INSTITUTE OF DEVELOPING ECONOMIES

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DISCUSSION PAPER No. 81

Transport Sector and Regional Price Differentials: A SCGE Model for Chinese Provinces

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December 2006

Abstract

With regression formulas replaced by equilibrium conditions, a spatial CGE model can substantially reduce data requirements. Detailed regional analyses are thus possible in countries where only limited regional statistics are available. While regional price differentials play important roles in multi-regional settings, transport does not receive much attention in existing models. This paper formulates a spatial CGE model that explicitly considers the transport sector and FOB/CIF prices. After describing the model, performance of our model is evaluated by comparing the benchmark equilibrium for China with survey-based regional I-O and interregional I-O tables for 1987. The structure of Chinese economies is summarized using information obtained from the benchmark equilibrium computation. This includes regional and sectoral production distributions and price differentials. The equilibrium for 1997 facilitates discussion of changes in regional economic structures that China has experienced in the decade.

Keywords: SCGE model, FOB/CIF prices, transport sector, Chinese regional economy.
JEL classification: C68, O5, R13, R15.

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1 Introduction

Macro-econometric models have traditionally been considered to be the major analytical tool for making practical evaluations of economic policies, even in multi-regional contexts. However, it is generally difficult to obtain sufficient statistical data to estimate model parameters that cover relatively smaller regions. This is particularly true when developing economies are studied; reliable regional statistics are difficult to obtain. In such cases, CGE models are the first choice due to their smaller data requirements; many regression equations in their macro-econometric counterpart may be replaced by equilibrium conditions based on microeconomic theory.[1]

From a policy maker's viewpoint, a national-level CGE model is insufficient because it cannot describe regional disparities that a policy can bring. This is especially true in relatively large countries, like China that has many provinces. Thus multi-regional or spatial CGE models have attracted much attention in recent years.[2] Such studies include pioneering works by Dixon (1982) who developed a top-down model that decomposes national variables into regional, and Whalley (1982) who evaluated the impact of multi-lateral trade agreements by linking national CGE models through international trade. Liew and Liew (1984), whose MRVIO model considers price differentials due to transportation within a multi-regional I-O model, can also be regarded as one of ancestors.

Progress in information technology has made large-scale multi-national analyses easier. The Global Trade Analysis Project (GTAP) represents such work.[3] It is unique in the sense that it also provides extensive sets of standardized data on national economies. Authors like Francois *et al.*(1996) and Kawasaki (1998) employ the GTAP for evaluating trade agreements in multi-national frameworks. While the GTAP's database is based on existing national I-O tables and trade matrices, Horridge *et al.*(2005) developed a bottom-up model called TERM (The Enormous Regional Model). It is used to assess the regional impacts of an economic event in a country, and is based on non-survey regional I-O tables and an interregional trade matrix. These are derived

[1] See Shoven and Whalley (1992) for basics of CGE models and their earlier development. Newer developments are reviewed in Ginsburgh and Keyzer (1997).

[2] No essential distinction between regions and countries is possible. While traditional international economics precludes factor mobility, barriers among countries are lowered due to free trade agreements that lead to emergence in the global market.

[3] Developed by the World Trade Analysis Center in 1992. See http://www.gtap.agecon.purdue.edu/ for details.

from the national table and a gravity-type formula, respectively.

Transport conditions, fares in particular, are a source of regional price differentials. However, existing studies tend to regard the transport sector as an ordinary service sector. To distinguish FOB and CIF prices that are consistent with spatial price equilibrium (SPE), it is necessary to consider the unique characteristics of the transport sector. Harker (1987) did this by introducing transport firms and networks into Takayama and Judge's (1971) framework. This made the SPE model a specific antecedent to development of the SCGE model.

In the early 1990's, several spatial applications of the CGE model appeared. Buckley (1992) proposed an interregional CGE model that explicitly considered transportation and wholesale services, where a nested production function is employed to combine commodities from various origins into a "composite good". This then distributed over demand sectors through a "clearing house". However, such composition is based on a Cobb-Douglas formula, and trade coefficients in monetary terms are thus fixed irrespective of regional price changes. Further, it is not clear how the *ad valorem* transport cost is determined.

Miyagi and Honbu (1993) applied the framework of Whalley's (1985) world trade model to the multi-regional context, and proposed a simple prototype SCGE model based on nested CES production and utility functions. In this model, regional price differentials are considered, but transport costs are charged by imaginary transport firms who require no resource for producing transport services. Further, equilibrium consumer prices are determined from average FOB prices weighted by trade coefficients. This is inconsistent with other parts of the model where separate CIF prices are calculated.

In recent years, many multi-regional CGE models have been developed for assessing various regional policies. The majority of them do not explicitly consider the transport sector or any distinction between FOB and CIF prices. (See Kim and Kim (2002) for an example.) In one exception, Lofgren and Robinson (2002) tried to implement a spatial network into Mozambique's SAM-based CGE model. They sought to analyze the impact of higher world prices and reduced domestic transport costs. Their model assumes a hub and spoke type network and is applicable to poor developing countries that have relatively simple trade structures. In their case study, they showed that transport cost changes affect the economy through changes in input coefficients for transport services, but these changes occur unilaterally without investing resources in the transport sector.

Bröcker and Schneider (2002) used a multiregional CGE model to quantify regional welfare effects arising from increasing trade flows between Austria and its eastern neighbors after opening the East European market. In their model, transport costs follow Samuelson's iceberg model; the consistency of their calibration is thus questionable because the transport sector in the national I-O table reflects actual costs. The fact that interregional transfers are neglected in their model makes clearing of national macro economies questionable.

Using a national input-output table and limited regional statistics, Ando and Shibata (1997) developed a multi-regional model of the Chinese economy that can estimate regional outputs, prices, and interregional trade. The main part of the model comprises parallel non-survey computations to derive two sets of regional input-output tables, nominal and real, which are consistent with the national table. Domestic trade is determined through a doubly constrained gravity model based on regional imbalances obtained from input-output computations. Though operational, the use of practical schemes such as the RAS and Fratar adjustments weakens the economic implications of the model even though solutions to the set of endogenous variables comparable to CGE models can be obtained.

Ando (1996) revised this model based on economic behaviors of individual agents such as the firms, households, and the government. Transport firms are explicitly considered in calculating equilibrium market prices under the given transport network. Though a theoretical framework for an operational SCGE model was proposed, empirical tests are lacking. Reliable survey-based data for checking model performance were unavailable then. With publication of the first survey-based interregional I-O table for China by Ichimura and Wang (2003, hereafter abbreviated as IW), tests of the model have become possible for the study year of 1987.

The present paper includes the following purposes: (1) To develop a SCGE model that explicitly considers the transport sector and regional price differentials, (2) To evaluate performance of this model by comparing benchmark equilibrium results with the survey-based data for China in 1987,[4] and (3) To illustrate the characteristics of Chinese regional economies including industrial composition, price differentials, and disparities in utilities.

[4] 1987 is considered as the base year for benchmark calculations since the IW and the Beijing tables (both for the year 1987) are the only survey-based I-O tables available as of 2004.

The SCGE model is formulated in Section 2. This is followed in Section 3 by a discussion of computational procedures used to reach equilibrium. Section 4 includes examination of the validity of the model by making comparisons with survey-based data. Some empirical findings on Chinese regional economies are provided in Section 5. These are derived from benchmark equilibria for 1987 and 1997. Concluding remarks are given in Section 6.

2 The SCGE Model

China is considered to be the primary study area for this paper. However, the model formulated here is general enough to apply to other countries. Of course, some assumptions reflect the unique statistical environment of China. In this section, the basic assumptions of the model are given, and these are followed by behavioral descriptions of individual economic agents. Equilibrium conditions of the entire system are then summarized.

2.1 Basic Assumptions

(1) **Seven industrial sectors.** Industrial sectors and the goods or services they produce are classified into seven categories: (1) Agriculture (Agr.), (2) Manufacturing (Mfg.), (3) Resources and Energy (R&E), (4) Construction (Cnst.), (5) Transport and Communication (T&C), (6) Commercial Trade (Com.), and (7) Services (Srv.). This classification is consistent with the IW table and facilitates comparisons in Section **4.3**.

(2) **Twenty-nine regions.** Mainland China is divided into 29 provinces, including five autonomous regions and three nationally governed municipalities as shown in Table 1.[5] The rest of world may be considered an extra region.

(3) **Competitive trade.** Commodities are traded among domestic regions as well as with foreign countries. They are identical in quality irrespective of origin, including foreign imports.

(4) **Two factors of production.** Two production factors of labor and physical capital are considered, and their mobility across national borders is precluded.

