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Contents

Econometric Modeling of Multi-Country and Multi-Sector System for the Asian Economies

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Abstract

This paper intends to model multi-country and multi-sector system for the Asian international input output system of Institute of Developing Economies from micro foundation; a) households maximize their utility functions under budget constraint, b) producers maximize their profits, resulting in yielding factor demands, and sector prices in dynamic sense. In environment of multi-country(R countries exist) and multi-sector (N sectors exist), we have N international oligopolistic markets of differentiated commodities supplied by R producers. The model system is demand oriented.

Keywords: East Asian Economy, international multi-sector model, dynamic price formation, international product differentiation, international oligopoly market, cost function, almost ideal demand system

JEL classification: D58, O53

1. Introduction

After World War II, econometricians have tried to construct macroeconometric models mainly in the US. Recent tendency for modeling has two folds; the first movement of economic modeling post 1970s is marked by Lucas critique in 1976. Macroeconomic modeling has been required to have micro foundation for seeking stability of "deep parameter." The second movement is to introduce stochastic elements for the disturbance terms of behavioral equations. Original contribution goes back to random shock theory by R. Frisch (1933); later, F. Adelman & I. Adelman (1959) have revived the theory in their computer simulation using Klein-Goldberger Model, and about ten years later leading econometricians at that time as well as L. R. Klein have recongnized, using couples of large scale econometric models, necessity of stochastic terms in the econometric models in 1969. (See B. G. Hickman (1972))

Econometricians have constructed various types of models on national economy. Single-country and single-sector model (SCSS model) is named macromodel, for which much efforts have been directed. An attempt to approach national economy by decompose macro-economy into several sectors has been first made by W. Leontief, which is called single-country and multi-sector model (SCMS model). After W. Leontief, sophisticated models have been made by G. Fromm & L. R. Klein (1975) and WEFA (1982). Recent CGE model belongs to SCMS. Superiority of SCMS model to SCSS model is macro and micro economics being united together in SCMS model. When one seeks to investigate national economy, one sometimes needs to consider international interrelationship among countries. This approach is called multi-country and single-sector model (MCSS model), which has

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been pioneered by L. R. Klein's Project LINK. The fourth type model is multi-country and multi-sector model (MCMS model), which has been first made by W. Leontief & F. Duchin (1983) Superiority of MCMS model to MCSS model is to be able to argue international trade such as inter-industry trade or intra-industry trade within MCMS system.

On MCMS, we have now three approaches; a) linking domestic SCMS within the trade by goods (See S. Kinoshita, et al. (1982), C. Almon (1991), F. G. Adams, B. Gangnes & S. Shishido (1993), and K. Uno (2002), b) international CGE by T. W. Hertel (1997) (GTAP model) and by W. J. McKibbin & P. J. Wilcoxen (1999) (G-Cubed model), and c) modeling MCMS on the data of international input output table (our model falls in this category). In the late 1970s, an Asian international input output table was first created by Institute of Developing Economies of Japan.

The next section will show an Asian international input output table and total picture of our analytical framework, section 3 will explain household's behavior, and section 4 producer's behavior for MCMS system from microeconomic foundation. Section 5 is simple comments on modeling for the rest of behaviors in MCMS, and in the last we conclude.

2. Multi-Country and Multi-Sector Modeling for an Asian International Input Output System

2.1 Tables of Local Currency and of Constant Price

Asian international input output tables have been published in dollar term for every five years ;tables of four time digit (1985, 1990, 1995 and 2000) are now available. (See IDE (1993), IDE (1998), IDE (2001), IDE (2006a), IDE (2006b)) We are going to convert tables of nominal dollar term into those of local currency and of constant price in advance. The reasons of conversion are explained in focusing the dubiousness on domestic economic transaction in dollar term.

a) Economic Decision Making in Real Term and in Local Currency

Economic decision making in model has to be formulated in real term. In line with this we have two alternatives: real term in dollar and real term in local currency. Most private and public economic agents are considered to make decisions in local currency; for examples, typical decision makings in production and in consumption are made in real term of local currency.

b) Foreign Exchange Market of Local Currency

People in Asian countries actually use dollar in international transaction, and at the same time they use local currency in domestic transaction; as a result, they need to exchange money at foreign exchange market.

c) Monetary Policy using Local Currency

Individual country has right to issue local currency under the name of monetary policy.

Generally, Asian international input output table have two aspects; a) the one is on demand side, and b) the other supply side. In line with this, we show layouts of converted tables; i.e., Table 1 is a total layout of Asian international input output table.

