\theta_j^s-1)} \tag{5}$$

$$\varphi_j^s = \left(\frac{K_j^s}{L_j^s} \right)^{1/\sigma_j^s} \Bigg/ \left[1 + \left(\frac{K_j^s}{L_j^s} \right)^{1/\sigma_j^s} \right] \tag{6}$$

$$\nu_j^s = (K_j^s + L_j^s) \Big/ \left[\varphi_j^s (K_j^s)^{(\sigma_j^s-1)/\sigma_j^s} + (1-\varphi_j^s)(L_j^s)^{(\sigma_j^s-1)/\sigma_j^s} \right]^{\sigma_j^s/(\sigma_j^s-1)} \tag{7}$$

$$p_j^s = \frac{1}{X_j^s} \left(\sum_i \sum_r q_{ij}^{rs} x_{ij}^{rs} + \rho_j^s K_j^s + \omega^s L_j^s \right) \tag{8}$$

$$x_{ij}^{rs} = a_{ij}^{rs} X_j^s \tag{9}$$

Equation 6 is derived from the first order conditions for cost minimization in each industry. Suppose price of every goods and factors are unity and profits of each industry is zero, Equation 7 is obtained. x_{ij}^{rs} is intermediate input goods i produced in region r, K_j^s is capital and L_j^s labor. Considering transportation cost, two type of price, that is producer price and consumer price, are introducd. Producer price of goods j in region s and consumer price of goods i produced in region r in region s are expressed as p_j^s and q_i^{rs} respectively. Consumer price q_i^{rs} is represented as the sum of producer price p_j^s and transportation cost c_{ij}^{rs} introduced later. Behavior of industry j in region s is formulated as minimization of cost. σ and θ are substitution elasticity. ρ_j^s is a rent of capital of industry j in s and ω^s is wage in region s.

3.3 Demand

Behavior of households is formulated as a utility maximization problem constrained with their income. The Cobb-Douglas utility function is adopted:

$$\max \quad U_k^s = \prod_i \left(\prod_r (y_{ik}^{rs})^{\beta_{ik}^{rs}} \right) \tag{10}$$

$$\text{s.t.} \qquad \sum_i \sum_r q_{ik}^{rs} y_{ik}^{rs} \le W_k^s$$

$$\sum_k \sum_i \sum_r \beta_{ik}^{rs} = 1$$

where y_{ik}^{rs} is consumption of goods i produced in region r at final demand sector k in region s, W_k^s is total consumption of final demand sector k in region s. Final demand sector k indicates 1: households consumption, 2: government consumption, 3: fixed capital formation and 4: increase in stocks.

Solve the maximization problem above, y_{ik}^{rs} is derived as follows.

$$y_{ik}^{rs} = \frac{\beta_{ik}^{rs} W_k^s}{q_{ik}^{rs}} \tag{11}$$

Suppose a transfer income of region s from other regions is TR^s and an indirect tax paid by industry j in region s is IT_j^s, total final demand G^s is represented as follows.

$$G^s = \sum_j \rho_j^s K_j^s + \omega^s \sum_j L_j^s + \sum_j IT_j^s + TR^s \tag{12}$$

Subtract taxes from G^S, disposable income of households W^S is deriverd.

$$W^s = (1 - \tau_K^s) \sum_j \rho_j^s K_j^s + (1 - \tau_L^s) \omega^s \sum_j L_j^s + TR^s \tag{13}$$

Here, τ_K^s and τ_L^s indicate corporate tax and income tax respectively.
Suppose savings rate of households in region s is σ^s, households consumption is

$$W_1^s = (1 - \sigma^s) W^s - \gamma_1^s W_4^s \tag{14}$$

and hence, government consumption is

$$W_2^s = \tau_K^s \sum_j \rho_j^s K_j^s + \tau_L^s \omega^s \sum_j L_j^s + \sum_j IT_j^s - \gamma_2^s W_4^s \tag{15}$$

where W_4^s is increase in stocks and γ_1^s and γ_2^s is weight parameter.