[5]Hainan Province separated from Guangdong Province in 1988, and Chongqing Municipality separated from Sichuan Province in 1997. The 29 regions reflect the status quo in 1987. Correspondence with the seven regions employed in the IW table is also shown for later reference.

Table 1: Regional Classification and Codes.

The Model's 29 Regions	IW's Seven Regions
Liaoning(6), Jilin(7) ,Heilongjiang(8)	Dongbei(DB)
Beijing(1), Tianjin(2), Hebei(3), Inner Mongolia(5), Shandong(F)	Huabei(HB)
Shanghai(9), Jiangsu(A), Zhejiang(B)	Huadong(HD)
Fujian(D), Guangdong(J)	Huanan(HN)
Shanxi(4), Anhui(C), Jiangxi(E), Henan(G), Hubei(H), Hunan(I)	Huazhong(HZ)
Shaanxi(P), Gansu(Q), Qinghai(R), Ningxia(S), Xinjiang(T)	Xibei(XB)
Guangxi(K), Sichuan(L), Guizhou(M), Yunnan(N), Tibet(O)	Xinan(XN)

(5) **Five types of economic agents.** There are five types of agents: (1) non-transport firms, (2) transport firms, (3) households, (4) investors, and (5) the government.

(6) **Transport demand.** Demand for transport services consists solely of derived demand that accompanies purchases of other commodities.[6] All shipping costs are paid at the origin.

(7) **Three types of regional expenditures.** The regional expenditures are divided into three categories: (1) household consumption (HHC), (2) capital formation (Inv.), and (3) government expenditure (Gov.).

2.2 Behavior of Economic Agents

(1) Non-transport firms

The aggregate production function of sector j in region s combines the two factor inputs of labor L_j^s and industrial capital stock K_j^s of sector j in region s with the intermediate inputs x_{ij}^{rs} of commodity i produced in region r.

$$X_j^s = \prod_{i \neq 4,5} (\sum_{r(e)} x_{ij}^{rs})^{\alpha_{ij}^s} (K_j^s)^{\alpha_{Kj}^s} (L_j^s)^{\alpha_{Lj}^s}, \tag{1}$$

where the symbol $r(e)$ indicates that the summation includes foreign countries (region e) as well as domestic regions. [7]

[6]This can be justified by the fact that Chinese statistics only list freight transport for the transport sector, and passenger transport is combined with other services. Communication activities, which constitute 8.6% of transport products in 1987, are included in the transport sector. However, postal services then command 86.6% of all communications. Since the cost of business communications can be regarded as a part of transport costs, only fractional demand for personal communications is left as primary demand.

[7]If dependable data of public capital stock, $\bar{K}_G^s$, in region s are available, $(\bar{K}_G)^{\alpha_{Gj}^s}$ can be multiplied to (1) as the Hicksian augmentation factor, with region and sector specific parameter α_{Gj}^s.

Sector 5 is excluded from the product. From *Basic Assumption* (6), demands for its services are derived solely from inputs of other commodities. For Sector 4, Chinese input-output tables regard all of construction outputs as a part of fixed capital at the location. Thus these outputs are non-tradable by definition. The fact that intermediate inputs appear as sums over production sites reflects a model configuration that assumes identical commodities. The following is further assumed for factor mobility:

Assumption 1 *All factors are immobile across regions and industries.*[8]

As a whole, firms face the problem of choosing a combination of $\{x_{ij}^{rs}, K_j^s, L_j^s\}$ that will maximize their profit function.

$$\pi_j^s = p_j^s X_j^s - \sum_{i \neq 4,5} q_i^s \sum_{r(e)} x_{ij}^{rs} - \rho_j^s K_j^s - \omega_j^s L_j^s, \tag{2}$$

where in region s, p_j^s is the producer's (FOB) price of commodity j, and q_i^s are the market price of commodity i. ρ_j^s and ω_j^s are the capital rent and the wage rate, respectively.

First-order conditions to problem (2) can be written as follows:

$$\alpha_{ij}^s = \frac{q_i^s \sum_r x_{ij}^{rs}}{p_j^s X_j^s}, \quad \alpha_{Kj}^s = \frac{\rho_j^s K_j^s}{p_j^s X_j^s} \quad \text{and} \quad \alpha_{Lj}^s = \frac{\omega_j^s L_j^s}{p_j^s X_j^s}. \tag{3}$$

Parameters in production functions, $\alpha_{ij}^s, \alpha_{Kj}^s$ and α_{Lj}^s are nothing but regional input coefficients measured in monetary terms. The following is assumed for these parameters:

Assumption 2 *The production function is linearly homogeneous, and the same parameters are shared by all regions, i.e.,* $\alpha_{ij}^s = \alpha_{ij}$ *and* $\sum_{i \neq 4,5} \alpha_{ij} + \alpha_{Kj} + \alpha_{Lj} = 1$.

Under linear homogeneity, the Cobb-Douglas production function is consistent with the input-output system. Substitution of physical inputs is still possible even under the uniform technology assumption. Suppose a_{ij}^{rs} denotes the interregional input coefficient in physical terms. Then assuming competitive import, the intermediate physical input can be written as follows:

$$x_{ij}^{rs} = a_{ij}^{rs} X_j^s = t_i^{rs} a_{ij}^s X_j^s,$$

[8] This assumption can easily be modified to facilitate mobile capital and/or labor.

where t_i^{rs} and a_{ij}^s are respectively the interregional trade coefficient and the regional input coefficients. Here, definition of the trade coefficient includes foreign import such that $\sum_{r(e)} t_i^{rs} = 1$. The first expression in (3) can then be simplified.

$$\alpha_{ij} = \frac{q_i^s \sum_{r(e)} t_i^{rs} a_{ij}^s X_j^s}{p_j^s X_j^s} = \frac{q_i^s}{p_j^s} a_{ij}^s, \quad \text{for} \quad \forall s$$

First-order conditions can thus be interpreted with the following conditions on regional input coefficients in physical terms, including those concerning non-tradable factor inputs.

$$a_{ij}^s = \frac{p_j^s}{q_i^s} \alpha_{ij}, \quad a_{Kj}^s = \frac{p_j^s}{\rho_j^s} \alpha_{Kj}, \quad \text{and} \quad a_{Lj}^s = \frac{p_j^s}{\omega_j^s} \alpha_{Lj}. \tag{4}$$

(2) Households

The source of income for households is the gross regional domestic product V^s comprising rent and wage payments:

$$V^s = \sum_j \rho_j^s K_j^s + \sum_j \omega_j^s L_j^s, \tag{5}$$

where regions are assumed to be closed in terms of factor income.

Assumption 3 *Firms and their capital are owned by the households of the region where they are located.*

Household disposable income W_D^s is obtained after subtracting taxes from and adding net income transfer TR^s to the gross income of domestic sources, V^s:

$$W_D^s = (1 - \tau_K) \sum_j \rho_j^s K_j^s + (1 - \tau_L) \sum_j \omega_j^s L_j^s + TR^s. \tag{6}$$

The following is assumed regarding the tax rates:

Assumption 4 *Uniform tax rates τ_K and τ_L respectively apply to capital and wage incomes.*[9] *Net income transfer to region s, TR^s, is tax-exempt.*

[9] For convenience, τ_K is called "corporate tax", and τ_L "income tax". Capital income may be considered as operating surplus before paying dividends. Under *Assumption 3*, whether the corporate tax is levied on firms or on households is not important.

The aggregate utility of households in region s is considered to depend on the amount of commodity i produced in region r consumed in s, y_{i1}^{rs}, and the present value of composite future consumption, C_F^s. Suppose that household aggregate utility is described by the nested Cobb-Douglas function shown below:

$$U^s = [\prod_{i \neq 4,5} (\sum_{r(e)} y_{i1}^{rs})^{\beta_{i1}}]^{1-\sigma^s} [C_F^s]^{\sigma^s}. \tag{7}$$

The problem then is to choose $\{y_{i1}^{rs}, C_F^s\}$ that maximize (7) under the budget constraint

$$\sum_{i \neq 4,5} q_i^s \sum_{r(e)} y_{i1}^{rs} + C_F^s \leq W_D^s. \tag{8}$$

Denoting the Lagrange multiplier associated with (8) by λ^s, first-order conditions are obtained for the problem as follows:

$$(1-\sigma^s)\beta_{i1}^s = \frac{\lambda^s q_i^s \sum_r y_{i1}^{rs}}{U^s} \quad \text{and} \quad \sigma^s = \frac{\lambda^s C_F^s}{U^s}. \tag{9}$$

When households are rational, their disposable income is fully allocated to present commodities and future consumption. This will be written as

$$W_D^s = \sum_{i \neq 4,5} q_i^s \sum_r y_{i1}^{rs} + C_F^s = \frac{U^s}{\lambda^s}[(1-\sigma^s) \sum_{i \neq 4,5} \beta_{i1}^s + \sigma^s]. \tag{10}$$

Parallel to the production function, linear homogeneity of the utility function is assumed.

