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Modeling International Input-Output Framework in Local Currencies

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Modeling International Input-Output Framework in Local Currencies [*]

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October, 2008

Abstract: Economic agents (including policy makers) make their decisions by focusing on economic performance of their economies in their currencies rather than a foreign currency. This shows that we must build a local currency-based model in order to analyze economic issues. However, international input-output tables are denominated in a specific currency. In this paper, we create international input-output tables in constant prices and local currencies by using the tables in the usual formats. Furthermore, we illustrate the theoretical structure of a local currency-based international input-output model which is built on the resultant international input-output tables. Since the model is local currency-based and can account for international economic interdependence, it enables us to analyze domestic economic policies as well as global economic issues by one unified system. The model has a great potential to become a new benchmark framework for multi-country multi-sectoral modeling.

Keywords: international input-output, local currency basis, imperfect competition

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1. Introduction

This paper constructs local currency-based international input-output tables in constant prices and presents the theoretical structure of a local currency-based international input-output model.

Since World War II, economic interdependence of nations has been strengthened through trade and investment. Project LINK is a pioneering global macroeconometric model which quantifies the effects of economic policies and/or changes in exogenous economic environment on the world economy.[1] Subsequently, many institutions and scholars construct multi-county macroeconometric models such as the International Monetary Fund's Global Economy Model (Pesenti, 2008), Fair's (1994) Multi-Country Model, Taylor's (1993) Multi-Country Model, and so on. However, trade is transactions of goods and the degree of globalization differs sector by sector. Therefore, global macroeconometric models are not necessarily adequate. Instead, global models at sector level is more appropriate for analyzing the current world economy. Regarding multi-country multi-sectoral models, the following four types of models have been developed: 1) computable general equilibrium (CGE) model such as the Michigan model (Deardorff and Stern, 1986), the GTAP model (Hertel, 1996) and the G-Cubed model (McKibbin and Wilcoxen, 1999)[2], 2) the INFORUM system which interlinks national input-output models with a trade linkage model (Almon, 1991; Uno, 2002), 3) single-period international input-output model (Torii et al. 1989; Kosaka, 1994; Yano and Kosaka, 2003), and 4) price-linked international

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[1] Project LINK, initiated in 1968 by Professor Lawrence Klein, is currently maintained at the United Nations.

[2] Among these example models, parameters of the G-Cubed model are econometrically estimated.

input-output model (Yano and Kosaka, 2008). However, the first three models have shortcomings: a typical CGE model lacks statistical foundations of parameters; the INFORUM system might have inconsistency between classifications in input-output tables and trade matrix; a single-period international input-output model has limitations in specifications and estimation of behavioral equations due to the use of only a single-period international input-output table. A price-linked international input-output model improves the flaws of these three model, yet it has a drawback: that is, a currency problem. The currency problem is inconsistency among local currencies and a unified currency applied in international input-output tables[3]. Economic agents (including policy makers) make their decisions by focusing on economic performance of their economies in their currencies rather than a foreign currency. However, international input-output tables are denominated in a specific currency. This shows that we must build a local currency-based model in order to analyze economic issues. To do this, this paper shows an approach to compile international input-output tables in constant prices and local currencies. In addition, the structure of a local currency-based international input-output model is also presented. Holding statistical foundations of parameters and consistency between classifications of industry and trade, the local currency-based international input-output model enables us to analyze global and sectoral effects effects of each economy's policies.

The rest of this paper consists of three sections. Section 2 illustrates the method to construct local currency-based international input-output tables in constant prices. Section 3 presents the

[3] We exclude a case where international input-output tables which consist of the members of the European Monetary Union only and are complied for the years 1999 and after.

model structure. Finally, section 4 provides concluding remarks.

2. Construction of Local Currency-Based International Input-Output Tables in Constant Prices

2.1 The Structure of an International Input-Output Table

A local currency-based international input-output model is built on local currency-based international input-output tables in constant prices. Since most international input-output tables are in current prices and denominated in a specific currency, it is imperative to transform them into the tables in constant prices and denominated in local currencies. Although our approach to construct the tables of interest can be applied to any international input-output tables which are complied for at least two years, we explain the procedure by using the Asian International Input-Output Table as a benchmark.

The Asian International Input-Output Table covers the ten economies (Indonesia, Malaysia, the Philippines, Singapore, Thailand, China, Taiwan, South Korea, Japan, the United States) and is available for the years 1985, 1990, 1995, and 2000 (Institute of Developing Economies 1993, 1998, 2001; Institute of Developing Economies-Japan External Trade Organization 2006a, 2006b). Figure 1 shows the structure of the 2000 Asian International Input-Output Table.[4] Its fundamental

[4] The structure of the tables for the other years is slightly different from that for the year 2000. For details, see Institute of Developing Economies (1993, 1998, 2001) and Institute of Developing Economies-Japan External Trade Organization (2006a, 2006b).

structure is the same as that of a single country input-output table: however, exports to and imports from the third world as well as trade related variables (i.e., international freight and insurance plus import duties) are added. It is worth noting that final demand (F) is further disaggregated into the following sub-categories: private consumption (CP), government consumption (CG), investment (IN), and inventories (IV). For later purpose, an international input-output table is split into the following four parts as in Figure 2: Part A for intermediate goods, Part B for final demand, exports to the third world, and statistical discrepancies, Part C for output, and Part D for value added.

<Please insert Figures 1 and 2 near here>

2.2 Currency Conversion

International input-output tables are typically denominated in a single currency: e.g., the Asian International Input-Output Tables for the four years are evaluated in U.S. dollars. In contrast, local currency-based international input-output tables consist of variables in currencies h (economy which supplies goods) and k (economy which consumes goods). Following the double deflation technique, intermediate goods (Part A of Figure 2), final demand, exports to the third world, statistical discrepancies (Part B of Figure 2), and output (Part C of Figure 2) are denominated in currency h. On the contrary, value added (Part D of Figure 2) is converted into that in currency k. In order to hold the consistency between the summation of inputs and demands, intermediate goods

(Part A of Figure 2) are evaluated by currency k as well: i.e., we have two sets of intermediates (one is evaluated by currency h and the other is by currency k). Consequently, the following five parts should be obtained: 1) intermediates evaluated by currency h, 2) intermediates evaluated by currency k, 3) final demand, exports to the third world, and statistical discrepancies evaluated by currency h, 4) output evaluated by currency h, and 5) value added evaluated by currency h.

2.3 Deflation

In order to deflate an input-output table, the double deflation technique is normally applied. By contrast, Hoen (2002) develops a different deflating procedure which uses the RAS method. As Hoen (2002) points out, his approach would be more proper than double deflation. However, the RAS approach requires various data in constant prices in advance of deflation. According to Hoen (2002, p.78), the following data in constant prices are required for deflating international input-output tables: sectoral output, sectoral exports to and imports from the third world, sectoral value added, and totals of final demand components of each economy which consists the corresponding tables. On many occasions, it is not easy to obtain the required data even for developed countries. Therefore, we employ Yano and Kosaka's (2008) simpler approach which uses the principles of double deflation. The double deflation method requires price data for each sector and economy prior to deflation: however, it is rare to find proper set of these data. Viewing sectoral GDP deflator as the corresponding sector's value added deflator in the international input-output framework, Yano and Kosaka (2008) obtain sectoral price equations of all economies by backtracking the double deflation method and compute the values by solving the system of the resultant price equations.

2.4 The Detailed Procedure

Consider a general case where international input-output tables have n sectors and r economies. The procedure of constructing local currency-based international input-output tables in constant prices is described as follows:

Step 1: Unification of sector classification

Sector classifications of international input-output tables and GDP deflators are not always identical. Therefore, we unify the sector classifications of these data, if necessary.

Step 2: Construction of international input-output tables in current prices and local currencies

Prior to deflating international input-output tables, we construct those in current prices and local currencies. Expressions of currency conversions are presented in Table 1. It is worth noting that intermediate goods in currency k are computed by converting intermediate goods in currency h into those in currency k since international input-output tables are deflated by currency h.