3.4 Savings and Investment

It is assumed that firms do not have internal reserve, therefore savings in region s is $\sigma^s W^s$ This is the funds for investments. Considering increase in stocks, the investment, that is fixed capital formation, is represented as follows.

$$W_3^s = \sigma^s W^s - \gamma_3^s W_4^s \tag{16}$$

3.5 Interregional Transportation

Relationship between transportation cost and intermediate input from interregional transportation firm to industry i in region r is

$$\sum_j \sum_k \sum_s \sum_i \sum_r (c_{ij}^{rs} x_{ij}^{rs} + c_{ik}^{rs} y_{ik}^{rs}) = \sum_i \sum_r \tau T_{ti}^r \tag{17}$$

$$c_{ij}^{rs} = m_i^r d^{rs} \tau \tag{18}$$

where c_{ij}^{rs} is a unit transportation cost of transaction x_{ij}^{rs}, τ is unit transportation fee, m_i^r is tonnage of unit price worth of goods i produced in region r, d^{rs} is distance between region r and region s, and T_{ti}^{r} is transportation service input from interregional transportation firm to industry i in region r at period t. Period t indicates 0: bench mark year and 1: future. Transportation service inputs in future are

$$T_{1i}^{r} = (N_1 - N_0)\,\delta_i^{r} + T_{0i}^{r} \qquad (19)$$

where N_t is total output of interregional transortation firm at period t and δ_i^r is proportion parameter. Besides, exports from industry i in region r to ROW in future is calculated by

$$E_{1i}^{r} = (M_1 - M_0)\,\varepsilon_i^{r} + E_{0i}^{r} \qquad (20)$$

where M_t is total output of ROW at period t and ε_i^r is proportion parameter.

Transportation cost between region r and region s c^{rs} is assumed identical irrespective of industry and it is represented as

$$c^{rs} = Tariff^{rs} - \phi \sum_i \sum_j m_i^r d^{rs}(x_{ij}^{rs} + y_{ik}^{rs}) \quad (r \neq s) \qquad (21)$$

$$c^{r'r'} = \frac{(\tau T - \sum_r \sum_{s(\neq r)} c^{rs})}{\sum_r (x_{ij}^{rr} + y_{ik}^{rr})} (\tau T - \sum_r \sum_{s(\neq r)} c^{rs}) \qquad (22)$$

where $Tariff^{rs}$ is a standard freight rate between region r and region s and ϕ (>0) is competition paremeter. It is derived from difference between producer price and consumer price in each transaction. The parameter ϕ cannot be obtained owing to data availability, therefore sensitivity of ϕ is observed in the numerical experiment.

4. NUMERICAL SPECIFICATION

The model is to be applied to four major economic regions, they are Japan, USA, EU and Asia. The basic source is the four regional international input-output table in 1990. This table is an accounting matrix including domestic transaction and interregional trade. Intermediate sectors of the table are reformed to demonstrate interregional transportation sector shown as Figure 1. Financial statements of three major ocean carriers in Japan, which are NYK, MO and KL, are referred and then input structure and sales amount of interregional transportation sector are estimated.

		Region 1 Goods 1 ·· Goods n	·· ·· ·· ··	Region m Goods 1 ·· Goods n	Transport
Region 1	Goods 1 : Goods n				
: :	: :				
Region m	Goods 1 : Goods n				
Transport					

Figure 1. Form of the input data

5. NUMERICAL EXPERIMENT

5.1 Port Related Cost

Suppose that port facilities are improved and port related costs, especially for large vessel are reduced in Japan. Unit transportation costs, τ, between Japan and EU and USA are discounted at ten-percent as Figure 2. Competition parameter ϕ set to zero. Goods are grouped in three divisions that are primary product, secondary product and tertiary product. Parameter m_i^r is set to 1 in case of primary and secondary products and is set to 0 in case of tertiary product, mainly due to the data availability.