Table 1 The Layout of the Asian International Input-Output Table

		Intermediate demand (X)										Final demand (F)										Export (E)			Output	
		idn	*mls*	*phl*	*sgp*	*tha*	*chn*	*twn*	*kor*	*jpn*	*usa*	*idn*	*mls*	*phl*	*sgp*	*tha*	*chn*	*twn*	*kor*	*jpn*	*usa*	EG	EO	EW	Q	XX
Intermediate input (X)	*idn*	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}
	mls	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}
	phl	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}
	sgp	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}
	tha	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}
	chn	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}
	twn	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}
	kor	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}
	jpn	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}
	usa	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: *Idn(I)* is Indonesia, m*ls(M)* is Malaysia, *phl(P)* is the Philippines, *sgp(S)* is Singapore, *tha(T)* is Thailand, *chn(C)* is China, *twn*(N) is Taiwan, *kor(K)* is south Korea, *jpn(J)* is Japan, *usa(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.

Our model for MCMS system has several features.
a) Model in Local Currency and in Real Term
Most behavioral equations in our model are presented in local currency and in real term.
b) Differ from CGE
Basic drawback of CGE is not to utilize information from sample data in the estimation of behavioral equations; instead, they use calibration using one period data.
c) Endogenize Domestic Saving
Household saving, namely future consumption, is taken explicitly in our household commodity.
d) Attach New Kind of Innovation to Producer's Cost Function
Cost function has price of the current sector besides output and input prices.
e) Formulate Dynamic Price Determination
Price is formulated in dynamic way in link with profit maximization.

2.2 Total Picture of MCMS

We try to construct MCMS system, having an Asian international input output table of Institute of Developing Economies (IDE) in mind. The IDE's Asian IO Tables in dollar term are converted into tables in local currency and in constant price. We already have detailed converting process from dollar based original nominal Asian IO tables into the tables of local currency and of constant price in T. Yano and H. Kosaka (2008).

The importance is to give platform of unified system where macro- and micro-economics could be merged. International trade of inter-industry or intra-industry requires framework of multi-country and multi-sector; so that, the common place must be provided. In exposing MCMS system, arguments closely concern with international trade. Traditional theory of international trade has centered on international exchange of goods between different markets among dissimilar countries based on constant returns to scale and factor endowment as inter-industry trade. But, T. Negishi (1969a) has opened a possibility of international trade based on increasing returns to scale from Marshallian externality. Ten years later, P. R. Krugman (1979) has proposed another possibility of international trade of Chamberlain's monopolistic competition following Dixit-Stiglitz formulation of industrial organization, also based on increasing returns to scale. Third possibility has been made by J. A. Brander & P. Krugman (1983) on the concept of Cournot oligopoly on the homogeneous market. These three attempts are called intra-industry trade. Now we come to fourth possibility. It is well known that automobile industry, exchanging automobiles between advanced countries as bilateral trade, is a typical industry producing highly differentiated goods of horizontal sense in the same market. (See, for example, P. K. Goldberg (1995)) Then the fourth possibility of intra-industry trade is given rise to in the market of horizontal differentiation in the presence of increasing returns to scale. Such cases are frequently seen; in addition to automobile industry, air transportation service or financial service among advanced and similar countries. Besides supply side of international trade, demand side is already familiar in similar tastes across countries as Linderian effect by S. B. Linder (1961).

Our framework on international trade has, therefore, two folds:
a) Oligopoly Market of Horizontal Differentiation
World markets of inhomogeneous commodities are introduced into MCMS system.
b) Multi-Commodity Markets of Block Recursive Interconnection

The differentiated markets are interconnected in block recursive way by input output nexus.

In the first we assume the following.
Assumption 01: Country and Sector
We suppose to have R countries (or regions), each having N sectors. In applying MCMS model to Asian input output system, included countries and regions are Indonesia, Singapore, Malaysia, Thailand, Philippines, China, Korea, Taiwan, Japan, and US(i.e. R=10). Included sectors are aggregated into six categories: 1)Agriculture, livestock, forestry, and fishery; 2)Mining, quarrying, and utilities (electricity, gas, and water supply); 3)Manufacturing; 4)Construction; 5)Trade and transportation; 6)Services (i.e. N=6).
Assumption 02: Oligopoly Market of Horizontal Differentiation with R Suppliers
The h-th country is supposed to have unique firm producing single i-th commodity of horizontally differentiation, featured by border, with different price P_i^h which is expressed in local currency. Then i-th commodity market has totally R suppliers.
Assumption 03: N Oligopoly Markets of Interconnection
From the Assumptions 01-02 we have N world commodity markets which are interconnected in block-recursive way by intermediate transactions, each commodity market being horizontally differentiated.