Assumption 5 *The utility function is linearly homogeneous with respect to the present commodities, and the same preference structure, except for the rate of time preference σ^s, applies to all the regions, i.e., $\beta_{i1}^s = \beta_{i1}$ and $\sum_{i \neq 4,5} \beta_{i1} = 1$.*

From eq. (10), λ^s implies the average utility of disposable income. Since σ^s can be interpreted as the marginal propensity to save, $W_1^s = (1-\sigma^s)W_D^s$ denotes the part of disposable income spent on present commodities. Consumption of commodity i by households in s can then be written as follows:

$$y_{i1}^s = \frac{\beta_{i1} W_1^s}{q_i^s}. \tag{11}$$

(3) Savings and investments

The relation between investment and government expenditure is shown in Figure 1. In the national I-O table of China, fixed capital formation W_2 is defined as the sum of firm investment I and public investment I_G, where the latter is financed by tax revenue T and government bonds B. Government bonds are assumed to occupy a fraction κ_S of total savings given by $S \equiv \sum_s \sigma^s W_D^s$. Although some bonds may be issued to cover deficits, here all bonds are assumed to be intended for public investment. κ_T denotes the portion of tax revenue spent on public investment, the amount of public investment becomes $I_G = \kappa_S S + \kappa_T T$.

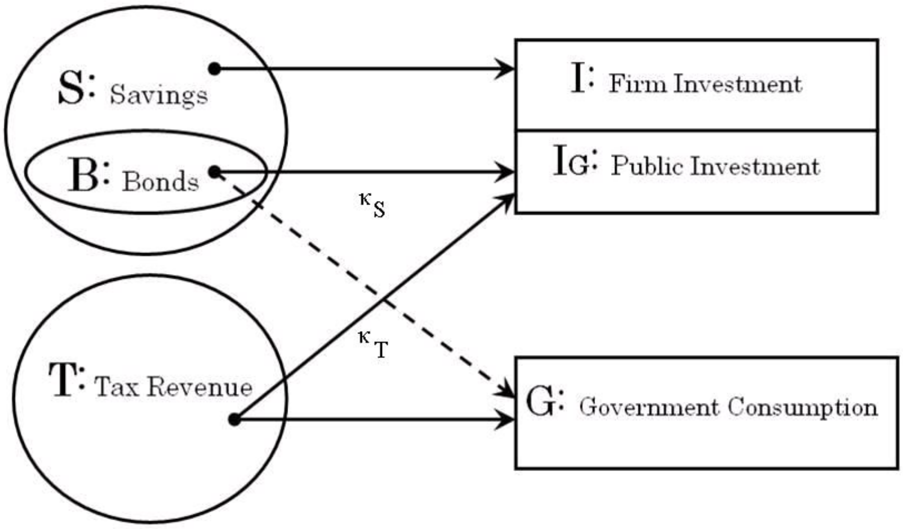


Figure 1: Financial Flows Related to Tax and Savings.

Since there is no need to reinvest savings or tax revenues in the region where they are made, fixed capital formation in region s can be described by the use of suitable distribution ratios as follows:

$$W_2^s = \sum_j h_j^s (1 - \kappa_S) S + g^s (\kappa_S S + \kappa_T T), \tag{12}$$

where h_j^s is the distribution ratio of firm investments to sector j in region s, and g^s is the same of public investment to region s. While public investment is given by government policy, firm investments may be expressed as a function of the capital rent revenue, ρ_j^s, that is expected from unit investment in the combination, j and s. The following formula provides one possible function:

$$h_j^s = \frac{\exp(\gamma\rho_j^s)}{\sum_s \sum_j \exp(\gamma\rho_j^s)}.$$

(4) Government

The role of the government in this model is to collect corporate and income taxes, and determine the amount of government expenditure.[10] Tax revenue T^s in region s can be written as

$$T^s = \tau_K \sum_j \rho_j^s K_j^s + \tau_L \sum_j \omega_j^s L_j^s. \tag{13}$$

Here, the national tax revenue $T = \sum_s T^s$ is completely used on government expenditure W_3 and public investment I_G.

The government may freely redistribute W_3 over regions regardless of regional tax revenues. Thus a proper distribution function is needed. For example, if regional populations $\bar{N}^s$ are known, distributing W_3 in accordance with population ratio $n^s = \bar{N}^s / \sum_s \bar{N}^s$ may provide a set of first approximations:

$$W_3^s = n^s((1 - \kappa_T) \sum_s T^s) \tag{14}$$

For simplicity, $\kappa_S = \kappa_T = 0$ is assumed in the computations that follow.

Assumption 6 *Public investment is fully financed by construction bonds, and tax revenues are spent solely on government consumption.*

It is likely that both capital formation ($j' = 2$) and government expenditure ($j' = 3$) have their own purchasing customs, similar to steel and cement in building construction. Nevertheless, substitutions are still possible among commodities and their origin. If the government and investors possess some utility function relative to their purchases, and *Assumption 5* applies to the parameters β_{i2}^s and β_{i3}^s, commodity compositions of these two expenditures may also be determined as follows:

$$y_{i2}^s = \frac{\beta_{i2} W_2^s}{q_i^s} \quad \text{and} \quad y_{i3}^s = \frac{\beta_{i3} W_3^s}{q_i^s}. \tag{15}$$

[10] The net income transfers TR^s may also be determined by the government. However, they comprise two segments: One is transfer from foreign countries, and the other is associated with investment and government expenditure. While the former need a separate distribution rule, their funding is basically independent of tax revenues.

(5) Transport firms

Under *Basic Assumption* (6), all demands of this sector are derived from purchases of other commodities. Non-transport firms can determine output levels to maximize their profits, but transport firms are required to provide transport services that are needed to fulfill demands of other commodities and services. Thus they seek to minimize costs given the level of services.

For convenience, the following assumption concerning transport cost payments is introduced:

Assumption 7 *Transport costs are paid at the origin of shipment. This scheme also applies to the purchases by transport firms themselves. However, these firms do not recognize imputed costs that accompany their own purchases from regions where they are located.*[11]

Suppose c_i^{sr} denotes the cost of transporting a unit of commodity i from region s to region r. *Assumption 7* also applies to foreign trade, so local transport firms would receive fares c_i^{se} for service to the exporting port nearest to region s. Likewise it can be assumed that domestic portions of fares associated with imports would be collected by foreign shippers. The total transport demands originating in region s, in monetary terms, would be given by the LHS of the following formula:

$$\sum_{i \neq 4,5} \sum_{r} c_i^{sr} (\sum_{j} x_{ij}^{sr} + \sum_{j} y_{ij}^{sr}) + \sum_{i \neq 4,5} c_i^{se} F_i^s \leq p_5^s X_5^s \tag{16}$$

Under *Assumption 7*, these demands would be fulfilled by transport firms in region s, whose monetary output $p_5^s X_5^s$ must exceed these demands. The cost to provide services required may then be written as follows:

$$C_5^s = \sum_{i \neq 4,5} q_i^s \sum_{r(e) \neq s} x_{i5}^{rs} + \sum_{i \neq 4,5} p_i^s x_{i5}^{ss} + \rho_5^s K_5^s + \omega_5^s L_5^s. \tag{17}$$

The production function of transport firms is also given by (1). The problem is to choose $\{x_{i5}^{rs}, K_5^s, L_5^s\}$ that minimize the total cost (17) while satisfying the transport demands (16).

The first-order condition of intermediate inputs may be written with the Lagrange multiplier μ^s associated with (16) as follows:

$$a_{i5}^s = \frac{\mu^s p_5^s}{q_i^s} \alpha_{i5} = \frac{\mu^s p_5^s}{p_i^s + \mu^s c_i^{ss}} \alpha_{i5}. \tag{18}$$

[11] Transport costs that accompany intra-regional purchases of transport firms are paid to transport firms themselves. Thus they can be deducted from the cost of producing the transport services required.