Summarized some previous research works, elasticity parameters are given as Table 1. Other parameters derived from the input-output table are shown in Table 2 and 3. If transportation costs are changed, producer prices, wages, rent and transaction amount are changed in equilibrium systems. The rates of change of above variables are shown in Table 4 and 5. Producer price and wage rise in only Japan. Rent rises in Japan, EU and primary industry in USA. Transaction amounts are standardized by price in bench mark year, therefore Table 5 shows the change in quantity. Table 5 ignores a transaction of tertiary product, because it does not involve freight movement. As the result, trade amounts increase on the whole, especially from/to Japan. Ten-percent reduction in transportation cost lead to about one-percent increase in trade amount.

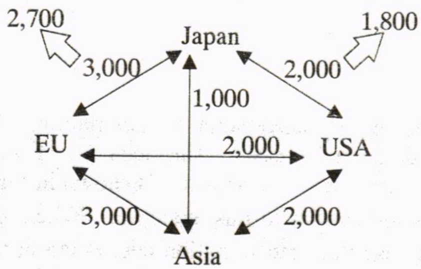

Figure 2. Change of Transportation Cost

Table 1. Parameters of elasticity

		σ_j^s	θ_j^s
Japan	Primary	0.6	0.6
	Secondary	0.9	1.2
	Tertiary	1.0	0.8
USA	Primary	0.6	0.9
	Secondary	0.9	1.0
	Tertiary	1.0	1.7
EU	Primary	0.6	0.9
	Secondary	0.9	1.2
	Tertiary	1.0	0.9
Asia	Primary	0.6	0.9
	Secondary	0.9	1.3
	Tertiary	1.0	1.0

Table 2. Savings rate, corporate tax rate and income tax rate

	σ^s	τ_K^s	τ_L^s
Japan	0.3338	0.0419	0.0310
USA	0.1526	0.1253	0.1100
EU	0.2319	0.1468	0.1468
Asia	0.3434	0.0071	0.0071

Table 3. Parameters of increase in stock

		γ_j^s
Japan	Households consumption	0.5834
	Government consumption	0.0917
	Fixed capital formation	0.3249
USA	Households consumption	0.6689
	Government consumption	0.1868
	Fixed capital formation	0.1443
EU	Households consumption	0.5917
	Government consumption	0.1967
	Fixed capital formation	0.2116
Asia	Households consumption	0.5702
	Government consumption	0.1088
	Fixed capital formation	0.3210

Table 4. Change of producer price, rent and wage (%)

		Producer price	Rent	Wage
Japan	Primary	0.0855	0.1153	0.1210
	Secondary	0.0531	0.1153	0.1210
	Tertiary	0.0886	0.1017	0.1210
USA	Primary	-0.0003	0.0415	-0.0209
	Secondary	-0.0227	-0.0115	-0.0209
	Tertiary	-0.0229	-0.0102	-0.0209
EU	Primary	-0.0001	0.0600	-0.0009
	Secondary	-0.0092	0.0329	-0.0009
	Tertiary	-0.0070	0.0191	-0.0009
Asia	Primary	-0.1015	-0.1114	-0.1287
	Secondary	-0.0800	-0.1157	-0.1287
	Tertiary	-0.1005	-0.1117	-0.1287

Table 5. Change of transaction amount (%)

	Intermediate Input				Final Demand			
	Japan	USA	EU	Asia	Japan	USA	EU	Asia
Japan	0.0410	0.9250	0.8110	-0.1123	0.0200	0.7617	0.9105	0.0808
USA	1.7210	0.0030	0.0010	0.0019	1.3102	0.0038	0.0119	0.1055
EU	1.1120	0.0090	0.0010	-0.1059	1.6182	0.0183	0.0031	0.0082
Asia	0.2190	0.0700	0.0020	-0.0209	0.2834	0.1166	0.0936	-0.0025
ROW	0.1100	-0.1800	-0.0990	-0.1171	0.1052	-0.0313	-0.0194	-0.0008

5.2 Freight Rate Discount

Suppose that freight rate competition is intensified in the interregional transportation. It is assumed that freight rate is reduced if transport demand increase. The behavior of whole system is observed, while ϕ is increased gradially from zero. One result is shown in Figure 3. Behaviors of trade amount among all regions are similar to this example. When ϕ is around fifteen, transaction amount is equal to the case that transportation cost is ten percent reduced. Although this system involves distortion at the transportation cost, behavior of results are stable. Since interregional trade amount is quite less than intra-regional trade amount, the change in the condition of interregional transportation does not affect whole system so much.