<Please insert Table 1 near here>

Step 3: Computation of sectoral prices by using the corresponding sector's GDP deflators

Following double deflation, value added deflator is written as:

$$PVA_j^k = \frac{XX_j^k - \sum_{h=1}^{r}\sum_{i=1}^{n} XH_{ij}^{hk}\frac{e^k}{e^h} - GA_j^k - OA_j^k - WA_j^k}{\frac{XX_j^k}{P_j^k} - \sum_{h=1}^{r}\sum_{i=1}^{n}\frac{XH_{ij}^{hk}}{P_i^h}\frac{e^{k*}}{e^{h*}} - \frac{GA_j^k}{PIM^k} - \frac{OA_j^k}{PIM^k} - \frac{WA_j^k}{PIM^k}} \quad j = 1,2, \dots, n;\ k = 1, 2, \dots, r \quad (1)$$

where PVA_j^k is value added deflator in sector *j* of economy *k*, XX_j^k is output in sector *j* of economy *k* in current prices and currency *k*, GA_j^k is exports to the European Union in sector *j* of economy *k* in current prices and currency *k*, OA_j^k is exports to Hong Kong in sector *j* of economy *k* in current prices and currency *k*, WA_j^k is exports to the rest of the world in sector *j* of economy *k* in current prices and currency *k*, P_j^k is price in sector *j* of economy *k*, XH_{ij}^{hk} is good *i* in sector *j* of economy *k* delivered from economy *h* in current prices and currency *h*, P_i^h is price in sector *i* of economy *h*, e^{k*} is the base-year exchange rate of economy *k*, e^{h*} is the base-year exchange rate of economy *h*, and PIM^k is import deflator of economy *k*. Rearranging equation (1) yields equation for P_j^k as:

$$P_j^k = \frac{XX_j^k}{B_j^k} \qquad j = 1,2, \dots, n;\ k = 1, 2, \dots, r \qquad (2)$$

where

$$B_j^k = \sum_{h=1}^{r}\sum_{i=1}^{n} \frac{XH_{ij}^{hk}}{P_i^h}\frac{e^{k*}}{e^{h*}} + \frac{GA_j^k}{PIM^k} + \frac{OA_j^k}{PIM^k} + \frac{WA_j^k}{PIM^k} + \frac{XX_j^k - \sum_{h=1}^{r}\sum_{i=1}^{n} XH_{ij}^{hk}\frac{e^k}{e^h} - GA_j^k - OA_j^k - WA_j^k}{PVA_j^k} \quad (3)$$

Stacking equation (2) of all sectors and economies and solving the resultant simultaneous system give values for sectoral prices of all economies in local currencies.

Step 4: Deflation of international input-output tables in current prices and local currencies

Applying the double deflation technique, we deflate intermediate goods, final demand components, exports to the third world, statistical discrepancies, and output at the sector level by using the corresponding sector's price obtained in the previous step. Expressions for deflation of variables are presented in Table 1. Intermediate goods in currency k are deflated by using intermediate goods in constant prices and currency h as:

$$XKR_{ij}^{hk} = XHR_{ij}^{hk} \times \frac{e^{k*}}{e^{h*}} \qquad i, j = 1, 2, \ldots, n;\ h, k = 1, 2, \ldots, r \quad (4)$$

where XKR_{ij}^{hk} is good i in sector j of economy k delivered from economy h in constant prices and currency k and XHR_{ij}^{hk} is good i in sector j of economy k delivered from economy h in constant prices and currency h.

3. The Model Structure

The fundamental structure of the models follows Yano and Kosaka (2008). Sectoral output is determined by the summation of intermediate and final demands, exports to the third world, and statistical discrepancies. Applying a modified model of consumer behavior in Ballard et al. (1985), we endogenize sectoral private consumption among final demand components. In contrast, sectoral price is explained by international price competition of firms. Sectoral output and price are concurrently determined. In this section, using the variables and notations in the Asian International Input-Output Tables in constant prices and local currencies, we describe the structure of a local currency-based international input-output model.

3.1 Producer Behavior

Consider the following international oligopolistic competition in price:[5]

1) a single firm produces a differentiated good in sector j of economy k,

2) firms in sector j of all economies (i.e., r firms) compete in price within the international market of good j.

Thus, we have n international markets in total and there are r firms in each market. Under this framework, derived demands and price at the sector level of all economies are explained.[6]

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[5] Due to recent theoretical developments, several multi-country multi-sectoral models apply imperfect competition. See, for example, Swaminathan and Hertel (1996) and Francois (1998).

[6] Diewert and Fox (2004) are helpful for the derivations in this subsection.

3.1.1 Sectoral Price

In order to produce a differentiated good, a firm employs intermediate goods and labor as inputs. Assume that the firm in sector j of economy k has the following Cobb-Douglas cost function with economies of scale:

$$C_j^k = \varphi_j^k \left(A_j^k\right)^{-\frac{1}{\varphi_j^k}} \left(XXR_j^k\right)^{\frac{1}{\varphi_j^k}} \left[\frac{w_j^k}{\alpha_j^k(L)}\right]^{\frac{\alpha_j^k(L)}{\varphi_j^k}} \prod_{q=1}^{r}\prod_{l=1}^{n}\left[\frac{\left(1+t_l^k\right)P_l^{qk}}{\alpha_{lj}^{qk}(X)}\right]^{\frac{\alpha_{lj}^{qk}(X)}{\varphi_j^k}} \tag{5}$$

$$j = 1, 2, \ldots, n;\ k = 1,2, \ldots, r$$

where C_j^k is cost function of the firm in sector j of economy k, A_j^k is an efficiency parameter in production function of the firm in sector j of economy k, XXR_j^k is output in sector j of economy k in currency k, w_j^k is the wage rate in sector j of economy k, $\alpha_j^k(L)$ and $\alpha_{lj}^{qk}(X)$ are parameters which satisfies $\varphi_j^k = \alpha_j^k(L) + \sum_{q=1}^{r}\sum_{l=1}^{n}\alpha_{lj}^{qk}(X)$, t_l^k is the tariff rate levied on sector l of economy k, and $P_l^{qk} = \dfrac{XK_{lj}^{qk}}{XKR_{lj}^{qk}}$.[7] Profit maximization problem of the firm in sector j of economy k is written as:

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[7] Since $\dfrac{XK_{lj}^{qk}}{XKR_{lj}^{qk}} = \dfrac{XH_{ij}^{hk}\left(\dfrac{e^k}{e^h}\right)}{\left(\dfrac{XH_{ij}^{hk}}{P_i^h}\right)\left(\dfrac{e^{k*}}{e^{h*}}\right)} = \dfrac{P_i^h\left(\dfrac{e^k}{e^h}\right)}{\left(\dfrac{e^{k*}}{e^{h*}}\right)}$, input price does not depend on the subscript j.

$$\pi_j^k = P_j^k XXR_j^k\left(\mathbf{P}, P_{SM}^k\right) - C_j^k\left(XXR_j^k\left(\mathbf{P}, P_{SM}^k\right)\right) \qquad j = 1, 2, \ldots, n; k = 1,2, \ldots, r \tag{6}$$

where $\mathbf{P} = \left(P_i^{hk}\right)$ and P_{SM}^k is price for savings of economy k.[8] The first-order necessary condition for this problem is given by:

$$\frac{\partial \pi_j^k}{\partial P_j^k} = XXR_j^k + P_j^k \frac{\partial XXR_j^k}{\partial P_j^k} - \frac{\partial C_j^k}{\partial XXR_j^k}\frac{\partial XXR_j^k}{\partial P_j^k} = 0 \qquad j = 1, 2, \ldots, n; k = 1,2, \ldots, r \tag{7}$$

Rearranging equation (7), we obtain the following the inverse elasticity rule:

$$\frac{P_j^k - MC_j^k}{P_j^k} = \frac{1}{\varepsilon_j^k} \qquad j = 1, 2, \ldots, n; k = 1,2, \ldots, r \tag{8}$$

where

$$\begin{aligned} MC_j^k &= \frac{\partial C_j^k}{\partial XXR_j^k} \\ &= \left(A_j^k\right)^{-\frac{1}{\varphi_j^k}} \left(XXR_j^k\right)^{\frac{1}{\varphi_j^k}-1} \left[\frac{w_j^k}{\alpha_j^k(L)}\right]^{\frac{\alpha_j^k(L)}{\varphi_j^k}} \prod_{q=1}^{r}\prod_{l=1}^{n}\left[\frac{\left(1+t_l^k\right)P_l^{qk}}{\alpha_{lj}^{qk}(X)}\right]^{\frac{\alpha_{lj}^{qk}(X)}{\varphi_j^k}} \\ &= \frac{1}{\varphi_j^k}\frac{C_j^k}{XXR_j^k} \end{aligned} \tag{9}$$

$$j = 1, 2, \ldots, n; k = 1,2, \ldots, r$$

[8] Details of price for savings are provided in Section 3.2.1.

and

$$\varepsilon_j^k = -\frac{\partial XXR_j^k}{\partial P_j^k}\frac{P_j^k}{XXR_j^k} \qquad j = 1, 2, \ldots, n; k = 1,2, \ldots, r \tag{10}$$

Hence, price in sector j of economy k is expressed as:

$$P_j^k = \left(\frac{\varepsilon_j^k}{\varepsilon_j^k - 1}\right) MC_j^k = \mu_j^k MC_j^k \qquad j = 1, 2, \ldots, n; k = 1,2, \ldots, r \tag{11}$$

where μ_j^k is the markup factor in sector j of economy k. As we show the expression, price in sector i of economy h in currency k is explained as:

$$P_i^{hk} = \frac{P_i^h\left(\dfrac{e^k}{e^h}\right)}{\left(\dfrac{e^{k*}}{e^{h*}}\right)} \qquad j = 1, 2, \ldots, n; k = 1,2, \ldots, r \tag{12}$$