The first expression represents purchases from other regions, $x_{i5}^{rs}(r \neq s)$; the second represents intra-regional purchases. The relation between producer and market prices is derived from (18):

$$q_i^s = p_i^s + \mu^s c_i^{ss} \tag{19}$$

Finally, conditions for factor inputs may be written as follows:

$$a_{K5}^s = \frac{\mu^s p_5^s}{\rho_5^s}\alpha_{K5} \quad \text{and} \quad a_{L5}^s = \frac{\mu^s p_5^s}{\omega_5^s}\alpha_{L5}. \tag{20}$$

(6) Interregional and foreign trade

In the above, interregional trade coefficients t_i^{rs} are assumed to be known in the model. In reality, except for the construction and transport sectors, they must also be determined within the model, Trade of transport services is automatically determined from the trade of other commodities and services, but coefficients in the former sector are given by definition: $t_4^{rs} = 0(r \neq s)$ and $t_4^{ss} = 1$.

Imports are assumed to be competitive with domestic products in quality, and competition is limited to the realm of CIF price differentials. This also applies to foreign products, whose CIF price is defined as the sums of international price p_i^e and transport cost from the nearest port c_i^{es}. Production capacities of originating regions would also affect trade coefficients. Thus quantities of interregional trade are positively related to production capacities and negatively related to CIF prices of the commodities produced in respective regions. A logit model may be employed to determine interregional trade coefficients t_i^{rs}:

$$t_i^{rs} \equiv \frac{X_i^r \ \exp(-\lambda_i(p_i^r + c_i^{rs}))}{\sum_{r(e)} X_i^r \ \exp(-\lambda_i(p_i^r + c_i^{rs}))} \quad (i \neq 4, 5) \tag{21}$$

Note that possible origins r include e (foreign countries),[12] while only domestic regions are considered as possible destinations s. Hence, this formula extends the definition of interregional trade coefficients to include "import coefficients" in the conventional input-output model.

Once import prices p_i^e are given, imports can be determined endogenously from domestic demand structures. However, it is impossible to determine total exports endogenously unless a sep-

[12]Since the production capacities of foreign country X_i^e are not available, they may be replaced by the values of national imports.

arate model describing overseas demand structures is prepared. In this model, exogenously given national exports can only be distributed over regions. When the national export of commodity i, $\bar{F}_i (i \neq 4,5)$, is given, regional shares of export may be determined by a logit model similar to (21) and based on FOB prices, $p_i^r + c_i^{re}$, at the exporting port:

$$F_i^r = f_i^r \bar{F}_i \equiv \frac{X_i^r \ \exp(-\lambda_i (p_i^r + c_i^{re}))}{\sum_r X_i^r \ \exp(-\lambda_i (p_i^r + c_i^{re}))} \bar{F}_i, \quad (i \neq 4,5), \tag{22}$$

where f_i^r may be called the export distribution coefficient.

2.3 Equilibrium Conditions

In this section, equilibrium conditions for the above model are summarized. Many are obtained by incorporating first-order conditions of individual agents into the price and output equations of the interregional input-output system.

(1) Price equations

Price equations correspond to column sums of the input-output table. Three different patterns of equations must be prepared for non-transport and transport sectors as well as for final demands. The equation for non-transport sectors may be written as follows:

$$p_j^s X_j^s = \sum_{i \neq 4,5} \sum_{r(e)} p_i^r t_i^{rs} a_{ij}^s X_j^s + \sum_{i \neq 4,5} \sum_{r(e)} c_i^{rs} t_i^{rs} a_{ij}^s X_j^s + \omega_j^s a_{Lj}^s X_j^s + \rho_j^s a_{Kj}^s X_j^s. \tag{23}$$

Using (4) to eliminate a_{ij}^s, and dividing both sides by $p_j^s X_j^s$,

$$1 = \sum_{i \neq 4,5} \frac{\alpha_{ij}}{q_i^s} \sum_{r(e)} (p_i^r + c_i^{rs}) t_i^{rs} + \alpha_{Lj}^s + \alpha_{Kj}^s. \tag{24}$$

Under competitive trade, it is rational to import commodities as much as possible from the region that offers the lowest CIF price if commodities are perfectly homogeneous. In reality, a region may import the same commodity from many other regions; every practical classification involves great diversity in quality. It is thus reasonable to assume that the market price q_i^s will settle at the weighted average of CIF prices of commodity i supplied from various regions.

Assumption 8 *The relation between market and producer prices is given by* $q_i^s = \sum_{r(e)}(p_i^r + c_i^{rs})t_i^{rs}$.

In this case, (24) simply implies *Assumption 2*; thus no additional information is obtained. A similar argument applies to final demands. For example,

$$W_1^s = \sum_{i \neq 4,5} \frac{\beta_{i1} W_1^s}{q_i^s} \sum_{r(e)} (p_i^r + c_i^{rs}) t_i^{rs}$$

for household consumption. It is easy to see that this is identical to *Assumption 5*.

The price equation for the transport sector becomes

$$\frac{1}{\mu^s} = \sum_{i \neq 4,5} \sum_{r(e)} \frac{(p_i^r + c_i^{rs}) t_i^{rs}}{q_i^s} \alpha_{i5} + \alpha_{K5} + \alpha_{L5}, \tag{25}$$

where costs accompanying intra-regional purchases of the transport sector itself are taken into account. Under *Assumption 8*, the RHS of this expression is simply $\sum_{i \neq 4,5} \alpha_{i5} + \alpha_{K5} + \alpha_{L5}$, and $\mu^s = 1$ must hold in order to comply with *Assumption 2*. Accordingly, (19) may be rewritten as

$$q_i^s = \sum_{r(e)} (p_i^r + c_i^{rs}) t_i^{rs} = p_i^s + c_i^{ss}. \tag{19$'$}$$

This is the only meaningful condition derived from the price equations.

(2) Output equations

Output equations correspond to row sums of the input-output table. Separate equations are needed for construction as well as for transport sectors. The former simply becomes

$$p_4^r X_4^r = \beta_{42} W_2^r \tag{26}$$

with investment expenditure being the only source of demand. For the latter,

$$p_5^r X_5^r = \sum_{i \neq 4,5} [\sum_s \frac{c_i^{rs} t_i^{rs}}{p_i^s + c_i^{ss}} (\sum_j \alpha_{ij} p_j^s X_j^s + \sum_j \beta_{ij'} W_{j'}^s) + c_i^{re} f_i^r \bar{F}_i], \tag{27}$$

where market prices q_i^s are replaced by $p_i^s + c_i^{ss}$ from (19)'.

Output levels in these two sectors can only be measured in monetary terms, but those for the other five sectors can be measured in physical units. Hence,

$$X_i^r = \sum_s \frac{t_i^{rs}}{p_i^s + c_i^{ss}} (\sum_j \alpha_{ij} p_j^s X_j^s + \sum_{j'} \beta_{ij'} W_{j'}^s) + f_i^r \bar{F}_i \quad (i \neq 4, 5). \tag{28}$$

(3) Factor market and final demands

Under *Assumption 1*, capital rents and the wage rates are determined in the following manner:

$$\omega_j^s = \alpha_{Lj}^s p_j^s X_j^s / L_j^s \quad \text{and} \quad \rho_j^s = \alpha_{Kj}^s p_j^s X_j^s / K_j^s. \tag{29}$$

Formulas for expenditure items may be summarized as follows:

$$W_1^s = (1 - \sigma^s)[(1 - \tau_K) \sum_j \rho_j^s K_j^s + (1 - \tau_L) \sum_j \omega_j^s L_j^s + TR^s], \tag{30}$$

$$W_2^s = \frac{\sum_j \exp(\gamma \rho_j^s)}{\sum_s \sum_j \exp(\gamma \rho_j^s)} \sum_s \sigma^s [(1 - \tau_K) \sum_j \rho_j^s K_j^s + (1 - \tau_L) \sum_j \omega_j^s L_j^s + TR^s]. \tag{31}$$

$$W_3^s = \frac{\bar{N}^s}{\sum_s \bar{N}^s} \sum_s (\tau_K \sum_j \rho_j^s K_j^s + \tau_L \sum_j \omega_j^s L_j^s). \tag{14$'$}$$

Equation (30) defines household consumption, (31) investment, and (14)' government expenditure. However, each of the last two expressions is only one of several feasible alternatives; they may be replaced by better formulas.

(4) Balance of payments, income transfer and Walras' Law

The model contains variables that represent absolute price levels. Interregional transport costs c_i^{rs}, import prices p_i^e, and other price variables $\{p_i^r, \rho_i^r, \omega_i^s\}$ are determined relative to those absolute levels. This makes price indeterminacy normally expected in general equilibrium inapplicable to the present model. Here, equivalence of values added and final demands may be regarded as the condition parallel to Walras' Law. Consider the regional balance of payments.