2.3 World Commodity Market of Horizontal Differentiation

The unique firm in h-th country provides horizontally differentiated i-th commodity for the world oligopolistic market; as a result, R differentiated prices coexist. As is well known in input output system, equation below shows market equilibrium that unique firm of producing i-th commodity in h-th country faces with; namely, left hand side stands for supply and right hand side for demand, and both are expressed in constant price and in local currency of h-th country.

$$X_i^h = \sum_{j=1}^{N}\sum_{k=1}^{R} x_{ij}^{hk} + \sum_{k=1}^{R} CP_i^{hk} + \sum_{k=1}^{R} G_i^{hk} + \sum_{k=1}^{R} I_i^{hk} + \sum_{k=1}^{R} IV_i^{hk} + E_i^h + Q_i^h \qquad i=1,..,N;\ h=1,..,R \tag{2.1}$$

X_i^h : i-th Commodity produced by Oligopoly Firm in h-th Country
x_{ij}^{hk} : Intermediate Demand for i-th Commodity in h-th Country by j-th Oligopoly Firm in k-th Country
CP_i^{hk} : Private Consumption for i-th Commodity of h-th Country by k-th Country
G_i^{hk} : Government Consumption for i-th Commodity of h-th Country by k-th Country
I_i^{hk} : Private Investment for i-th Commodity of h-th Country by k-th Country
IV_i^{hk} : Inventory Investment for i-th Commodity of h-th Country by k-th Country
E_i^h : Export for i-th Commodity of h-th Country
Q_i^h : Statistical Discrepancy for i-th Commodity of h-th Country

3. Household Behavior

This subsection explains private consumption CP_i^{hk} and related behaviors of household from micro foundation dealing with household in k-th country as a unit. Suppose household earns wage from working in production of j-th sector in k-th country, so that wage rate w_j^k and labor demand L_j^k of j-th sector in k-th country are determined endogenously. As earned wage and property income Y_r^k totalizes disposable income M^k, we have the accounting identity.

Definition of Nominal Disposable Income in k-th Country

$$M^k = \sum_{j=1}^{N} w_j^k L_j^k + Y_r^k \tag{3.1}$$

For theoretical development for consumption by commodity, we have already Stone's linear expenditure system (LES), Rotterdam model and an ideal demand system (AIDS) by A. S. Deaton & J. Muellbauer (1980). Dual feature of AIDS approach is, like an analogy of argument that cost function of production a prior given leads to factor demands via Shephard's lemma, that given household expenditure function a prior leads to demands of commodities via Shephard's lemma.

Thus expenditure function possesses all the information on commodity demand in itself. In considering factors governing commodity demand besides income and prices, we must inquire for expenditure function.

a) Cohort and Life Cycle

While cohort asks the time when consumer was born, life cycle asks consumer's age. Effects of cohort and life cycle on consumption are seen in categorized consumptions by ages. As both factors would shifts household utility, expenditure function would have factors inside. A. S. Deaton & C. Paxson(1994) have investigated inequality of consumption from the viewpoint of cohort and life cycle.

b) Habit Formation - Dynamics in Consumption -

Persistence of consumption for particular commodities comes from habit formation in consumption. Expenditure function for expressing habit formation holds consumption with time lag. (See, for example, L. A. Blanciforti and R. D. Green (1983))

c) Family

Difference of family structure would affect economic activity, and also consumption of commodity. In the pioneering work of E. Engel, family charactering index is made in "equivalence scale," which is put into expenditure function. (See R. Ray (1986))

d) Advertisement

Advertisement or sale promotion activity to stimulate demands of consumers is big in the real world; unfortunately, economics has been inclined to ignore it in theoretical development. As advertisement would enter household utility, expenditure function would have such variables. (See, E. A. Selvanathan and K. W. Clements (1995))

e) Population

It is often said decrease of production population of age15-age64 tends to be responsible for stalemate of Japanese economy recent years. This is an evidence of expenditure function dependent on population (See R. Ray (1996))

f) Consumption of Leisure - Labor Supply -

C. L. Ballard, D. Fullerton, J. B. Shoven and J. Whalley (1985) introduced leisure in household utility; then, they deduced labor supply with commodity consumption.

g) Recent Tendency for Food Consumption

Recent tendency of caring health shows distortion in disaggregated food consumption as is seen in vegetarians or consumer in favor of foods less cholesterol. Study reflecting this tendency by D. J. Brown & L. Schrader (1990) included index of cholesterol in the utilities of these consumers.

h) Future Consumption - Household Saving -

As a final extension we are going to introduce future consumption in the last commodity, namely household saving. Following C. L. Ballard, D. Fullerton, J. B. Shoven and J. Whalley (1985), we endogenize future consumption in much the same way.

Argument like linear expenditure system (LES) without future consumption is that consumer expends all the income; but, in reality they have saving. This approach is considered to be in two-stepped; a) saving decision is predetermined, and secondly b) expenditure for commodities is made afterwards. Yet, in this approach, saving process is described in implicit. We intend to endogenize household saving in explicit; we state disposable income partly goes to consumptions of N commodities, and partly goes to increase of saving (future consumption), which is treated as (N+1)-th commodity. For this purpose we have to define price of future consumption in the first.