3.1.2 Derived Demands

The Shephard's lemma respectively yields intermediate and labor demands as:

$$XKR_{ij}^{hk} = \frac{\partial C_j^k}{\partial\left(1+t_l^k\right)P_{ij}^{hk}}$$

$$= \left(A_j^k\right)^{\frac{-1}{\varphi_j^k}} \left(XXR_j^k\right)^{\frac{1}{\varphi_j^k}} \left[\frac{\alpha_{ij}^{hk}(X)}{\left(1+t_i^k\right)P_i^{hk}}\right] \left[\frac{w_j^k}{\alpha_j^k(L)}\right]^{\frac{\alpha_j^k(L)}{\varphi_j^k}} \prod_{q=1}^{r}\prod_{l=1}^{n}\left[\frac{\left(1+t_l^k\right)P_l^{qk}}{\alpha_{lj}^{qk}(X)}\right]^{\frac{\alpha_{lj}^{qk}(X)}{\varphi_j^k}} \tag{13}$$

$i,j = 1, 2, \ldots, n; h, k = 1,2, \ldots, r$

$$L_j^k = \frac{\partial C_j^k}{\partial w_j^k}$$

$$= \left(A_j^k\right)^{\frac{-1}{\varphi_j^k}} \left(XXR_j^k\right)^{\frac{1}{\varphi_j^k}} \left[\frac{w_j^k}{\alpha_j^k(L)}\right]^{\frac{-\sum_{h=1}^{r}\sum_{i=1}^{n}\alpha_{ij}^{hk}(X)}{\varphi_j^k}} \prod_{q=1}^{r}\prod_{l=1}^{n}\left[\frac{\left(1+t_l^k\right)P_l^{qk}}{\alpha_{lj}^{qk}(X)}\right]^{\frac{\alpha_{lj}^{qk}(X)}{\varphi_j^k}} \tag{14}$$

$j = 1, 2, \ldots, n; k = 1,2, \ldots, r$

Good i delivered from economy h to sector j of economy k in current and constant prices as well as currency h are respectively given by:

$$XH_{ij}^{hk} = XKR_{ij}^{hk} \times P_i^{hk} \times \frac{e^h}{e^k} \qquad i,j = 1, 2, \ldots, n; h, k = 1,2, \ldots, r \tag{15}$$

$$XHR_{ij}^{hk} = \frac{XH_{ij}^{hk}}{P_i^h} \qquad i,j = 1, 2, \ldots, n; h, k = 1,2, \ldots, r \tag{16}$$

3.2 Household Behavior

Household behavior of the model is a slight modification of Ballard et al. (1985). Major dissimilarities are following aspects: 1) our model explains only private consumption: i.e., determination of labor supply is omitted and 2) consumption-savings decision is made by maximizing a Cobb-Douglas utility function, not a constant-elasticity-of-substitution (CES) utility function.[9] In our framework, current consumption and savings are determined in the first stage whereas current consumption is further disaggregated into consumption by sector and economy.

3.2.1 Consumption-Savings Decision

A representative household in economy k splits its income into consumption and savings by solving the following utility maximization problem as:

$$\max U^k = \overline{CPKR}^{k\,\alpha^k} \; CKR_F^{k\;1-\alpha^k} \qquad k = 1,2, \ldots, r \tag{17}$$

subject to

$$YIK^k = \overline{P}_{CPK}^k \, \overline{CPKR}^k + P_{SK}^k SKR^k \qquad k = 1,2, \ldots, r \tag{18}$$

where U^k is a Cobb-Douglas utility function of the household in economy k, $\overline{CPKR}^k$ is current

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[9] In order to prevent from using the saving elasticity for the calibration of parameters in household behavior, we adopt nested Cobb-Douglas utility functions.

consumption of economy k in constant prices and currency k, CKR_F^k is future consumption of economy k in constant prices and currency k, α^k is a parameter of economy k, YIK^k is income of economy k in current prices and currency k, $\overline{P}_{CPK}^k$ is price for $\overline{CPKR}^k$, P_{SK}^k is price for SKR^k,[10] and SKR^k is savings of economy k in constant prices and currency k. Current consumption consists of consumption by sector and is expressed as:[11]

$$\overline{CPKR}^k = \prod_{h=1}^{r} \prod_{i=1}^{n} \left(CPKR_i^{hk}\right)^{\lambda_{CPK_i^{hk}}^k} \qquad k = 1,2, \ldots, r \tag{19}$$

where $CPKR_i^{hk} = CPR_i^{hk} \times \left(\dfrac{e^{k*}}{e^{h*}}\right)$. In order for this problem to be solvable, we establish a linkage between future consumption and savings. By assumption, the representative household purchases capital goods by its savings and lends purchased capital goods to firms. Consequently, the household obtains the expected return per unit of savings which is expressed as $P_K^{Dk} \zeta^k$. In this expression, P_K^{Dk} and ζ^k are price and unit service of capital goods in economy k, respectively. Using the return, the household purchases future goods which, by assumption, have the same price as the current consumption of economy k, $\overline{P}_{CPK}^k$. As a result, the following equation which bond future consumption to nominal savings of economy k is established:

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[10] Following Ballard et al. (1985), price for savings of economy k is explained by

$P_{SK}^k = \sum_{i=1}^{n} P_i^k \left(\dfrac{XXR_i^k}{\sum_{l=1}^{n} XXR_l^k} \right)$ where P_i^k is price in sector i of economy k.

[11] Since current consumption is a Cobb-Douglas composite, we have $\sum_{h=1}^{r} \sum_{i=1}^{n} \lambda_{CPK_i^{hk}}^k = 1$.

$$P_{SK}^{k}\ SKR^{k} = P_{FK}^{k} CKR_{F}^{k} \qquad k = 1,2,\ \ldots,\ r \tag{20}$$

where $P_{FK}^{k} = \dfrac{P_{S}^{k}\overline{P}_{CPK}^{k}}{P_{K}^{Dk}\varsigma^{k}}$. Accordingly, the constraint of the utility maximization problem can be rewritten as:

$$YIK^{k} = \overline{P}_{CPK}^{k}\ \overline{CPKR}^{k} + P_{FK}^{k} CKR_{F}^{k} \qquad k = 1,2,\ \ldots,\ r \tag{21}$$

Setting up the Lagrangian:

$$L_{1}^{k} = \overline{CPKR}^{k\,\alpha^{k}}\ CKR_{F}^{k\,1-\alpha^{k}} + \mu^{k}\left(YIK^{k} - \overline{P}_{CPK}^{k}\ \overline{CPKR}^{k} - P_{FK}^{k} CKR_{F}^{k}\right) \qquad k = 1,2,\ \ldots,\ r \tag{22}$$

where μ^{k} is the Lagrange multiplier of economy k, we obtain the following first-order necessary conditions:

$$\alpha^{k} U^{k}\ \overline{CPKR}^{k^{-1}} = \mu^{k}\ \overline{P}_{CPK}^{k} \qquad k = 1,2,\ \ldots,\ r \tag{23}$$

$$\left(1-\alpha^{k}\right)U^{k} CKR_{F}^{k^{-1}} = \mu^{k} P_{FK}^{k} \qquad k = 1,2,\ \ldots,\ r \tag{24}$$

$$YIK^k = \overline{P}^k_{CPK}\, \overline{CPKR}^k + P^k_{FK}\, CKR^k_F \qquad k = 1,2, \ldots, r \tag{25}$$

Manipulating these first-order necessary conditions respectively yields current and future consumptions of economy k as:

$$\overline{CPKR}^k = \frac{\alpha^k YIK^k}{\overline{P}^k_{CPK}} \qquad k = 1,2, \ldots, r \tag{26}$$

$$CKR^k_F = \frac{\left(1-\alpha^k\right) YIK^k}{P^k_{FK}} \qquad k = 1,2, \ldots, r \tag{27}$$

Substituting equation (27) into equation (20) gives savings of economy k as:

$$SKR^k = \frac{\left(1-\alpha^k\right) YIK^k}{P^k_{SK}} \qquad k = 1,2, \ldots, r \tag{28}$$

3.2.2 Consumption by Sector and Economy

The household in economy k determines its consumption by sector and economy by solving the following optimization problem:

$$\max \overline{CPKR}^k = \prod_{h=1}^{r} \prod_{i=1}^{n} \left(CPKR_i^{hk}\right)^{\lambda^k_{CPK_i^{hk}}} \qquad k = 1,2, \ldots, r \tag{29}$$

subject to the constraint:[12,13]

$$YIK^k - P_{SK}^k SKR^k = \sum_{h=1}^{r}\sum_{i=1}^{n} P_i^{hk} CPKR_i^{hk} \qquad k = 1,2, \ldots, r \tag{30}$$

The Lagrangian for the second stage utility maximization of the household in economy k can be expressed as:

$$L_2^k = \prod_{h=1}^{r}\prod_{i=1}^{n}\left(CPKR_i^{hk}\right)^{\lambda_{CPK_i^{hk}}^k} + \psi^k\left(YIK^k - P_{SK}^k SKR^k - \sum_{h=1}^{r}\sum_{i=1}^{n} P_i^{hk} CPKR_i^{hk}\right) \qquad k = 1,2, \ldots, r \tag{31}$$

where ψ^k is the Lagrange multiplier. Solving this problem, we obtain the following first-order necessary conditions:

$$\lambda_{CPK_i^{hk}}^k \frac{\overline{CPKR}^k}{CPKR_i^{hk}} = \psi^k P_i^{hk}, \qquad i = 1, 2, \ldots, n;\ h, k = 1,2, \ldots, r \tag{32}$$

$$YIK^k - P_{SK}^k SKR^k = \sum_{h=1}^{r}\sum_{i=1}^{n} P_i^{hk} CPKR_i^{hk} \qquad k = 1,2, \ldots, r \tag{33}$$

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[12] Due to the principles of double deflation, price for $CPKR_i^{hk}$ equals P_i^{hk}.