First, if monetary values of domestic supply and demand of region s are denoted by S^s and D^s, they may be written as follows:

$$S^s = \sum_{i\neq 5}\sum_{r\neq e}\frac{(p_i^s + c_i^{sr})t_i^{sr}}{p_i^r + c_i^{rr}}(\sum_j \alpha_{ij}p_j^r X_j^r + \sum_{j'}\beta_{ij'}W_{j'}^r) \quad (32)$$

$$D^s = \sum_{i\neq 5}\sum_{r\neq e}\frac{(p_i^r + c_i^{rs})t_i^{rs}}{p_i^s + c_i^{ss}}(\sum_j \alpha_{ij}p_j^s X_j^s + \sum_{j'}\beta_{ij'}W_{j'}^s) \quad (33)$$

The value of regional net export can be described using (33) and (33):

$$TFM^s = (S^s - D^s) + \sum_{i\neq 5}(p_i^s + c_i^{se})f_i^s\bar{F}_i - \sum_{i\neq 5}\frac{(p_i^e + c_i^{es})t_i^{es}}{p_i^s + c_i^{ss}}(\sum_j \alpha_{ij}p_j^s X_j^s + \sum_{j'}\beta_{ij'}W_{j'}^s)$$

$$= \sum_i p_i^s X_i^s - \sum_j (1 - \alpha_{Kj} - \alpha_{Lj})p_j^s X_j^s - \sum_{j'} W_{j'}^s = \sum_j \rho_j^s K_j^s + \sum_j \omega_j^s L_j^s - \sum_{j'} W_{j'}^s. \quad (34)$$

The value of net export is equivalent to the difference between the total values added that are produced in the region and total regional final expenditures, where the latter is the sum of (30), (31), and (14)'. Thus the national final expenditure becomes

$$\sum_s\sum_{j'} W_{j'}^s = \sum_s\sum_j \rho_j^s K_j^s + \sum_s\sum_j \omega_j^s L_j^s + \sum_s TR^s, \quad (35)$$

and this coincides with the sum of domestic products and the net transfer from foreign countries $\sum_s V^s + TR$. The transfer TR^s to households in region s must be determined in such a way that their national total coincides with TR. Considering the fact that sums of domestic supplies and demands must coincide, the national total of (34) equals the foreign trade balance FM.[13]

$$TR = \sum_s TR^s = -\sum_s TFM^s = -FM. \quad (36)$$

Walras' Law states that when added, the monetary values of excessive demands for all goods, services and factors in the market are identically equal to zero. The equilibrium system then becomes linearly dependent so that absolute prices cannot be determined. Thus one good is designated as numéraire, and other prices are determined relative to that good. In the present context,

[13]Government and investment expenditures also contribute to redistribution of income among regions. The real transfer to region s, including that associated with these expenditures, is defined as the difference between regional domestic products and regional final expenditures; $\tilde{TR}^s \equiv \sum_{j'} W_{j'}^s - \sum_j \rho_j^s \bar{K}_j^s - \sum_j \omega_j^s \bar{L}_j^s$. It is easy to confirm that $\sum_s \tilde{TR}^s = \sum_s TR^s$.

the law is expressed in the following manner:

$$\sum_s (D^s - S^s) - FM + \sum_s \sum_j \omega_j^s (L_j^s(\omega_j^s) - \bar{L}_j^s) + \sum_s \sum_j \rho_j^s (K_j^s(\rho_j^s) - \bar{K}_j^s) = TR, \tag{37}$$

where $\bar{L}_j^s$ and $\bar{K}_j^s$ represent factor supplies, and these are fixed under *Assumption 1*.

Given fixed input coefficients in monetary terms, (29) may be regarded as equilibrium conditions for regional factor markets. When factor markets are in equilibrium, (37) is satisfied in equality from (36). The LHS of (37) represents the value of national excess demand, and this implies that Walras' Law will not meet by TR. This corresponds to the fact that economies in the real world are rarely closed in terms of commodity trade. Excess demand in the commodity market is permitted with the transfer to keep the national balance of payment. The proper amount of transfer depends on the prices of imported goods, which are exogenous to the model. Thus all prices in the present model are determined relative to import prices.

3 Computational Procedure

This section discusses computational procedure used to obtain benchmark equilibrium for the model formulated above. Prior to this, primary data requirements of the model are summarized, and procedures to fill in necessary but unavailable data are proposed.

3.1 Data

There are two major sources of data available: (1) *Statistical Yearbook of China* (SYC), published annually by Chinese National Statistics Bureau and (2) the national I-O table. The model developed in this paper may be operated with the national I-O table and a limited set of regional statistics. These include employment and capital stock compiled by region and sector as well as interregional transport costs. Employment data are available in SYC, but capital stock $K_i^r(t)$ cannot be obtained directly from existing Chinese statistics.

Investment data are basically available by sectors and regions, but fixed asset data are only available at the national level for state-owned firms. Thus sectoral depreciation rates for state-owned firms are first calculated using

$$\delta_i(t) = 1 - \frac{\bar{K}_i(t) - \bar{I}_i(t)}{\bar{K}_i(t-1)},$$

where $\bar{K}_i(t)$ are fixed assets and $\bar{I}_i(t)$ investments of state-owned firms. It is assumed that sectoral depreciation rates can be represented by those for state-owned firms and are applicable to all regions. Then existing capital stock at a point in time are only data needed to calculate industry-wide data. Since all major firms were virtually state-owned prior to 1983, fixed assets of state-owned firms may be used as proxies for sectoral capital stocks in the initial year of 1983 when regional values are distributed over regions proportional to gross regional domestic products (GRP) V_i^r: $K_i^r = (V_i^r / \sum_r V_i^r)\bar{K}_i$. Annual regional capital stock can be calculated by the conventional accumulation formula[14]

$$K_i^r(t) = (1 - \delta_i(t))K_i^r(t-1) + I_i^r(t). \tag{38}$$

Interregional transport costs, which are considered exogenous to the model, are to be estimated. For simplicity, railroads are assumed to provide the sole mode of freight transportation across provinces. This is because railroads virtually half the total freight volume in ton-kilometers with ships, and the former is the only mode that serves all provinces with the exception, until recently, of Tibet. Comprehensive information on road transportation has not been available for the base year of the model, and the road network was still inadequate for long-haul carriage at that time. Thus interregional time-distances d^{rs}, based on the shortest time paths between pairs of provincial capitals, are employed. [15] Further, actual transport costs c_i^{rs}, which are different among sectors, are assumed to be proportional to d^{rs}: $c_i^{rs} = \xi_i d^{rs}$ with an unknown parameter ξ_i that may be calibrated through equilibrium computations.

3.2 Variables, Equations, and Model Blocks

Since prices in the construction and transport sectors cannot be distinguished from their quantities, their products, $p_4^r X_4^r$ and $p_5^r X_5^r$, may be considered independent variables. Suppose $m = 5$ denotes

[14]Errors in initial distributions are thinned out due to repeated depreciations approaching the base year.

[15]The shortest paths are calculated from the railroad network comprising 132 nodes and 167 links, which was compiled from the Chinese train timetable as of 1989 by Ando and Shibata (1997).

the number of sectors other than the two mentioned, and $n = 29$ denotes the number of domestic regions. A total of 5336 unknown variables are then summarized in Table 2. In theory, they may be solved using equations (28), (26), (27), (29), (30), (31), (14)', (19)', (21), and (22) combined. The total number of these equations is also calculated as $n(mn + 6m + 9) = 5336$. Table 2 also summarizes the exogenous variables and parameters of the model; some of these are determined through calibration.

Table 2: Variables and Parameters.

Endogenous Variables ():# of Variables	$X_j^s(mn)$, $p_4^s X_4^s(n)$, $p_5^s X_5^s(n)$, $p_j^s(mn)$, $\omega_j^s(mn+2n)$, $\rho_j^s(mn+2n)$, $W_1^s(n)$, $W_2^s(n)$, $W_3^s(n)$ (subtotal: n(4m+9)=841)
	$t_i^{rs}(mn(n+1))$, $f_i^r(mn)$ (subtotal: mn(n+2)=4495)
Exogenous Variables	$\bar{K}_j^s$, $\bar{L}_j^s$, $\bar{N}^s$, $\bar{p}_i^e$, $\bar{F}_i$, $\bar{X}_i^e$, $\bar{d}^{rs}$
Parameters	c_i^{rs}, α_{ij}, α_{Kj}, α_{Lj}, $\beta_{ij'}$, τ_K, τ_L, σ^s
	ξ_i, γ, λ_i (parameters to be calibrated.)