Definition of Price of Future Consumption in k-th Country

Price of future consumption p_f^k in k-th country is defined as weighted average of domestic consumption for N goods at recent year.

$$p_f^k = \sum_{i=1}^{N} \left(\frac{\overline{CP}_i^{kk}}{\sum_{\mu=1}^{N} \overline{CP}_\mu^{kk}} \right) p_i^k \tag{3.2}$$

$\overline{CP}_i^{kk}$: Consumption of i-th Commodity produced by i-th Sector in k-th Country in recent year

p_i^k : Price of i-th Commodity in k-th Country

Note that we use, in weighting coefficients of (3.2), prices of domestic goods ignoring the other countries' prices. Note also that we possibly take geometric average or rational expectation for future price in (3.2) instead of arithmetic average.

Now we face with optimal decision on allocation of disposable income over (N+1) commodities in k-th country's household; the k-th country's household is supposed to decide optimal allocation of disposable income over i-th commodity C_i^{hk} and future consumption C_f^k by maximizing household utility under its budget constraint expressed in nominal k-th country's currency.

$$M^k = \sum_{h=1}^{R} \sum_{i=1}^{N} p_i^{hk*} CP_i^{hk} + p_f^k CP_f^k \tag{3.3}$$

$p_i^{hk*} = (1+t_i^k)\left(e^k/e^h\right)(1-s_i^h)p_i^h = (1+t_i^k)\left(e^k/e^h\right)p_i^{h*}$: Price of p_i^h received

by k-th Country
s_i^h : Rate of Export Subsidy of i-th Commodity in h-th Country
CP_i^{hk} : k-th Household Consumption of i-th Commodity produced by i-th Sector in h-th Country
CP_f^k : k-th Household Future Consumption
e^k, e^h: Foreign Exchange Rates of k-th and h-th Country per Dollar respectively

Future consumption leads to an increase of saving.

$$\Delta S^k = p_f CP_f^k \tag{3.4}$$

$$S^k = S_{-1}^k + \Delta S^k \tag{3.5}$$

Equation (3.5) determines total amount of saving (S^k); yet, we leave unmentioned to the contents of saving, namely, its portfolio. Total saving will become primary deposit; as a result, it might lead to variable of financial model. Property income is determined by the following equation.

$$Y_r^k = \zeta_0^k + \zeta_1^k (r^k S_{-1}^k) \tag{3.6}$$

r^k : Long-term Interest Rate in k-th Country

Now, in determining optimal demand for i-th commodity CP_i^{hk} and future consumption CP_f^k in k-th country, we will employ AIDS model by A.S.Deaton & J.Muellbauer(1980).

AIDS for MCMS System

Define vectors and matrix (T stands for transpose);

$$(P^k)^T = \{p_1^{1k*}..p_1^{Rk*}; p_2^{1k*}..p_2^{Rk*};..; p_N^{1k*}..p_N^{Rk*}\} \qquad (\widetilde{P}^k)^T = \{(P^k)^T; p_f^k\}$$

$$(\alpha^k)^T = \{\alpha_1^{1k}..\alpha_1^{Rk}; \alpha_2^{1k}..\alpha_2^{Rk};..; \alpha_N^{1k}..\alpha_N^{Rk}\} \qquad (\widetilde{\alpha}^k)^T = \{(\alpha^k)^T; \alpha_f^k\}$$

$$\Gamma = \{\gamma_{ij}; i, j = 1,.., N \times R + 1\}.$$

Then, nominal share model of M^k is;

$$w_i = \alpha_i + \beta_i \log \frac{M^k}{P2^k} + \Gamma_i \log P2^k \tag{3.7}$$

in which $\log P2^k = (\widetilde{\alpha}^k)^T (\log \widetilde{P}^k) + \frac{1}{2} (\log \widetilde{P}^k)^T \Gamma (\log \widetilde{P}^k)$ and Γ_i is i-th row vector of Γ. The case $i=N\times R+1$ is of future consumption. Relative price in share equation in (3.7) is essential in view of commodity consumption across countries. Notify that estimation of individual equation (3.7) is interdependent on each other via parameter vector $\widetilde{\alpha}^k$. And, factors of shifting consumer demand such as advertisement, sale promotion activities, product innovation and transportation are assumed to be all expressed in $\widetilde{\alpha}^k$. Note also that AIDS model needs to have three conditions: $\sum w_i=1$, $\sum \alpha_i=1$, $\sum \beta_i=0$.

4. Producer's Behavior

4.1 Designing Multi-Sector Model

First we have to distinguish in viewing world market is in equilibrium or in disequilibrium. As is seen in the preceding section, the market is in equilibrium and in an oligopoly with product differentiation of R suppliers. In the world j-th commodity market, excess demand $X_j^{k(D)} > X_j^{k(S)}$ forces price to go up or cut off a part of demand; inversely, excess supply $X_j^{k(D)} < X_j^{k(S)}$ would decrease supply to meet demand. Such mechanism works for production to stock; but, supply meets demand automaticaly in order production.