[13] Import duties levied on final demand components are omitted since they do not involve in the determination of sectoral output and price.

Consequently, consumption in sector i of economy k delivered from economy h in constant prices and currency k is given by:

$$CPKR_i^{hk} = \frac{\lambda^k_{CPK_i^{hk}}}{P_i^{hk}} \left(YIK^k - P^k_{SK} SKR^k \right) \qquad j = 1, 2, \ldots, n;\ h, k = 1,2, \ldots, r \tag{34}$$

Substituting equation (34) into equation (29) of this problem yields the price for $\overline{CPKR}^k$.

Using the identity that $YIK^k - P^k_{SK} SKR^k = \overline{P}^k_{CPK}\, \overline{CPKR}^k$, we have

$$\overline{P}^k_{CPK} = \prod_{h=1}^{r} \prod_{i=1}^{n} \left(\frac{CPKR_i^{hk}}{\lambda^k_{CPK_i^{hk}}} \right)^{\lambda^k_{CPK_i^{hk}}} \qquad k = 1, 2, \ldots r \tag{35}$$

3.2.3 Household Income and Its Deflator

Wages of economy k in currency k explains household income of economy k in currency k as:

$$YIK^k = YIK^k \left(\sum_j w_j^k L_j^k \right) \qquad k = 1, 2, \ldots r \tag{36}$$

The deflator for household income of economy k in currency k is determined by the weighted average of sectoral prices of economy k (i.e., price for savings of economy k) as:

$$P_{YIK}^{k} = P_{YIK}^{k}\left(P_{SK}^{k}\right) \qquad k = 1, 2, \ldots r \qquad (37)$$

3.2.5 Consumption in Currency *h*

Although private consumption determined in this section are denominated in currency *k*, we need them in currency *h* so as to determine sectoral output which is denominated in currency *h*. The conversion can be carried out as:

$$CP_i^{hk} = CPKR_i^{hk} \times P_i^{hk} \times \left(\frac{e^h}{e^k}\right) \qquad i = 1, 2, \ldots, n;\ h, k = 1,2, \ldots, r \qquad (38)$$

and

$$CPR_i^{hk} = \frac{CP_i^{hk}}{P_i^h} \qquad i = 1, 2, \ldots, n;\ h, k = 1,2, \ldots, r \qquad (39)$$

where CP_i^{hk} is private consumption in sector *i* of economy *k* delivered from economy *h* in current prices and currency *h* and CPR_i^{hk} is private consumption in sector *i* of economy *k* delivered from economy *h* in constant prices and currency *h*.

3.3 Sectoral Output

Sectoral output is determined by summing up the corresponding intermediate and final demands as:

$$XXR_i^h = \sum_{k=1}^{r}\sum_{j=1}^{n} XHR_{ij}^{hk} + \sum_{k=1}^{r} CPR_i^{hk} + \sum_{k=1}^{r} CGR_i^{hk} + \sum_{k=1}^{r} INPR_i^{hk} + \sum_{k=1}^{r} IVR_i^{hk} + EXR_i^h + QR_i^h \tag{40}$$

$$i = 1, 2, \ldots, n;\ h = 1,2, \ldots, r$$

where XXR_i^h is output in sector i of economy h in constant prices and currency h, CGR_i^{hk} is government consumption in sector i of economy k delivered from economy h in constant prices and currency h, INR_i^{hk} is investment in sector i of economy k delivered from economy h in constant prices and currency h, IVR_i^{hk} is inventories in sector i of economy k delivered from economy h in constant prices and currency h, EXR_i^h is exports to the third world in sector i of economy h in constant prices and currency h, and QR_i^h is statistical discrepancies in sector i of economy h in constant prices and currency h.[14] Note that final demand components (in exception to private consumption) are exogenous in the model.

[14] Note that $EXR_i^h = EGR_i^h + EOR_i^h + EWR_i^h$.

3.4 Sectoral Wage Rate

Following Yano and Kosaka (2008), the sectoral wage rate is explained by a slight modification of McKibbin and Nguyen (2004, p.47) as:

$$w_j^k = \left(EPC^k\right)^{\beta^k}\left(\frac{XXR_j^k}{L_j^k}\right)^{\xi_j^k} \qquad j = 1, 2, \ldots, n;\ k = 1,2, \ldots, r \tag{41}$$

where w_j^k is the wage rate in sector j of economy k, EPC^k is the expected consumer price of economy k, β^k is a parameter of economy k, and ξ_j^k is a parameter on sectoral labor productivity in sector j of economy k.

4. Concluding Remarks

In this paper, we construct local currency-based international input-output tables in constant prices and develop the theoretical structure of a local currency-based international input-output model. Analogous to most multi-country multi-sectoral models, the model has micro foundations: i.e., expressions for producer behavior and household behavior come from profit and utility maximization, respectively. Additionally, the model includes international price competition.

Since the model is one of the global model, we can apply it to analyze global economic issues such as global warming and international trade. Moreover, since the model is local currency-based, it enables us to evaluate national economic policies such as monetary and fiscal policies within a unified international framework. In these respects, the model is quite unique and can provide a new approach to empirical economic analysis. In order to apply the model to economic problems, further work such as estimation and testing of the model is necessary. This is our next research topic.

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Figure 1: The Structure of the 2000 Asian International Input-Output Table