The model composes a system of nonlinear simultaneous equations. However, each equation is not uniformly interconnected with other equations. Several blocks of equations can be identified that are relatively independent from other blocks. These include *Block X* that consists of equations (28), (26), and (27), *K/L* of equation (29), *W* of equations (30), (31), (14)', and (19)', and *Block T/F* consisting of equations (21) and (22). Each block takes the form of nonlinear programming to minimize the sum of squared errors from relevant equilibrium conditions. The solution procedure constitutes a series of convergence calculations as illustrated in Figure 2, where the Walras error ratio serves as the convergence criterion. Walras' Law suggests that prices in a general equilibrium are unique up to proportional changes, and thus, one can arbitrarily choose a numéraire. As mentioned before, it is not applicable to the present model because some prices, such as those for imported goods, are exogenous, and others are determined relative to those prices.[16]

[16] In practice, the 1987 national I-O table is regarded as the physical table. Average regional prices weighted by regional outputs then become unity in benchmark equilibrium.

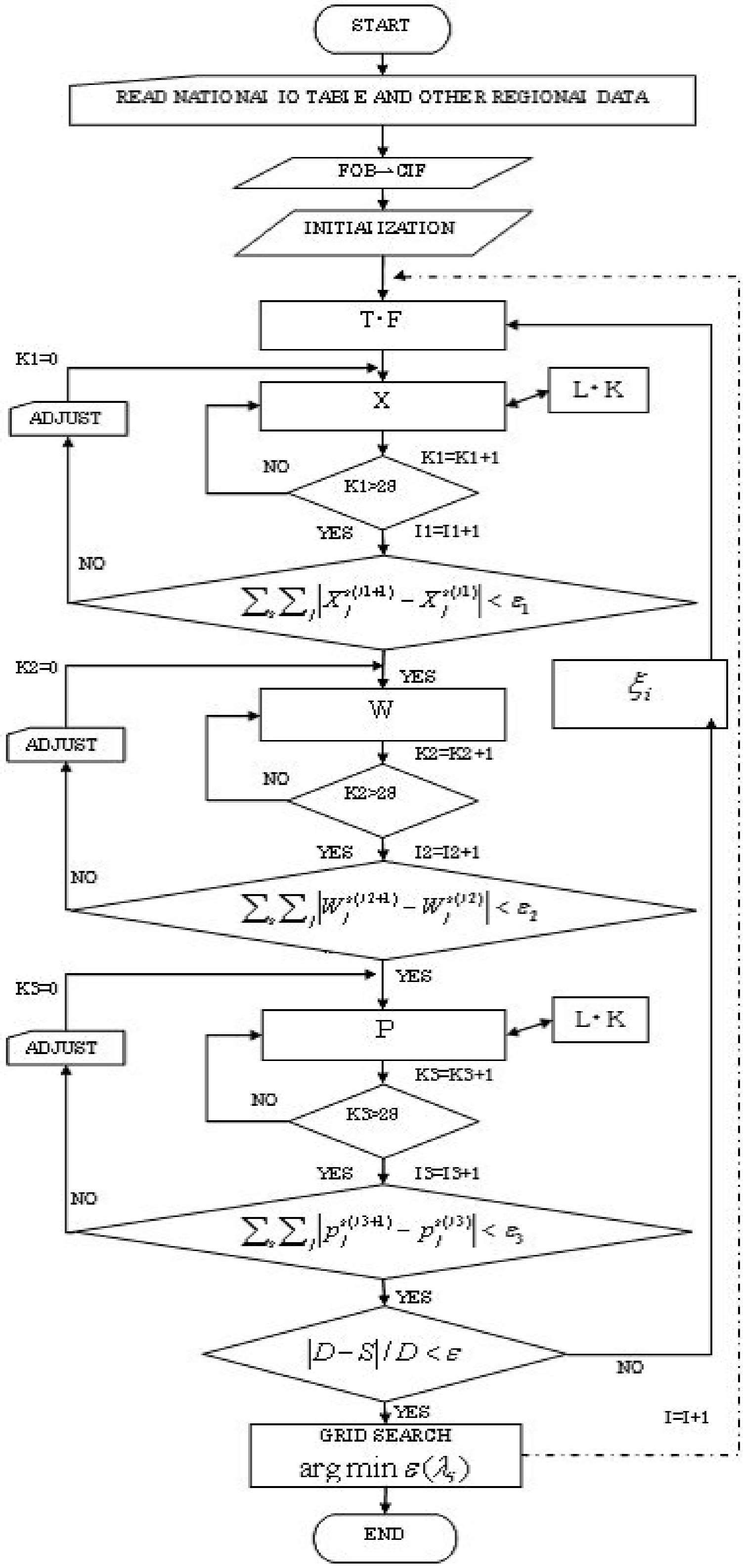


Figure 2: Computational Procedure.

4 Comparisons with Survey-Based Data

Following the procedure summarized in Figure 2, benchmark equilibrium was calculated for the base year of 1987. This produces two types of non-survey based I-O tables: regional I-O tables and the interregional I-O table for 29 provinces. It thus becomes possible to check model performance by comparing these results with published survey-based tables.

4.1 Convergence Errors

Let S and D denote the sums of equations (33) and (33) over regions, respectively. The Walras error ratio is defined as the ratio of the discrepancy between total domestic supply S and demand D to S or D. Two alternative ratios, $|S - D|/S = 0.003663$ and $|S - D|/D = 0.003679$, are less than 0.4%, and this may be acceptable when considering complexity of computations necessary to simultaneously determine 5336 variables. However, they are significantly greater than zero, and inconsistent with the expectation that all the equations in a CGE model be satisfied in equality. The model presented here includes some probabilistic formulas such as equations (21) and (22). Thus resulted trade patterns will not be of an all-or-nothing type as presumed in usual CGE models.

Table 3 provides a breakdown of errors into sectors and final demand items at the national level. Errors are measured by the following three indices:

$$EX = |\sum_s p_j^s X_j^s - \bar{X}_j|/\bar{X}_j, \quad EP = |\sum_s p_j^s X_j^s / \sum_s X_j^s - 1|, \quad \text{and} \quad EW = |\sum_s W_{j'}^s - \bar{W}_{j'}|/\bar{W}_{j'}.$$

The first two indices are used to evaluate sectoral errors. EX is the error ratio to national output, and corresponds to the condition that the aggregate value of regional outputs coincides national output $\bar{X}_j$ as given in the national I-O table. EP evaluates the deviation of the national average price from unity. Relative to final demand items, EW is used to evaluate the error ratio of aggregated regional values to $\bar{W}_{j'}$ as shown in the national I-O table.

Prices cannot be separated from values in the construction and transport sectors, so EP cannot be calculated for these sectors. The transport sector contains the largest error ratio. This may be explained by the deviation implied by *Basic Assumption* (6), but the error margin of 0.001% is quite acceptable. Price deviations EP are less than 0.1% in all sectors for which the index may be calculated. These error margins seem somewhat larger than EX. However, absolute errors in

Table 3: Error Indices on Model Coherence at the National Level.

Sectors	Agr.	Mfg.	R&E	Cnst.
EX	0.183E-5	0.639E-6	0.596E-5	0.408E-5
EP	0.986E-3	0.973E-3	0.948E-3	-
Sectors	T&C	Com.	Srv.	
EX	0.146E-4	0.744E-5	0.345E-5	
EP	-	0.996E-3	0.968E-3	
Final Demand	HHC	Inv.	Gov.	
EW	0.157E-5	0.259E-5	0.783E-5	

national outputs may be larger when EX is multiplied by $\bar{X}_j$. Error margins in final demand items EW are similar to those for national outputs. The government shows a slightly larger error, and this may be explained by the over-simplified distribution rule (14)' being applied to government expenditure.

4.2 The IW Interregional Table

The IW table was published in 2003 as the first survey-based interregional I-O table for China. This table can be used to check accuracy of the trade structure solved from the model on the ground of aggregated regions as shown in Table 1. Unfortunately, consistency of the IW table is questionable. Aggregating the IW table to the national level and calculating correlation coefficients with columns and rows of the 1987 national table, values ranging between 0.903 and 0.997 for the inter-sectoral transactions and between 0.979 and 0.998 for the exogenous sectors are obtained. Though the IW table seems adequate for relevant correlations, MAPE's at the national level are fairly large; 65.2% for the inter-sectoral transactions and 63.5% for all the cells.[17]

Table 4 summarizes correlations of the interregional I-O table aggregated from the benchmark solution with the IW table. As noted earlier, the IW table may not be perfect as the reference point. Thus correlation coefficients shown in Table 4 may be used to provide a rough assessment of model performance. An interregional I-O table has four dimensions including sending and receiving sectors as well as regions. Therefore, there are six ways to categorize correlation coefficients for endogenous transactions into matrix form. Two of them, viz. (a) the inter-sectoral and (b) the interregional results, are shown.