In the following, we intend to see factor demand and price determination behaviors; how are these two described in link with rational economic behaviors? An attempt to model multi-sector system from micro-foundation was first made by L. Johansen (1960); profit maximization (hereafter PM in short) make factor demand under perfect competition, so that he has no mechanism to determine price (then price remains exogenous). M. Saito (1971) states; PM makes factor demand in perfect competition with constant return to scale, and demand/supply nexus determines price in dynamics like cobweb model. And K. Tsujimura & M. Kuroda (1974) designed; SFS production function makes factor demand under economy of scale, and PM determines price in static way under imperfect competition. Traditional microeconomics PM describes price in the absence of intermediate input. CGE model depicts that PM makes factor demand, and price is made by accounting identity (See, for example, C. L. Ballard et al. (1985)). The paper provides cost function for factor demand via Shephard's lemma, and provides PM under imperfect competition for price determination.

4.2 Factor Demand - Cost Function Approach -

Following W. E. Diewert & K. J. Fox (2008), in a given cost function, we deduce factor demands by Shephard's lemma, which lead to price determination. For this we take long-run cost function having capital stock inside. Now develop Bertrant competition with price as strategic variable for aggregated profit. Demand $X_j^{k(D)}$ and supply $X_j^{k(S)}$ are clearly distinguished.

The j-th firm has two agents, each collaborating for production; upper agent (agent 1) is aiming at price setting by profit maximization, and lower agent (agent 2) is aiming at deciding factor demand by cost minimization. Cost minimization is firstly explained.

The second agent allocates factors optimally by cost minimization under production command $X_j^{k(S)}$ and given prices.

$$C_j^k(X_j^{k(S)}, P^k, w_j^k, r^k, t) = \min_{\widetilde{x}_j^k, L_j^k, K_j^k} \left(\sum_{h=1}^{R} \sum_{i=1}^{N} p_i^{hk*} x_{ij}^{hk} + w_j^k L_j^k + r^k K_j^k \right)$$
$$k = 1,.., R;\ j = 1,.., N \tag{4.1}$$

C_j^k : Cost Function of j-th industry in k-th country
$\widetilde{x}_j^k = \{x_{ij}^{hk}; i,j = 1,2,.., N; h,k = 1,2,.., R\}$
p_i^{hk*} : price of i-th product of h-th country received by k-th country
r^k : capital cost in k-th country

After the lower decision is first made by agent 2, then upper decision is made by agent 1 using the optimal first decision. The scheme is analogical to Stackelberg game in an oligopolistic market; a) agent 2(Stackelberg follower) makes decision using price P^k and production $X_j^{k(S)}$ as parameter values, and b) the agent 1(Stackerberg leader) makes optimal decision for price and production using cost function.

Specification of Cost Function

We will employ an approach of deriving factor demand equation via Shephard lemma given cost function a priori. Generally cost function shows no special kind of behavior; then, translog cost function, ignoring more than third order terms in Taylor series expansion of the functions, has been widely used, which function was first posed for production function by L. R. Christensen, D. W. Jorgenson and L. J. Lau (1973). However, the cost function should have economic rationality. The generalized Leontief cost function by M. A. Fuss (1977) should be remarked; $c\ (y,\ p,\ t,)=\sum_{i,j} h_{ij}\ (y,\ t)\sqrt{p_i}\ \sqrt{p_j}$ in which p_i, y and $h_{ij}\ (y,t)$ are factor price, production, and unspecified symmetric concave function respectively. As M. A. Fuss did not specify $h_{ij}\ (y,t)$ in his cost function, a number of contributions have been made by various authors. Current paper intends to have long-run cost function having capital inside. Instead of $C_j^k\ (X_j^{k(S)},\ P^k,\ w_j^k,\ r^k,\ t)$, now write $C_j^{k(K)}\ (X_j^{k(S)},\ P^k,\ w_j^k,\ r^k,\ t)$ as cost function; accordingly $x_{ij}^{hk} = \partial C_j^{k(K)} / \partial p_i^{hk*}$, $L_j^k = \partial C_j^{k(K)} / \partial w_j^k$, $K_j^{k(CM)} = \partial C_j^{k(K)} / \partial r^k$. Now introduce adjusting process for capital formation, resulting in the cost function $\widetilde{C}_j^k$, as R.S.Pindyck & J.J.Rotemberg (1983) have done; optimal capital demand $K_j^{k(CM)}$ is to be adjusted. Desired level of capital K_j^{k*} is assumed to have $\partial K_j^{k*} / \partial K_j^k = 0$.

$$\widetilde{C}_j^k = \min_{K_j^k}\left\{C_j^{k(K)}(X_j^{k(S)},P^k,w_j^k,r^k,t)+\frac{1}{2}c_{j(K1)}^k\left(K_j^k-K_j^{k*}\right)^2+\frac{1}{2}c_{j(K2)}^k\left(K_j^k-K_{j,-1}^k\right)^2\right\}$$

$$=\min_{K_j^k}\left\{C_j^{k(K)}(X_j^{k(S)},P^k,w_j^k,r^k,t)+\frac{1}{2}c_{j(K1)}^k\left(K_j^k-K_j^{k*}\right)^2+\frac{1}{2}c_{j(K2)}^k\left(K_j^k-K_{j,-1}^k\right)^2\right\} \tag{4.2}$$