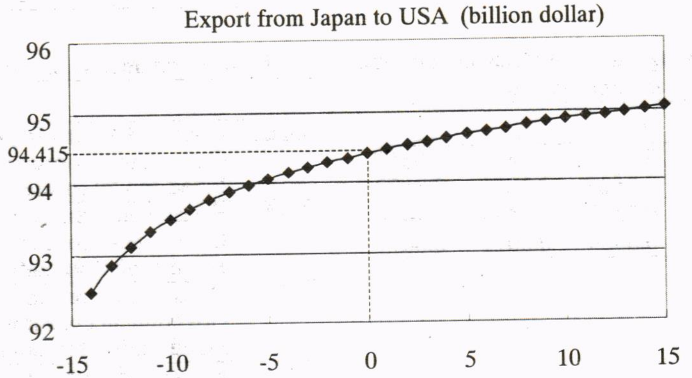

Figure 3. Sensitivity of competition paremeter ϕ

6. CONCLUSION

This paper presented SCGE model, which can discuss behavior of interregional transport sector as an independent economic unit and freight rate competition. The stability of the model is confirmed by numerical experiment. Change of price of goods, total output, GDP and trade amount in each region can be measured. Change of welfare in each region is also measurable. The numerical experiment considers only three goods in four major regions, however it is not the matter to apply this model to more goods and regions if necessary data is available. Ministry of International Trade and Industry in Japan has already composed input-output table of forty goods in four major regions. An analysis of trade of forty goods is practicable.

For more reliable model, it will be observed the change of freight rate and trade amounts and cleared the relationship of them. To clarify the meaning of value of competition parameter and relationship between parameter and actual situation are the further studies. And this model leaves much to be desired, for example a way of conversion from monetary amount into weight amount.

REFERENCES

Batten, D. F. (1983) **Spatial Analysis of Interaction Economics**, Kluwer-Nijhoff, Boston.

Batten, D. F. and B. Johansson (1985) Price adjustments and multiregional rigidities in the analysis of world trade, **Papers of the Regional Science Association**, 56, 145-166.

Buckley, P. H. (1992) A transportation-oriented interregional computable general equilibrium model of the United States, **The Annals of Regional Science**, 26, 331-338.

Conrad, K., and M. Schroder (1993) Choosing environmental policy instruments using general equilibrium models, **Journal of Policy Modeling**, 15, 521-543.

Harker, P. T. (1988) Dispersed spatial price equilibrium, **Environment and Planning A**, 20, 353-368.

Harrigan, F., and P. G. McGregor (1989) Neoclassical and Keynesian perspectives on the regional macroeconomy: A computable general equilibrium approach, **Journal of Regional Science**, 29, 555-573.

Harrigan, F., P. G. McGregor, J. K. Swales, and N. Dourmashkm (1992) Imperfect competition in regional labour markets: A computable general equilibrium analysis, **Environment and Planning A**, 24, 1463-1481.

Harrrgan F P. G. McGregor, and J. K. Swales (1996) The system-wide impact on the recipient region of a regional labor subsidy, **Oxford Economic Papers**, 48, 105-133.

Hertel, T. W. (1985) Partial vs. general equilibrium analysis and choice of functional form: Implications for policy modeling, **Journal of Policy Modeling**, 7, 281-303.

Hertel, T. W., and T D Mount (1985) The pricing of natural resources in a regional economy, **Land Economics**, 61, 229-243.

Hoffmann, S., S. Robinson, and S. Subramanian (1996) The role of defense cuts in the California recession: Computable general equilibrium models and interstate factor mobility, **Journal of Regional Science**, 36, 571-595.