[17]MAPE's for individual columns and rows of the table may also be calculated. The highest MAPE of 207.0% is observed for the transport column, which is followed by 162.2% for the agricultural row.

Table 4: Correlation Coefficients with the IW Table.

(a) Correlation Coefficients Given Pairs of Sectors.

	Agr.	Mfg.	R&E	Cnst.	T&C	Com.	Srv.
Agr.	0.828	0.816	0.174	0.202	0.460	0.543	0.535
Mfg.	0.760	0.857	0.774	0.790	0.690	0.816	0.738
R&E	0.749	0.778	0.843	0.622	0.843	0.731	0.754
Cnst.	-	-	-	-	-	-	-
T&C	0.286	0.585	0.494	0.432	0.170	0.487	0.490
Com.	0.843	0.886	0.805	0.841	0.832	0.579	0.881
Srv.	0.724	0.888	0.837	0.808	0.768	0.949	0.736

(b) Correlation Coefficients Given Pairs of Regions.

	Dongbei	Huabei	Huadong	Huanan	Huazhong	Xibei	Xinan
Dongbei	0.970	0.973	0.922	0.635	0.301	0.937	0.201
Huabei	0.937	0.991	0.974	0.827	0.682	0.930	0.695
Huadong	0.995	0.980	0.959	0.981	0.942	0.934	0.968
Huanan	0.529	0.787	0.977	0.967	0.845	0.051	0.900
Huazhong	0.710	0.969	0.915	0.753	0.983	0.379	0.629
Xibei	0.790	0.823	0.950	0.305	0.480	0.942	0.943
Xinan	0.960	0.994	0.951	0.966	0.938	0.916	0.972

(c) Correlation Coefficients for Final Demand Items and Values Added.

Final Demand	HHC	Inv.	Gov.	Export/Import
Column	0.933	0.934	0.817	0.658/0.734
Value Added	Labor	Capital	Output	All cells
Row	0.957	0.925	0.988	0.892

Each cell in part (a) shows the correlation coefficient of interregional trade, given a combination of sectors and thus based on 49 observations. Most low correlations pivot on the agricultural sector such as the agriculture to resources, construction, and transport, as well as transport to agriculture. The first three combinations represent cells with fifth, third, and first smallest transactions in the 1987 national table. This makes the correlation coefficients unstable even with minor errors. The lowest correlation is found for transactions within the transport sector; this had the second smallest volume in 1987. Further, the transport row is under the influence of the *basic assumption* and diversity of transport modes.

Each cell in part (b) shows the correlation coefficient of inter-sectoral transactions, considering a combination of regions. Given the definition of the construction sector, each coefficient is based on 42 observations. Huadong and Xinan demonstrate high row correlations. The former is a Chinese industrial center, and its export to other regions is dominated by manufactured goods. The latter is a developing region with low self-sufficiency ratios, and most regional products are consumed within the region. Such industrial structures may explain the high correlations for trade originated in these two regions. Regions with high row correlations are not necessarily accompanied by high column correlations. The difference in self-sufficiency ratios may also explain this. Low correlations are observed for trade between Xibei and Huanan or Huazhong as well as between Dongbei and Xinan or Huazhong. With the exception of Dongbei to Huazhong, smaller trade volumes due to long-haul shipping requirements may contribute to instability.

Part (c) shows correlation coefficients for final demand items and values added. These are based on 42 or 49 region by sector observations depending on applicability of construction entries. As the national table only provides net export, it is divided into export and import using estimates given in Teng (2001). Those national values are then distributed over regions in the model. Inaccuracy of control totals may explain low correlations in foreign trade. The low correlation in government consumption may also be a result of the simple distributional formula. Part (c) includes a correlation coefficient for the output row as well as one for the entire table. The latter is based on 2366 observations. With a correlation of 0.892, the interregional performance of the model appears acceptable.

Benchmark equilibrium is also compared with the 1987 Beijing table, which has long been the only published regional table. In terms of correlation coefficients, the overall result of 0.963 based on 42 cells of the non-zero intersectoral transactions is generally acceptable. The lowest correlation (0.556) is observed for agricultural column. This implies that the input structure of suburban agriculture may be far from the uniform pecuniary technology assumed in the model. Transport row, government, export, and import columns demonstrate relatively low correlations (0.687–0.766). These results are also relevant to the model assumptions, and similar reasoning as with the IW table may apply.

5 Empirical Results

Ando and Shibata (1997) studied Chinese regional economies and their changes using the principal components. In this paper, similar analyses are made based on benchmark equilibria of the model. To facilitate evaluations of economic changes took place after the base year of 1987, benchmark equilibrium is also solved for 1997.

5.1 Characteristics of Regional Economies

Table 5: Principal Component Analysis of Regional Economic Variables.

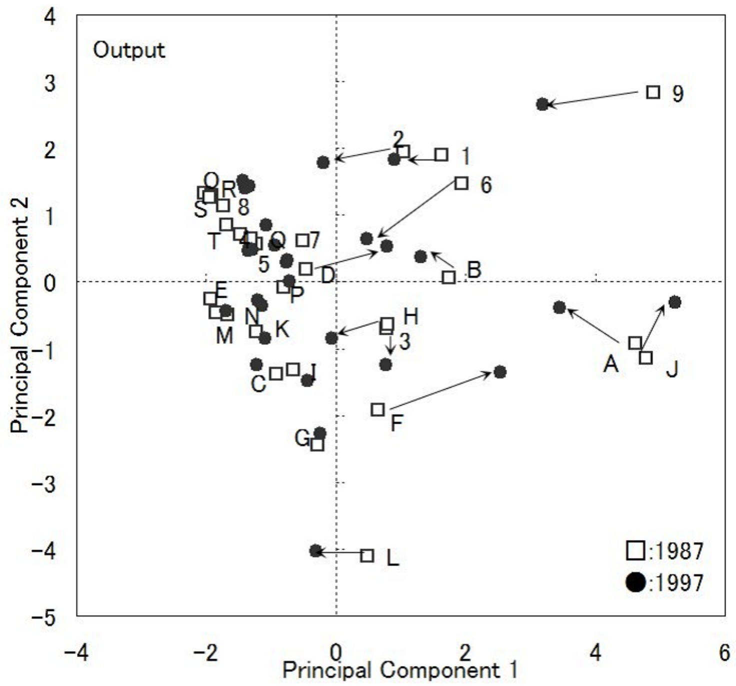
Scale Variables	Principal Component		Price Variables	Principal Component	
	1	2		1	2
Agr.	0.898	-0.337	Agr.	0.982	-0.042
Mfg.	0.928	0.282	Mfg.	0.973	0.050
R&E	0.722	-0.219	R&E	0.965	0.044
Cnst.	0.965	0.088	Com.	0.990	-0.022
T&C	0.969	0.157	Srv.	0.990	-0.002
Com.	0.962	0.196	Wage rate	-0.210	0.816
Srv.	0.959	0.230	Capital rent	-0.178	-0.817
Population	0.788	-0.568			
CR %	81.570	8.589	CR %	69.661	19.155
Cum. CR %	81.570	90.160	Cum. CR %	69.661	88.816

Principal Component Analyses (CPA) are applied to two sets of variables included in equilibrium for 1987. One set of variables are those representing regional economic scales, including sectoral nominal outputs along with exogenously given regional populations. The other set includes price variables, which are basically evaluated at CIF. Construction and transportation prices are excluded due to their inseparability from the outputs, but regional factor prices are included instead. Table 5 gives a summary of the load factors and contribution ratios (CR) of the first two components for respective sets of variables based on correlations.