Since the first order condition for (4.2) is $c_{j(k1)}^k\ \left(K_j^k - K_j^{k*}\right) + c_{j(k2)}^k\ \left(K_j^k - K_{j,-1}^k\right) = 0$, we obtain;

$$K_j^k - K_{j,-1}^k = \frac{c_{j(K1)}^k}{c_{j(K1)}^k + c_{j(K2)}^k}\left(K_j^{k*} - K_{j,-1}^k\right). \tag{4.3}$$

The equation (4.3) is depicting noted stock adjusting rule.(See, for example, L. R. Klein (1983)) It might be possible to put $K_j^{k*} = K_{j,-1}^{k(CM)}$ or to put $K_j^{k*} = K_j^{k(CM)}$ afterwards. For empirical study, function $h_{ij}\ (y,t)$ should be specified, and we follow S. Nakamura (1990); he named Generalized Ozaki cost function. In the absence of $h_{ij}\ (y,t)(i \neq j)$, the Generalized Ozaki cost function for our MCMS is simplified to the following, in which the second and third terms refers to wage and capital respectively. Terms of time trend stands for Hicks neutral technological change.

$$C_j^{k(K)} = \sum_{\eta=1}^{R}\sum_{\mu=1}^{N} b_{1\eta\mu}^k(p)p_\mu^{\eta k*}(X_j^{k(S)})^{b_{1\eta\mu}^k(X)}e^{b_{1\eta\mu}^k(t)t}$$

$$+b_2^k(w)w_j^k(X_j^{k(S)})^{b_2^k(X)}e^{b_2^k(t)t}+b_3^k(K)r^k(X_j^{k(S)})^{b_3^k(X)}e^{b_3^k(t)t}$$

$$j=1,..,N;k=1,..,R \tag{4.4}$$

$X_j^{k(S)}$: Output of j-th Sector in k-th Country
$p_\mu^{\eta k}$: Price of μ-th Sector in η-th Country received by k-th Country
w_j^k : Wage Rate of j-th Sector in k-th Country
r^k : Capital Cost in k-th Country
t : Time Index used to capture Effects of Disembodied Technical Change
$b_{1\eta\mu}^k(p),\ b_{1\eta\mu}^k(X),\ b_{1\eta\mu}^k(t),\ b_2^k(w),\ b_2^k(X),\ b_2^k(t),\ b_3^k(K),\ b_3^k(X),\ b_3^k(t)$:
Unkown Parameters

Innovation attached to Cost Function

We will assume technical progress which is attached to the cost function and its corresponding factor demand equations. The term of time trend expresses technical progress of Hicks neutrality. Including Hicks technical progress, S. Shishido & O. Nakamura (1992) classified three kinds of technical progress.

A Type: Price Independent Technical Progress

This type is related to S of R. Stone's RAS method. The progress not saves particular factors such as labor, but saves all factors independently from prices of factors and production price. They exemplify a) reducing cost by introducing innovative technology, b) quality control or total quality control and c) IT innovation. Cost function holds term of time trend for expressing this technical progress.

B Type: Technical Progress depending on Output Price

Cost reducing behavior, done by management efforts, reacts to reduction of output price, but does not aim at reducing particular factor demands. These behaviors, caused by globalization and currency appreciation mainly after 1990s, could be seen in most manufacturing industries in Japan.

C Type: Technical Progress depending on Input Price

This type is related to R of R. Stone's RAS method, and is aroused from rise of factor price such as material (e.g., rise of oil price), labor and capital.

Cost function embodying B-type technology is exposed in account of above consideration in the following way by entering $p_j^{k(e)}$.

$$C_j^{k(K)} = \sum_{\eta=1}^{R}\sum_{\mu=1}^{N} b_{1\eta\mu}^k(p)p_\mu^{\eta k*}(p_j^{k(e)})^{b_{1\eta\mu}^k(pj)}(X_j^{k(S)})^{b_{1\eta\mu}^k(X)}\exp b_{1\eta\mu}^k(t)t$$

$$+b_2^k(w)w_j^k(p_j^{k(e)})^{b_{2ki}^k(pj)}(X_j^{k(S)})^{b_2^k(X)}\exp b_2^k(t)t$$

$$+b_3^k(K)r^k(p_j^{k(e)})^{b_{3ki}^k(pj)}(X_j^{k(S)})^{b_3^k(X)}\exp b_3^k(t)t \tag{4.5}$$

$p_j^{k(e)}$: Expected Price of p_j^k

Now, by Shephard's lemma, we obtain the intermediate, labor and capital demand equations respectively.