Isard, W and W. Dean (1960) Gravity, Potential and Spatial Interaction Models, In **Method of Regional Analysis**, eds. W. Isard, MIT Press.

Jones, R., and J. Whalley (1989) A Canadian regional general equilibrium model and some applications, **Journal of Urban Economics**, 25, 368-404.

Jones, R., and J. Whalley (1990): Regional balance sheets of gains and losses from national policies, **Regional Science and Urban Economics**, 20, 421-435.

Kimbell, L. J., and G. W. Harrison (1984) General equilibrium analysis of regional fiscal incidence, In **Applied general equilibrium analysis**, eds. H. Scarf and J. Shoven, Cambridge University Press.

Koh, Y. K.. D. F. Schreiner, and H. Shin (1993) Comparisons of regional fixed price and general equilibrium models, **Regional Science Perspectives**, 23, 33-80.

Leontief, W. and A. Strout (1963) Multiregional input-output analysis, In **Structural Interdependence and Economic Development**, eds. T. Barna, McMillian, London.

Li, P., and A. Rose (1995) Global warming policy and the Pennsylvania economy: A computable general equilibrium analysis, **Economic Systems Research**, 7, 151-171.

Liew, L. H. (1984) "Tops-down" versus "bottoms-up" approaches to regional modeling, **Journal of Policy Modeling**, 6, 351-367.

Liew, C. K. and C. J. Liew (1984) Measuring the development impact of a proposed transportation system, **Regional Science and Urban Economics**, 14, 175-198.

McGregor, P. G., J. K. Swales, and Y. P. Yin (1996) A long-run interpretation of regional input-output analysis, **Journal of Regional Science**, 36, 479-500.

Miyagi, T. (1997) Resent developments in Multiregional general equilibrium modelling: Economic-transportation interaction models, **Studies in Regional Science**, 27-1, 213-227.

Morgan. W.. J. Mutti, and D. Rickman (1996) Tax exporting, regional economic growth, and welfare, **Journal of Urban Economics**, 39, 131-159.

Norrie K H and M B Percy (1983) Freight rate reform and regional burden: A general equilibrium analysis of Western freight rate proposals, **Canadian journal of Economics**, 16, 325-49.

Oosterhaven, J. (1984) A family of square and rectangular interregional input-output tables and models, **Regional Science and Urban Economics**, 14.

Partridge, M. D. and D. S. Rickman (1998) Regional computable general equilibrium modeling: A survey and critical appraisal, **International Regional Science Review**, 21-3, 205-248.

Polenske, K. R. (1970) An empirical test of interregional input-output models: Estimation of 1963 Japanese production, **American Economic Review**, 60, 76-82.

Samuelson, P. A. (1952) Spatial price equilibrium and linear programming, **American Economic Review**, 42, 283-303.

Scarf. H. (1967) The approximation of fixed points of a continuous mapping, **SIAM Journal of Applied Mathematics**, 15, 1328-1343.

Scarf. H. and T. Hansen (1973) **The computation of economic equilibria,** Yale University Press.

Shoven, J. B. and J. Whalley (1992) **Applying General Equilibrium**, Cambridge University Press.

Takayama, T. and Judge, G. G. (1964) Equilibrium among spatial separated markets. A reformation, **Econometrica**, 32, 510-524.

Takayama, T. and Judge, G. G. (1971) **Spatial and temporal price and allocation models**, North-Holland, Amsterdam.

Waters, E., D. W. Holland, and B. A. Weber (1997) Economic impacts of a property tax limitation: A computable general equilibrium analysis of Oregon's Measure 5, **Land Economics**, 73,72-89.

West, G. R. (1995) Comparison of input-output, input-output econometric and computable general equilibrium impact models at the regional level, **Economic Systems Research** 7, 209-227.

Whalley, J. (1985) **Trade Liberalization Among Major World Trading Areas**, MIT Press.

Wilson, A. G. (1970) Interregional commodity flows: entropy maximizing approaches, **Geographical Analysis**, 2, 255-282.