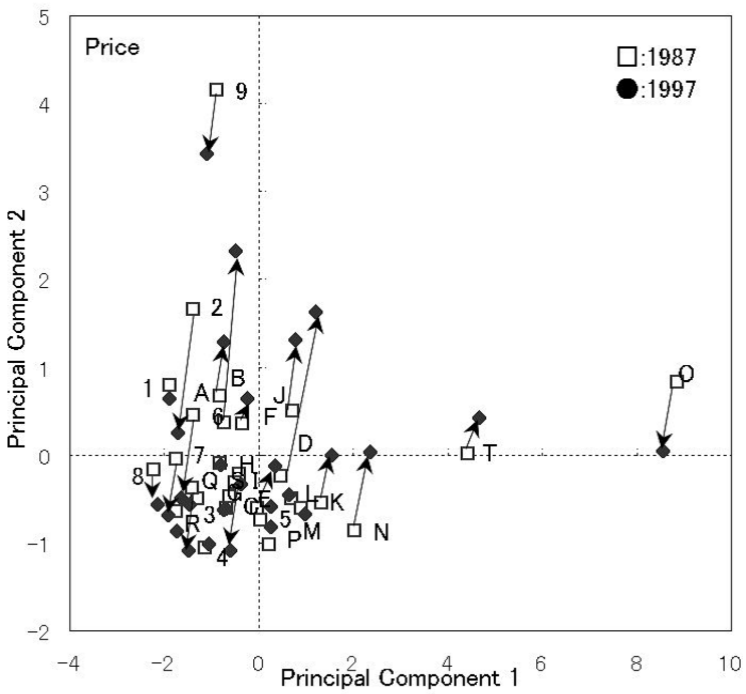
First and second components for scale variables imply respectively the scale of regional economic activities and the degree of industrialization. With reference to price variables, the second component implies higher labor and lower capital costs. This is generally observed in developed areas, while the first component implies the overall level of commodity prices. Given factor loadings for 1987, component scores were calculated based on benchmark equilibria for 1987 and 1997. The movements of each region on the score planes for the first set of variables during the decade are shown in Panel (a) of Figure 3. Letters identify the provinces as defined in Table 1.

The southern coastal regions of Guangdong (J:2 $\rightarrow$ 1) and Fujian (D:13 $\rightarrow$ 9) as well as Jiangsu (A:3 $\rightarrow$ 2), Zhejiang (B:5 $\rightarrow$ 5), and Shandong (F:10 $\rightarrow$ 4) in the east coast, gained in the level of industrialization while improving their economic positions.[18] Shanghai (9:1 $\rightarrow$ 3) dominated

[18] Numbers following the regional identifier in parentheses represent changes in ranks of the given province in the decade relative to the first component.



(a) Scale variables.



(b) Price variables.

Figure 3: Regional Component Scores and Their Changes.

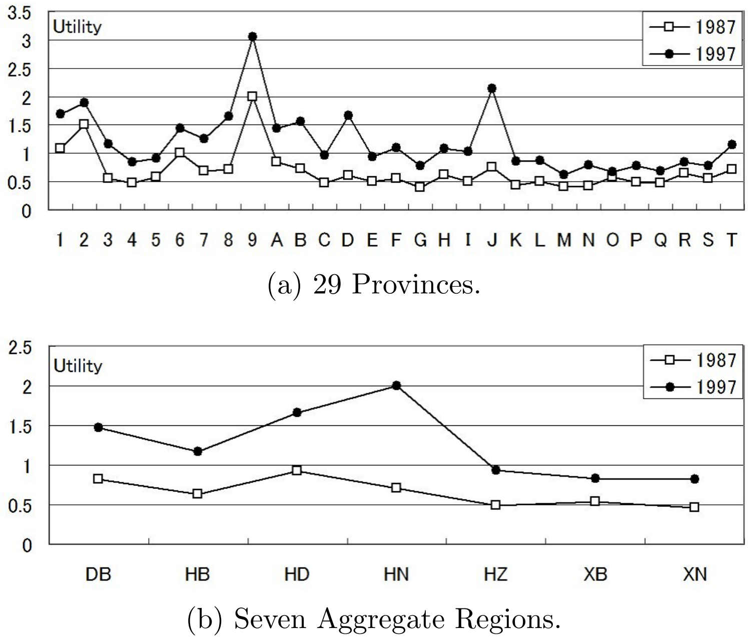
the three directly governed cities in both components. There was a relative decline in its position, and similar changes were observed for Tianjin (2:7 → 11). Beijing (1:6 → 6) maintained its position. Among the northeastern provinces, Jilin (7:14 → 17) and Liaoning (6:4 → 7) experienced declines. They belong to the old industrial center equipped with out-dated industrial capital, but Heilongjiang (8:24 → 16) seemed to be an exception. Other than Sichuan (L:11 → 13), no significant changes were found for the inland regions.

Panel (b) plots the first two component scores for price variables. The northeastern region and directly governed cities generally experienced declines in both prices and wages. However, it is obvious that the latter still enjoyed higher purchasing power. Costal provinces such as Jiangsu (A), Zhejian (B), Fujian (D), Shandong (F), and Guangdong (J) along with some southwestern provinces, including Guangxi (K) and Yunnan (N), also gained from improved purchasing power due to their faster wage increase than prices. The price levels in remote provinces such as Xinjiang (T) and Tibet (O) were particularly high due to high transport costs, but the latter apparently lost from declined wage. The rest of China, mostly inland regions, maintained their price structures during the decade with relatively lower wage and prices.

5.2 Utility Differentials

The utility function of the model is linearly homogenous and depends on commodities consumed. *Per capita* utility levels by region can easily be calculated, and are shown in panel (a) of Figure 4. Such a comparison is possible because regional populations are fixed in the model. Alternatively, *Per capita* utilities can be equalized to endogenize regional populations by allowing interregional migration.

The three directly governed cities and Liaoning (6) enjoyed higher utility in 1987. Owing to economic development in the decade, some coastal regions such as Zhejiang (B), Fujian (D), Shandong (F), and Guangdong (J) enjoyed big improvements. Inland regions such as Shanxi (4), Jiangxi (E), Henan (G), Guizhou (M), and Yunnan (N) were left behind at lower utility levels. These outcomes are consistent with the CPA results. Regional utility will increase when purchasing power increases. In terms of components based on price variables, such increases will occur when the second component score (wage level) increases faster than the first (overall price level). This movement is typically observed for the coastal provinces.



(a) 29 Provinces.

(b) Seven Aggregate Regions.

Figure 4: Utility Differentials among Regions.

To get a brief picture of regional utility changes, panel (b) shows the above results aggregated into IW's seven regions. Every region became better off in the decade, but Huanan (HN), which comprises Fujian and Guangdong, gained most to become the "best-off" region. Huadong (HD), including Shanghai, maintained higher utility, but this may have been partially cancelled out by overwhelming in-migration. Utility increases in remote regions, Xibei (XB) and Xinan (XN), were minimal.

To see the influence of economic development on regional disparity, a coefficient of variations (CV) for *per capita* utility was calculated based on 29 provinces. The results are 0.439 for 1987 and 0.496 for 1997. Thus it may be concluded that economic development during the decade contributed to the increase in regional disparity in China.

6 Concluding Remarks

The SCGE model presented in this paper provides a promising framework for multi-regional analysis. It makes detailed regional analyses possible in countries where only limited regional statistics are available. The major feature of the model is that FOB and CIF prices are distinguished through explicit consideration of transport firms. Equilibrium market prices are calculated corresponding to the existing transport network.

To evaluate the performance of the model, 29 provinces of China were selected for the study area. Benchmark equilibrium for 1987 was calculated under the assumption of immobile factors. Results were compared with IW's interregional I-O table available for the same year. The model appears satisfactory in terms of both operational capability and accuracy when compared with survey-based data. However, the transport sector, which is subject to several idealistic assumptions and probabilistic formulation, seems accompanied by relatively large errors.

Equilibrium for 1997 was also obtained to see how Chinese regional economies changed in the decade. Principal component scores that were based on the sets of variables representing regional economic scales and price levels were used. Economic success of coastal regions appears obvious from the results. These are consistent with improved *per capita* utility levels based on faster wage increase than prices in those regions. In essence, Chinese economic growth in the decade brought larger disparity in regional utility levels.

Several important limitations of the model should be mentioned in both theoretical and practical contexts. First, interregional trade was determined through a potential function based on regional production capacities and CIF prices. While this is one way to represent cross-hauling and imperfect substitution of commodities relative to their origins, it is desirable to develop an alternative formulation of trade coefficients that has a behavioral base (see Meng and Ando, 2005). Second, the validity of certain assumptions made in the model must be examined, specifically those concerning the transport sector and factor mobility. This is necessary primarily because of the limited availability of Chinese statistics. Third, formulas used to distribute investment and government consumption over regions may be too simple. More realistic *location models* should be developed to improve model performance. Finally, the model is formulated as a system of non-linear equations. Hence, existence and uniqueness of equilibrium as well as development of formulas to reduce Walras errors should be investigated.

There is room for improvement of the SCGE model presented in this paper. However, the model has proved capable of providing rich information about Chinese regional economies including outputs and prices. The merit of SCGE models is that they can dramatically reduce the size of data required for research when compared to conventional regional econometric models since the former replaces statistical expressions in the latter with equilibrium conditions. The question then becomes whether or not "equilibrium" can be expected in developing economies. Of course, this is difficult to answer unless there is sufficient data relative to the economy of concern.

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