		Intermediate demand (X)										Final demand (F)										Export (E)				
		I	M	P	S	T	C	N	K	J	U	I	M	P	S	T	C	N	K	J	U	EG	EO	EW	Q	XX
Intermediate input (X)	I	X^{II}	X^{IM}	X^{IP}	X^{IS}	X^{IT}	X^{IC}	X^{IN}	X^{IK}	X^{IJ}	X^{IU}	F^{II}	F^{IM}	F^{IP}	F^{IS}	F^{IT}	F^{IC}	F^{IN}	F^{IK}	F^{IJ}	F^{IU}	EG^{I}	EO^{I}	EW^{I}	Q^{I}	XX^{I}
	M	X^{MI}	X^{MM}	X^{MP}	X^{MS}	X^{MT}	X^{MC}	X^{MN}	X^{MK}	X^{MJ}	X^{MU}	F^{MI}	F^{MM}	F^{MP}	F^{MS}	F^{MT}	F^{MC}	F^{MN}	F^{MK}	F^{MJ}	F^{MU}	EG^{M}	EO^{M}	EW^{M}	Q^{M}	XX^{M}
	P	X^{PI}	X^{PM}	X^{PP}	X^{PS}	X^{PT}	X^{PC}	X^{PN}	X^{PK}	X^{PJ}	X^{PU}	F^{PI}	F^{PM}	F^{PP}	F^{PS}	F^{PT}	F^{PC}	F^{PN}	F^{PK}	F^{PJ}	F^{PU}	EG^{P}	EO^{P}	EW^{P}	Q^{P}	XX^{P}
	S	X^{SI}	X^{SM}	X^{SP}	X^{SS}	X^{ST}	X^{SC}	X^{SN}	X^{SK}	X^{SJ}	X^{SU}	F^{SI}	F^{SM}	F^{SP}	F^{SS}	F^{ST}	F^{SC}	F^{SN}	F^{SK}	F^{SJ}	F^{SU}	EG^{S}	EO^{S}	EW^{S}	Q^{S}	XX^{S}
	T	X^{TI}	X^{TM}	X^{TP}	X^{TS}	X^{TT}	X^{TC}	X^{TN}	X^{TK}	X^{TJ}	X^{TU}	F^{TI}	F^{TM}	F^{TP}	F^{TS}	F^{TT}	F^{TC}	F^{TN}	F^{TK}	F^{TJ}	F^{TU}	EG^{T}	EO^{T}	EW^{T}	Q^{T}	XX^{T}
	C	X^{CI}	X^{CM}	X^{CP}	X^{CS}	X^{CT}	X^{CC}	X^{CN}	X^{CK}	X^{CJ}	X^{CU}	F^{CI}	F^{CM}	F^{CP}	F^{CS}	F^{CT}	F^{CC}	F^{CN}	F^{CK}	F^{CJ}	F^{CU}	EG^{C}	EO^{C}	EW^{C}	Q^{C}	XX^{C}
	N	X^{NI}	X^{NM}	X^{NP}	X^{NS}	X^{NT}	X^{NC}	X^{NN}	X^{NK}	X^{NJ}	X^{NU}	F^{NI}	F^{NM}	F^{NP}	F^{NS}	F^{NT}	F^{NC}	F^{NN}	F^{NK}	F^{NJ}	F^{NU}	EG^{N}	EO^{N}	EW^{N}	Q^{N}	XX^{N}
	K	X^{KI}	X^{KM}	X^{KP}	X^{KS}	X^{KT}	X^{KC}	X^{KN}	X^{KK}	X^{KJ}	X^{KU}	F^{KI}	F^{KM}	F^{KP}	F^{KS}	F^{KT}	F^{KC}	F^{KN}	F^{KK}	F^{KJ}	F^{KU}	EG^{K}	EO^{K}	EW^{K}	Q^{K}	XX^{K}
	J	X^{JI}	X^{JM}	X^{JP}	X^{JS}	X^{JT}	X^{JC}	X^{JN}	X^{JK}	X^{JJ}	X^{JU}	F^{JI}	F^{JM}	F^{JP}	F^{JS}	F^{JT}	F^{JC}	F^{JN}	F^{JK}	F^{JJ}	F^{JU}	EG^{J}	EO^{J}	EW^{J}	Q^{J}	XX^{J}
	U	X^{UI}	X^{UM}	X^{UP}	X^{US}	X^{UT}	X^{UC}	X^{UN}	X^{UK}	X^{UJ}	X^{UU}	F^{UI}	F^{UM}	F^{UP}	F^{US}	F^{UT}	F^{UC}	F^{UN}	F^{UK}	F^{UJ}	F^{UU}	EG^{U}	EO^{U}	EW^{U}	Q^{U}	XX^{U}
B		BA^{I}	BA^{M}	BA^{P}	BA^{S}	BA^{T}	BA^{C}	BA^{N}	BA^{K}	BA^{J}	BA^{U}	BF^{I}	BF^{M}	BF^{P}	BF^{S}	BF^{T}	BF^{C}	BF^{N}	BF^{K}	BF^{J}	BF^{U}					
G		GA^{I}	GA^{M}	GA^{P}	GA^{S}	GA^{T}	GA^{C}	GA^{N}	GA^{K}	GA^{J}	GA^{U}	GF^{I}	GF^{M}	GF^{P}	GF^{S}	GF^{T}	GF^{C}	GF^{N}	GF^{K}	GF^{J}	GF^{U}					
O		OA^{I}	OA^{M}	OA^{P}	OA^{S}	OA^{T}	OA^{C}	OA^{N}	OA^{K}	OA^{J}	OA^{U}	OF^{I}	OF^{M}	OF^{P}	OF^{S}	OF^{T}	OF^{C}	OF^{N}	OF^{K}	OF^{J}	OF^{U}					
W		WA^{I}	WA^{M}	WA^{P}	WA^{S}	WA^{T}	WA^{C}	WA^{N}	WA^{K}	WA^{J}	WA^{U}	WF^{I}	WF^{M}	WF^{P}	WF^{S}	WF^{T}	WF^{C}	WF^{N}	WF^{K}	WF^{J}	WF^{U}					
D		DA^{I}	DA^{M}	DA^{P}	DA^{S}	DA^{T}	DA^{C}	DA^{N}	DA^{K}	DA^{J}	DA^{U}	DF^{I}	DF^{M}	DF^{P}	DF^{S}	DF^{T}	DF^{C}	DF^{N}	DF^{K}	DF^{J}	DF^{U}					
Value added	WS	WS^{I}	WS^{M}	WS^{P}	WS^{S}	WS^{T}	WS^{C}	WS^{N}	WS^{K}	WS^{J}	WS^{U}															
	YC	YC^{I}	YC^{M}	YC^{P}	YC^{S}	YC^{T}	YC^{C}	YC^{N}	YC^{K}	YC^{J}	YC^{U}															
	DP	DP^{I}	DP^{M}	DP^{P}	DP^{S}	DP^{T}	DP^{C}	DP^{N}	DP^{K}	DP^{J}	DP^{U}															
	IT	IT^{I}	IT^{M}	IT^{P}	IT^{S}	IT^{T}	IT^{C}	IT^{N}	IT^{K}	IT^{J}	IT^{U}															
Output		XX^{I}	XX^{M}	XX^{P}	XX^{S}	XX^{T}	XX^{C}	XX^{N}	XX^{K}	XX^{J}	XX^{U}															

Note: I is Indonesia, M is Malaysia, P is the Philippines, S is Singapore, T is Thailand, C is China, N is Taiwan, K is South Korea, J is Japan, U is the United States, EG is exports to Hong Kong, EO is exports to the European Union, EW is exports to the rest of the world, Q is statistical discrepancies, B is international freight and insurance, G is imports from Hong Kong, O is imports from the European Union, W is imports from the rest of the world, D is import duties, WS is wages and salaries, YC is operation surplus, DP is depreciations, and IT is indirect taxes less subsidies.

Source: Institute of Developing Economies-Japan External Trade Organization (2006b).

Figure 2: Partitions of International Input-Output Tables

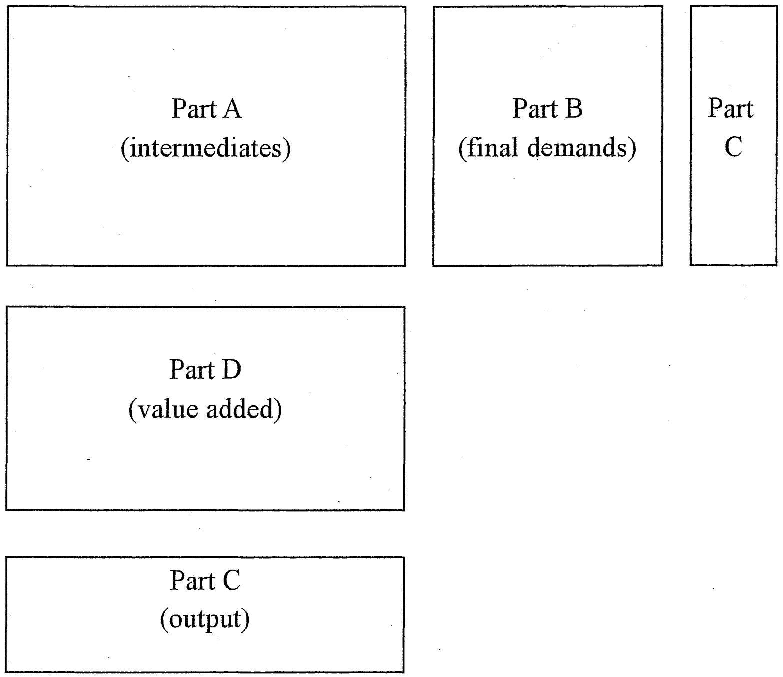

Table 1: Variables of Local Currency-Based International Input-Output Tables in Constant Prices

Part	Description	Variables in U.S. Dollars	Variables in Currency h	Variables in Currency k
A	Intermediate good (nominal)	$X\$_{ij}^{hk}$	$XH_{ij}^{hk} = X\$_{ij}^{hk} \times e^{h}$	$XK_{ij}^{hk} = XH_{ij}^{hk} \times \left(e^{k}/e^{h}\right)$
	Intermediate good (real)		$XHR_{ij}^{hk} = XH_{ij}^{hk} / P_{i}^{h}$	$XKR_{ij}^{hk} = XHR_{ij}^{hk} \times \left(e^{k*}/e^{h*}\right)$
B	Private consumption (nominal)	$CP\$_{i}^{hk}$	$CP_{i}^{hk} = CP\$_{i}^{hk} \times e^{h}$	
	Private consumption (real)		$CPR_{i}^{hk} = CP_{i}^{hk} / P_{i}^{h}$	
	Government consumption (nominal)	$CG\$_{i}^{hk}$	$CG_{i}^{hk} = CG\$_{i}^{hk} \times e^{h}$	
	Government consumption (real)		$CGR_{i}^{hk} = CG_{i}^{hk} / P_{i}^{h}$	
	Investment (nominal)	$IN\$_{i}^{hk}$	$IN_{i}^{hk} = IN\$_{i}^{hk} \times e^{h}$	
	Investment (real)		$INR_{i}^{hk} = IN_{i}^{hk} / P_{i}^{h}$	
	Inventories (nominal)	$IV\$_{i}^{hk}$	$IV_{i}^{hk} = IV\$_{i}^{hk} \times e^{h}$	
	Inventories (real)		$IVR_{i}^{hk} = IV_{i}^{hk} / P_{i}^{h}$	
	Exports to Hong Kong (nominal)	$EG\$_{i}^{h}$	$EG_{i}^{h} = EG\$_{i}^{h} \times e^{h}$	
	Exports to Hong Kong (real)		$EGR_{i}^{h} = EG_{i}^{h} / P_{i}^{h}$	
	Exports to the European Union (nominal)	$EO\$_{i}^{h}$	$EO_{i}^{h} = EO\$_{i}^{h} \times e^{h}$	