$$x_{ij}^{hk} = \partial C_j^{k(K)} \Big/ \partial p_i^{hk*} = b_{1hi}^k(p)(p_j^{k(e)})^{b_{1hi}^k(pj)}(X_j^{k(S)})^{b_{1hi}^k(X)}e^{b_{1hi}^k(t)t} \tag{4.6}$$

$$L_j^k = \partial C_j^{k(K)} \Big/ \partial w_j^k = b_2^k(w)(p_j^{k(e)})^{b_2^k(pj)}(X_j^{k(S)})^{b_2^k(X)}\exp b_2^k(t)t \tag{4.7}$$

$$K_j^{k(CM)} = \partial C_j^{k(K)} \Big/ \partial r^k = b_3^k(K)(p_j^{k(e)})^{b_3^k(pj)}(X_j^{k(S)})^{b_3^k(X)}\exp b_3^k(t)t \tag{4.8}$$

These equations have alternative expressions for estimation.

$$\log x_{ij}^{hk} = \log b_{1hi}^{k}(p) + b_{1hi}^{k}(pj)\log(p_{j}^{k(e)}) + b_{1hi}^{k}(X)\log X_{j}^{k} + b_{1hi}^{k}(t)t \tag{4.9}$$

$$\log L_{j}^{k} = \log b_{2}^{k}(w) + b_{2}^{k}(pj)\log(p_{j}^{k(e)}) + b_{2}^{k}(X)\log X_{j}^{k} + b_{2}^{k}(t)t \tag{4.10}$$

$$\log K_{j}^{k(CM)} = \log b_{3}^{k}(w) + b_{3}^{k}(pj)\log(p_{j}^{k(e)}) + b_{3}^{k}(X)\log X_{j}^{k} + b_{3}^{k}(t)t \tag{4.11}$$

Equation (4.6)-(4.8) or (4.9)-(4.11) are estimated in use of an Asian international input output data; we note that the cost function (4.4) can be directly estimable if sufficient data is available. Additional comments are; shift factor of intermediate demand is expressed in $\log b_{1hi}^{k}(p)$ by transportation distance, product innovation, and is expressed in $\log b_{2}^{k}(w)$ by immigration. Once factor demand equations are estimated from empirical data assuming $X_j^S = X_j^D = X_j$, cost function is estimable indirectly from inserting coefficients of factor demand equations to the cost function.

Substitution and Complementarity of Intermediate Demands

Definition of substitution and complementarity for two inputs is stated.

$$\partial x_{ij}^{hk} / \partial p_{\mu}^{\eta k*} > 0 : \text{substitutive}$$

$$\partial x_{ij}^{hk} / \partial p_{\mu}^{\eta k*} < 0 : \text{complementary} \quad \mu \neq i \tag{4.12}$$

x_{ij}^{hk} : Factor Demand of i-th Commodity in h-th Country by j-th Sector in k-th Country

$p_{\mu}^{\eta k*}$: Price of μ-th Commodity in η-th Country received by k-th Country

Allen's elasticity of substitution in MCMS is the following.

$$\sigma_{i\mu,j}^{h\eta,k} = \frac{\left(\dfrac{\partial x_{ij}^{hk}}{\partial p_{\mu}^{\eta k*}}\right) C_j^k}{x_{ij}^{hk} x_{\mu j}^{\eta k}} = \frac{\left(\dfrac{\partial x_{ij}^{hk}}{\partial (1+t_i^h)(e^h/e^\eta) p_{\mu}^{\eta k*}}\right) C_j^k}{x_{ij}^{hk} x_{\mu j}^{\eta k}} \tag{4.13}$$

Economy of Scale

$$SE_j^k = \frac{AC_j^k}{MC_j^k} = \frac{C_j^k / X_j^k}{MC_j^k} \tag{4.14}$$

MC_j^k : Marginal Cost

Rate of Technical Progress

Formula of technical progress of j-th sector in k-th country in virtue of cost function is product of two elements associated with cost function where left hand side is unknown, but elements of right hand side are computed in ease.

$$\frac{\partial \log f_j^k(x,t)}{\partial t} = -\left(\frac{\partial \log C_j^k(X_j^k, p, t)}{\partial t}\right) \times \frac{1}{\dfrac{\partial \log C_j^k(X_j^k, p, t)}{\partial \log X_j^k}} \tag{4.15}$$

Total Factor Productivity(TFP)

TFP of j-th sector in k-th country is straightforward.

$$\frac{d \log TFP_j^k}{dt} = \frac{d \log X_j^k}{dt} - \frac{d \log C_j^k(X_j^k, p, R(t))}{dt} \tag{4.16}$$

$$\frac{d \log C_j^k}{dt} = \left(\frac{\partial \log C_j^k}{\partial \log X_j^k}\right)\left(\frac{d \log X_j^k}{dt}\right) + \sum_{h=1}^{R}\sum_{i=1}^{N}\left(\frac{\partial \log C_j^k}{\partial \log p_i^{hk*}}\right)\left(\frac{d \log p_i^{hk*}}{dt}\right)$$
$$+ \left(\frac{\partial \log C_j^k}{\partial \log R(t)}\right)\left(\frac{d \log R(t)}{dt}\right) \tag{4.17}$$