	Exports to the European Union (real)		$EOR_i^h = EO_i^h / P_i^h$	
	Exports to the ROW (nominal)	$EW\$_i^h$	$EW_i^h = EW\$_i^h \times e^h$	
	Exports to the ROW (real)		$EWR_i^h = EW_i^h / P_i^h$	
	Statistical discrepancies (nominal)	$Q\$_i^h$	$Q_i^h = Q\$_i^h \times e^h$	
	Statistical discrepancies (real)		$QR_i^h = QX_i^h / P_i^h$	
C	Output (nominal)	$XX\$_i^h$	$XX_i^h = XX\$_i^h \times e^h$	
	Output (real)		$XXR_i^h = XX_i^h / P_i^h$	
D	International freight and insurance (nominal)	$BA\$_j^k$		$BA_j^k = BA\$_j^k \times e^k$
	Imports from Hong Kong (nominal)	$GA\$_j^k$		$GA_j^k = GA\$_j^k \times e^k$
	Imports from the European Union (nominal)	$OA\$_j^k$		$OA_j^k = OA\$_j^k \times e^k$
	Imports from the ROW (nominal)	$WA\$_j^k$		$WA_j^k = WA\$_j^k \times e^k$
	Import duties (nominal)	$DA\$_j^k$		$DA_j^k = DA\$_j^k \times e^k$
	Wages (nominal)	$WS\$_j^k$		$WS_j^k = WS\$_j^k \times e^k$
	Operating surplus (nominal)	$YC\$_j^k$		$YC_j^k = YC\$_j^k \times e^k$
	Depreciations (nominal)	$DP\$_j^k$		$DP_j^k = DP\$_j^k \times e^k$

Indirect tax less subsidies (nominal)	$IT\$_j^k$	$IT_j^k = IT\$_j^k \times e^k$

Note: ROW denotes rest of the world, P_i^h is price in sector i of economy h, e^h is the exchange rate of economy h, and e^{h*} is the base-year exchange rate of economy h.

Appendix

A.1 Estimation of Household Income and Savings

Household income is estimated by applying the method in Yano and Kosaka (2008). For reference purposes, this appendix is drawn from Yano and Kosaka (2008).

Although international input-output tables provide wages, wages are not sufficient for income data. Since income of workers other than employees is a fraction of operating surplus in international input-output framework, it is required to add this part to wages. To do so, we estimate a modified version of consumption function in Klein's (1950) Model I which is written as:

$$\sum_{h=1}^{r}\sum_{i=1}^{n} CPKR_i^{hk} = c_1^k \left(\frac{\sum_{j=1}^{n} WS_j^k}{P_{CPK}^k} \right) + c_2^k \left(\frac{\sum_{j=1}^{n} YC_j^k}{P_{CPK}^k} \right) \qquad k = 1, 2, \ldots r \tag{A1}$$

where WS_j^k is wages in sector j of economy k in currency k, YC_j^k is operating surplus in sector j of economy k in currency k, and $P_{CPK}^k = \sum_{h=1}^{r}\sum_{i=1}^{n} P_i^{hk} \left(\frac{CPKR_i^{hk}}{\sum_{q=1}^{r}\sum_{l=1}^{n} CPKR_l^{qk}} \right)$. Equation (A1) is rewritten as:

$$\sum_{h=1}^{r}\sum_{i=1}^{n} CPKR_i^{hk} = c_1^k \frac{\left[\sum_{j=1}^{n} WS_j^k + \left(\frac{c_2^k}{c_1^k} \right) \sum_{j=1}^{n} YC_j^k \right]}{P_{CPK}^k} \qquad k = 1, 2, \ldots r \tag{A2}$$

We can interpret the parameter c_1^k and numerator of equation (A2) as the average propensity to consume and nominal income, respectively, Hence, nominal income of economy k in currency k can be written as:

$$YIK^k = \sum_{j=1}^{n} WS_j^k + \left(\frac{c_2^k}{c_1^k}\right)\sum_{j=1}^{n} YC_j^k \qquad k = 1, 2, \dots r \tag{A3}$$

Since savings equal income less total consumption, we can express savings as:

$$SK^k = YIK^k - \sum_{h=1}^{r}\sum_{i=1}^{n} CPKR_i^{hk} \qquad k = 1, 2, \dots r \tag{A4}$$

where SK^k is savings of economy k in current prices and currency k.

A.2 Derivation of the Cost Function

A firm in sector j of economy k solves the following cost minimization problem:

$$\min C_j^k = w_j^k L_j^k + \sum_{h=}^{r}\sum_{i=1}^{n}\left(1 + t_i^k\right)P_i^{hk} XKR_{ij}^{hk} \qquad j = 1, 2, \dots, n; k = 1,2, \dots, r \tag{A5}$$

subject to

$$XXR_j^k = A_j^k \left(L_j^k\right)^{\alpha_j^k(L)} \prod_{h=}^{r}\prod_{i=1}^{n}\left(XKR_{ij}^{hk}\right)^{\alpha_{ij}^{hk}(X)} \qquad j = 1, 2, \dots, n; k = 1,2, \dots, r \tag{A6}$$

The Lagrangian can be set up as:

$$J_j^k = w_j^k L_j^k + \sum_{h=}^{r}\sum_{i=1}^{n}\left(1+t_i^k\right)P_i^{hk} XKR_{ij}^{hk} + \lambda_j^k\left(XXR_j^k - A_j^k\left(L_j^k\right)^{\alpha_j^k(L)}\prod_{h=}^{r}\prod_{i=1}^{n}\left(XKR_{ij}^{hk}\right)^{\alpha_{ij}^{hk}(X)}\right) \quad \text{(A7)}$$

$j = 1, 2, \ldots, n;\ k = 1,2, \ldots, r$

The first-order necessary conditions are:

$$w_j^k = \lambda_j^k \alpha_j^k(L)\frac{XXR_j^k}{L_j^k} \qquad j = 1, 2, \ldots, n;\ k = 1,2, \ldots, r \quad \text{(A8)}$$

$$\left(1+t_i^k\right)P_i^{hk} = \lambda_j^k \alpha_{ij}^{hk}(X)\frac{XXR_j^k}{XKR_{ij}^{hk}} \qquad i,j = 1, 2, \ldots, n;\ h, k = 1,2, \ldots, r \quad \text{(A9)}$$

$$XXR_j^k = A_j^k\left(L_j^k\right)^{\alpha_j^k(L)}\prod_{h=}^{r}\prod_{i=1}^{n}\left(XKR_{ij}^{hk}\right)^{\alpha_{ij}^{hk}(X)} \qquad j = 1, 2, \ldots, n;\ k = 1,2, \ldots, r \quad \text{(A10)}$$

Combining equations (A8) and (A9) yields:

$$\frac{w_j^k}{\left(1+t_i^k\right)P_i^{hk}} = \frac{\alpha_j^k(L)}{\alpha_{ij}^{hk}(X)}\frac{XKR_{ij}^{hk}}{L_j^k} \qquad i,j = 1, 2, \ldots, n;\ h, k = 1,2, \ldots, r \quad \text{(A11)}$$

Manipulating equation (A9), we also have:

$$\frac{\left(1+t_i^k\right)P_i^{hk}}{\left(1+t_l^k\right)P_l^{qk}} = \frac{\alpha_{ij}^{hk}(X)}{\alpha_{lj}^{qk}(X)}\frac{XKR_{lj}^{qk}}{XKR_{ij}^{hk}} \qquad i,j,l = 1, 2, \ldots, n;\ h, k, q = 1,2, \ldots, r \quad \text{(A12)}$$

Solving equation (A12) for XKR_{ij}^{hk} gives:

$$XKR_{ij}^{hk} = \frac{\alpha_{ij}^{hk}(X)}{\alpha_{lj}^{qk}(X)}\frac{P_l^{qk}}{P_i^{hk}}XKR_{lj}^{qk} \qquad i,j,l = 1, 2, \ldots, n;\ h, k, q = 1,2, \ldots, r \quad \text{(A13)}$$

Substituting equation (A13) into equation (A11) and rearranging the resultant yields:

$$L_j^k = \frac{\alpha_j^k(L)}{\alpha_{lj}^{qk}(X)} \frac{\left(1+t_l^k\right)P_{lj}^{qk}}{w_j^k} XKR_{lj}^{qk} \qquad j, l = 1, 2, \ldots, n;\ k, q = 1,2, \ldots, r \tag{A14}$$

Substituting equations (A13) and (A14) into equation (A10) gives:

$$\begin{aligned} XXR_j^k &= A_j^k \left[\frac{\left(1+t_l^k\right)P_{lj}^{qk}}{\alpha_{lj}^{qk}(X)}\right]^{\alpha_j^k(L)+\sum_{h=1}^{r}\sum_{i=1}^{n}\alpha_{ij}^{hk}(X)} \left[\frac{\alpha_j^k(L)}{w_j^k}\right]^{\alpha_j^k(L)} \\ &\times \left(XKR_{lj}^{qk}\right)^{\alpha_j^k(L)+\sum_{h=1}^{r}\sum_{i=1}^{n}\alpha_{ij}^{hk}(X)} \prod_{h=1}^{r}\prod_{i=1}^{n}\left[\frac{\alpha_{ij}^{hk}(X)}{\left(1+t_i^k\right)P_i^{hk}}\right]^{\alpha_{ij}^{hk}(X)}, \\ &\qquad j, l = 1, 2, \ldots, n;\ k, q = 1,2, \ldots, r \end{aligned} \tag{A15}$$

Subsequently, the expression for XKR_{lj}^{qk} can be obtained by rearranging equation (A15) as:

$$XKR_{lj}^{qk} = \left(A_j^k\right)^{\frac{-1}{\varphi_j^k}} \left(XXR_j^k\right)^{\frac{1}{\varphi_j^k}} \left[\frac{\alpha_{lj}^{qk}(X)}{\left(1+t_l^k\right)P_l^{qk}}\right]\left[\frac{w_j^k}{\alpha_j^k(L)}\right]^{\frac{\alpha_j^k(L)}{\varphi_j^k}} \prod_{h=1}^{r}\prod_{i=1}^{n}\left[\frac{\left(1+t_i^k\right)P_i^{hk}}{\alpha_{ij}^{hk}(X)}\right]^{\frac{\alpha_{ij}^{hk}(X)}{\varphi_j^k}} \tag{A16}$$

$$j, l = 1, 2, \ldots, n;\ k, q = 1,2, \ldots, r$$

where $\varphi_j^k = \alpha_j^k(L) + \sum_{h=1}^{r}\sum_{i=1}^{n}\alpha_{ij}^{hk}(X)$. Substituting equation (A16) into (A14) yields the expression for labor demand in sector j of economy k as:

$$L_j^k = \left(A_j^k\right)^{\frac{-1}{\varphi_j^k}} \left(XXR_j^k\right)^{\frac{1}{\varphi_j^k}} \left[\frac{w_j^k}{\alpha_j^k(L)}\right]^{\frac{-\sum_{h=1}^{r}\sum_{i=1}^{n}\alpha_{ij}^{hk}(X)}{\varphi_j^k}} \prod_{h=1}^{r}\prod_{i=1}^{n}\left[\frac{\left(1+t_i^k\right)P_i^{hk}}{\alpha_{ij}^{hk}(X)}\right]^{\frac{\alpha_{ij}^{hk}(X)}{\varphi_j^k}} \tag{A17}$$

$$j = 1, 2, \ldots, n;\ k = 1,2, \ldots, r$$

Replacing, respectively, the subscripts h and i with q and l of equations (A16) and (A17) and substituting the resultant into equation (A5) gives the following cost function:

$$C_j^k = \varphi_j^k \left(A_j^k\right)^{-\frac{1}{\varphi_j^k}} \left(XXR_j^k\right)^{\frac{1}{\varphi_j^k}} \left[\frac{w_j^k}{\alpha_j^k(L)}\right]^{\frac{\alpha_j^k(L)}{\varphi_j^k}} \prod_{q=1}^{r}\prod_{l=1}^{n}\left[\frac{\left(1+t_l^k\right)P_l^{qk}}{\alpha_{lj}^{qk}(X)}\right]^{\frac{\alpha_{lj}^{qk}(X)}{\varphi_j^k}} \tag{A18}$$

$j = 1, 2, \ldots, n;\ k = 1,2, \ldots, r$

A.3 Calibration of the Parameters of Producer Behavior

In this appendix, we present a method to calibrate the parameters $\alpha_{ij}^{hk}(X)$ and $\alpha_j^k(L)$ $(i, j = 1,$ $2, \ldots, n;\ h, k = 1,2, \ldots, r)$.

Using equation (5), we can respectively rewrite expressions for XKR_{ij}^{hk} and L_j^k as:

$$XKR_{ij}^{hk} = \frac{\alpha_{ij}^{hk}(X)}{\varphi_j^k} \frac{C_j^k}{(1+t_i^k)P_{ij}^{hk}} \qquad i, j = 1, 2, \ldots, n;\ h, k = 1,2, \ldots, r \tag{A19}$$

$$L_j^k = \frac{\alpha_j^k(L)}{\varphi_j^k} \frac{C_j^k}{w_j^k} \qquad i, j = 1, 2, \ldots, n;\ h, k = 1,2, \ldots, r \tag{A20}$$

Estimating a system which consists of equations (A19) and (A20) for sector j of economy k by Zellner's (1962) seemingly unrelated regression (SUR) technique subject to the constraint that $\varphi_j^k = \alpha_j^k(L) + \sum_{h=1}^{r}\sum_{i=1}^{n}\alpha_{ij}^{hk}(X)$, we can obtain $\frac{\alpha_{ij}^{hk}(X)}{\varphi_j^k}$ and $\frac{\alpha_j^k(L)}{\varphi_j^k}$.

In order to obtain $\alpha_{ij}^{hk}(X)$, we take the logarithm of equation (13). Rearranging the resultant equation yields:

$$\ln XKR_{ij}^{hk} + \ln\left(\left(1+t_i^k\right)P_i^{hk}\right) - \sum_{q=1}^{r}\sum_{l=1}^{n}\frac{\alpha_{lj}^{qk}(X)}{\varphi_j^k}\ln\left(\left(1+t_l^k\right)P_l^{qk}\right) - \frac{\alpha_j^k(L)}{\varphi_j^k}\ln w_j^k =$$

$$-\frac{1}{\varphi_j^k}\ln A_j^k + \ln\alpha_{ij}^{hk}(X) - \frac{\alpha_j^k(L)}{\varphi_j^k}\ln\alpha_j^k(L) - \sum_{q=1}^{r}\sum_{l=1}^{n}\frac{\alpha_{lj}^{qk}(X)}{\varphi_j^k}\ln\alpha_{lj}^{qk}(X) + \frac{1}{\varphi_j^k}\ln XXR_j^k \qquad \text{(A21)}$$

$i,j = 1, 2, \ldots, n;\ h, k = 1,2, \ldots, r$

Applying the similar procedure to equation (14), we have:

$$\ln L_j^k + \frac{\sum_{i=1}^{n}\alpha_{ij}^k(X)}{\varphi_j^k}\ln w_j^k - \sum_{q=1}^{r}\sum_{l=1}^{n}\frac{\alpha_{lj}^{qk}(X)}{\varphi_j^k}\left(\ln\left(1+t_l^k\right)P_l^{qk}\right) =$$

$$-\frac{1}{\varphi_j^k}\ln A_j^k + \frac{\sum_{i=1}^{n}\alpha_{ij}^k(X)}{\varphi_j^k}\ln\alpha_j^k(L) - \sum_{q=1}^{r}\sum_{l=1}^{n}\frac{\alpha_{lj}^{qk}(X)}{\varphi_j^k}\ln\alpha_{lj}^{qk}(X) + \frac{1}{\varphi_j^k}\ln XXR_j^k \qquad \text{(A22)}$$

$j = 1, 2, \ldots, n;\ k = 1,2, \ldots, r$

The first four and three terms of the right hand side of equations (A21) and (A22) are constants, respectively. Stacking equations (A21) and (A22) for sector j of economy k and estimating the resultant system by the SUR technique give the parameter $\frac{1}{\varphi_j^k}$. Since we have estimated parameters for $\frac{\alpha_{ij}^{hk}(X)}{\varphi_j^k}$, $\frac{\alpha_j^k(L)}{\varphi_j^k}$, and $\frac{1}{\varphi_j^k}$, we can compute $\alpha_{ij}^{hk}(X)$ and $\alpha_j^k(L)$.

A.4 Computation of Sectoral Prices and Wage Rates for a Six-Sector Version of the Asian

International Input-Output Tables in Constant Prices and Local Currencies

Following the procedure explained in Section 2, we compute sectoral prices and wage rates for a six-sector version of the Asian International Input-Output Tables in constant prices and local currencies. To begin, we show necessary data and their sources.

- Twenty-four-sector version of Asian International Input-Output Tables for 1985, 1990, 1995, and 2000 in current prices and U.S. dollars taken from Institute of Developing Economies (1993, 1998, 2001) and Institute of Developing Economies-Japan External Trade Organization (2006a, 2006b)
- Imports of goods and services and sectoral value added in current and 1990 prices (evaluated in local currencies) taken from the United Nations' National Accounts Main Aggregates Database (http://unstats.un.org/unsd/snama/Introduction.asp; accessed August 4, 2008) and the Directorate General of Budget, Accounting and Statistics, Executive Yuan, R.O.C. (http://eng.stat.gov.tw/lp.asp?ctNode=3567&CtUnit=1179&BaseDSD=7; accessed August 4, 2008)
- Exchange rates (period average) taken from the International Monetary Fund's International Financial Statistics Online (accessed August 4, 2008) and the Central Bank of the Republic of China (http://www.cbc.gov.tw/Enghome/Eeconomic/Statistics/Category/Foreign.asp; accessed August 4, 2008)
- Employment by industry taken from the International Labor Organization's Key Indicators of the Labor Market, Fifth Edition (accessed August 4, 2008) and the Statistical Yearbook of the

Republic of China 2006

(http://eng.dgbas.gov.tw/lp.asp?CtNode=2351&CtUnit=1072&BaseDSD=36&xq_xCat=03; accessed August 23, 2008)

Since the sector classification of the Asian International Input-Output Tables differs from those of national accounts data of the United Nations and Taiwan, we must rearrange the classifications of these data sets. In this appendix, we use the six-sector classification of Yano and Kosaka (2008). Details of the classification are presented in Table A.1.[15] It is worth noting that inconsistency of industrial coverage for the fifth and sixth sectors between the United Nations data and the Asian International Input-Output tables still remains: however, we ignore it in the computation of sectoral prices.[16] After computing implicit deflators for imports and sectoral value added, we obtain sectoral prices in local currencies by following the steps in Section 2.4. Computed sectoral prices are presented in Table A.2.

In order to implement the model, it is required to compute the sectoral wage rates in addition to sectoral prices. Since sectoral wages are provided in the Asian International Input-Output Tables, we need sectoral employment data for the computation of the sectoral wage rates. The sector classification of employment data differs economy by economy. The classifications applied for the construction of the tables are summarized in Table A.3. In order to hold consistency between

[15] The sector classification of Taiwan's GDP is omitted. Details of Taiwan's sector classification for GDP are provided in the Directorate General of Budget, Accounting and Statistics, Executive Yuan, R.O.C. (http://eng.stat.gov.tw/lp.asp?ctNode=3567&CtUnit=1179&BaseDSD=7).

[16] The number of sectors in Taiwan's classification of GDP is far greater than that in the Asian International Input-Output Tables. Thus, the inconsistency in sector classification does not occur for Taiwan.

sector classifications of employment data and the Asian International Input-Output Tables, we reorganize the classification of sectoral employment as in Table A.4.[17] Regarding China, data before 1986 are omitted. Data of China for the two years are extrapolated. Additionally, data for Singapore in 1990 are also blank. We use the arithmetic average of 1989 and 1991 as its proxy.

[17] The sector classification of Taiwan's employment is omitted. Details of Taiwan's sector classification for employment are provided in the Statistical Yearbook of the Republic of China 2006 (http://eng.dgbas.gov.tw/lp.asp?CtNode=2351&CtUnit=1072&BaseDSD=36&xq_xCat=03).

Table A.1: Sector Classification

AIIO Table (6 sectors)	UN-SNA (7 sectors)	AIIO Table (24 sectors)
1 Agriculture, livestock, forestry, and fishery	1 Agriculture, hunting, forestry, and fishery	1 Paddy
		2 Other agricultural products
		3 Livestock
		4 Forestry
		5 Fishery
2 Mining, quarrying, and utilities (electricity, gas, and water supply)	2 Mining, quarrying, and utilities (less manufacturing)	6 Crude petroleum and natural gas
		7 Other mining
		20 Electricity, gas, and water supply
3 Manufacturing	3 Manufacturing	8 Food, beverage, and tobacco
		9 Textile, leather, and the products thereof
		10 Timber and wooden products
		11 Pulp, paper, and printing
		12 Chemical products
		13 Petroleum and petro products
		14 Rubber products
		15 Non-metallic mineral products
		16 Metal products
		17 Machinery
		18 Transport equipment
		19 Other manufacturing products
4 Construction	4 Construction	21 Construction
5 Trade and transportation	5 Trade, restaurants, and hotels	22 Trade and transportation
	6 Transportation and communication	
6 Services	7 Other activities	23 Services
		24 Public administration

Note: This table is tabulated following the Institute of Developing Economies-Japan External Trade Organization (2006b). AIIO stands for Asian International Input-Output. UN-SNA denotes the United Nations' System of National Accounts data.
Source: Yano and Kosaka (2008).

Table A.2: Computed Sectoral Prices

	Sector					
	1	2	3	4	5	6
Indonesia						
1985	0.646	0.594	0.590	0.616	0.643	0.659
1990	1.000	1.000	1.000	1.000	1.000	1.000
1995	1.605	1.297	1.486	1.474	1.432	1.535
2000	4.247	4.843	4.072	4.270	3.752	4.150
Malaysia						
1985	0.987	0.860	0.900	0.720	0.806	0.855
1990	1.000	1.000	1.000	1.000	1.000	1.000
1995	1.455	0.819	1.153	1.232	1.176	1.179
2000	1.515	1.486	1.483	1.507	1.368	1.345
Philippines						
1985	0.682	0.720	0.687	0.666	0.695	0.619
1990	1.000	1.000	1.000	1.000	1.000	1.000
1995	1.601	1.420	1.475	1.507	1.501	1.717
2000	1.987	2.153	2.170	2.207	2.308	2.773
Singapore						
1985	0.967	1.017	1.037	0.915	0.962	0.899
1990	1.000	1.000	1.000	1.000	1.000	1.000
1995	1.001	1.027	1.035	1.060	1.027	1.107
2000	1.002	1.018	1.026	0.977	0.990	1.099
Thailand						
1985	0.768	1.008	0.905	0.880	0.939	0.925
1990	1.000	1.000	1.000	1.000	1.000	1.000
1995	1.350	1.128	1.255	1.311	1.232	1.388
2000	1.489	1.635	1.699	1.734	1.729	1.785
China						
1985	0.625	0.690	0.681	0.648	0.684	0.663
1990	1.000	1.000	1.000	1.000	1.000	1.000
1995	1.906	1.816	1.745	1.881	2.002	2.322
2000	1.984	1.969	1.794	2.044	2.220	2.983
Taiwan						
1985	0.904	1.047	0.967	0.883	0.905	0.877
1990	1.000	1.000	1.000	1.000	1.000	1.000
1995	1.242	1.128	1.143	1.170	1.182	1.196
2000	1.180	1.149	1.168	1.180	1.300	1.275

South Korea						
1985	0.709	0.870	0.825	0.656	0.779	0.618
1990	1.000	1.000	1.000	1.000	1.000	1.000
1995	1.385	1.436	1.397	1.477	1.375	1.612
2000	1.482	1.724	1.590	1.721	1.547	2.061
Japan						
1985	0.972	1.072	1.024	0.927	0.994	0.900
1990	1.000	1.000	1.000	1.000	1.000	1.000
1995	1.035	1.041	0.960	1.033	1.007	1.073
2000	0.928	0.968	0.901	1.015	0.959	1.069
United States						
1985	0.854	0.916	0.888	0.832	0.896	0.787
1990	1.000	1.000	1.000	1.000	1.000	1.000
1995	1.051	1.043	1.085	1.121	1.119	1.187
2000	0.852	1.059	1.052	1.231	1.060	1.395

Table A.3: Construction of Sectoral Employment Data

Economy	Approach for Construction of Data
Indonesia	ISIC Revision 2 for all years
Malaysia	After 2001: ISIC Revision 3; until 2000: ISIC Revision 2
Philippines	After 2001: ISIC Revision 3; until 2000: ISIC Revision 2
Singapore	ISIC Revision 3 for all years in exception to the year 2000; 76-sector version of sectoral employment in the 2000 Asian International Input-Output Table for 2000
Thailand	After 1990: ISIC Revision 3; until 1989: ISIC Revision 2
China	ISIC Revision 2 from 1987
Taiwan	After 1999: 7th edition of standard industrial classification of the Republic of China; until 1998: older classification;
South Korea	After 1992: ISIC Revision 3; until 1991: ISIC Revision 2
Japan	After 2003: ISIC Revision 3; until 2002: ISIC Revision 2
United States	After 2003: ISIC Revision 3; until 2002: ISIC Revision 2

Note: ISIC stands for International Standard Industrial Classification.

Table A.4: Sector Classification of Employment

	AIIO Table (6 sectors)		ISIC Revision 2		ISIC Revision 3
1	Agriculture	0	Activities not adequately defined	A	Agriculture, hunting and forestry
		1	Agriculture, hunting, forestry and fishing	B	Fishing
2	Mining and utilities (electricity, gas, and water)	2	Mining and quarrying	C	Mining and quarrying
		4	Electricity, gas and water	E	Electricity, gas and water supply
3	Manufacturing	3	Manufacturing	D	Manufacturing
4	Construction	5	Construction	F	Construction
5	Trade and transportation	6	Wholesale and retail trade and restaurants and hotels	G	Wholesale and retail trade; repair of motor vehicles, motorcycles and personal and household goods
		7	Transport, storage and communication	H	Hotels and restaurants
				I	Transport, storage and communications
6	Services	8	Financing, insurance, real estate and business services	J	Financial intermediation
				K	Real estate, renting and business activities
		9	Community, social and personal services	L	Public administration and defense; compulsory social security
				M	Education
				N	Health and social work
				O	Other community, social and personal services activities
				P	Private households with employed persons
				Q	Extra-territorial organizations and bodies
				X	Not classifiable by economic activity

Note: AIIO and ISIC denote Asian International Input-Output and International Standard Industrial Classification, respectively.