4.3 Dynamic Pricing of Oligopoly Firms with Product Differentiation

Inputting the estimated coefficients of factor demand equations into cost function, one can calculate the cost function empirically. Profit maximization in use of the cost function leads to monopoly price, but the price does not coincide with the current price; profit maximization could not describe the current price, so that another mechanism other than direct profit maximization has to be provided. Following the line, T. Shibata & H. Kosaka (2011), in Japanese interregional input output system, and H. Kosaka (2011), in Asian international input output system, have introduced conjectural variation in profit maximization to explain the current price. Yet, this paper intends to explain the current price in dynamic way in the absence of conjectural variation. Profit maximization states; $\max_{p_j^k} \pi_j^k = \max_{p_j^k} \{p_j^k X_j^{k(D)} - \widetilde{C}_j^k (X_j^{k(S)}, P^k, w_j^k, r^k, t)\}$, in which $X_j^{k(D)}$ stands for perceived demand function by T. Negishi (1961); the variable $X_j^{k(D)}$ might be real demand function or subjective demand curve differing from the former. The demand function works in profit maximization.

Once A. W. Phillips (1954) has proposed proportionate, derivative and integrated policies as policy response functions in an argument of macroeconomic stabilization policy within multiplier-acceleration model; inversely it would be possible to pose various social welfare functions which are pairs to policy response functions. Utilizing the A. W. Phillips' idea, one could add quadratic loss of price to profit; then, one could design price determination in dynamical way in maximizing profit related objective function. Price setting behavior of oligopolistic firms is assumed to be in disfavor of drastic price change. The quadratic loss is two kinds: increasing rate and difference. The loss of increasing rate is to seek $(p_j^k - p_{j,-1}^k) / p_{j,-1}^k$ to certain level b, which is interpreted to force $(p_j^k - (1+b) p_{j,-1}^k)=0$. The behavior is modeled to put $c_{c1}^k (p_j^k - c_{c2}^k p_{j,-1}^k)^2$ $(c_{p1}^k > 0)$ to objective function. The difference objective is to have c_{p3}^k $(p_j^k - p_{j,-1}^k - c_{p4}^k)^2$ $(c_{p3}^k > 0)$, which is also interpreted to put price difference to particular level c_{p4}^k in gaining finally $p_j^k - p_{j,-1}^k = c_{p4}^k$. Accordingly, profit related objective is altered to the following;

$$\max_{p_j^k} \widetilde{\pi}_j^k = \max_{p_j^k} \left\{ -\frac{1}{2} c_{p1}^k (p_j^k - c_{p2}^k p_{j,-1}^k)^2 - \frac{1}{2} c_{p3}^k (p_j^k - p_{j,-1}^k - c_{p4}^k)^2 + \frac{1}{X_j^{k*}} \left(p_j^k X_j^{k(D)} - \widetilde{C}_j^k\right) \right\}. \tag{4.18}$$

The variable X_j^{k*} stands for normal production, namely denominator for making unit profit; $\partial X_j^{k*} / \partial p_j^k = 0$ is assumed. Optimization makes the first order condition;

$$\frac{\partial \tilde{\pi}_j^k}{\partial p_j^k} = -c_{p1}^k (p_j^k - c_{p2}^k p_{j,-1}^k) - c_{c3}^k (p_j^k - p_{j,-1}^k - c_{c4}^k)$$

$$+ \frac{1}{X_j^{k*}} \left(p_j^k \frac{\partial X_j^{k(D)}}{\partial p_j^k} + X_j^{k(D)} - MC_j^k \frac{\partial X_j^{k(S)}}{\partial p_j^k} \right) = 0 . \quad (4.19)$$

Re-arranging terms for price give the dynamic price formation equation.

$$p_j^k = \frac{c_{p3}^k c_{p4}^k}{\left(c_{p1}^k + c_{p3}^k\right)} + \frac{(c_{p1}^k c_{p2}^k + c_{p3}^k)}{(c_{p1}^k + c_{p3}^k)} p_{j,-1}^k$$

$$+ \frac{1}{(c_{p1}^k + c_{p3}^k)} \times \left(\frac{1}{X_j^{k*}} \right) \times \left(X_j^{k(D)} + p_j^k \frac{\partial X_j^{k(D)}}{\partial p_j^k} - MC_j^k \frac{\partial X_j^{k(S)}}{\partial X_j^{k(D)}} \frac{\partial X_j^{k(D)}}{\partial p_j^k} \right) \quad (4.20)$$

As is seen above, many authors created sophisticated demand mechanism by goods on $X_j^{k\,(D)}$; among others, AIDS model by A. S. Deaton & J. Muellbauer (1980) should be notified. But, our subjective demand is simplified to $\partial X_j^{k\,(D)} / \partial p_j^k = \beta_j^k \times \left(X_j^{k\,(D)} / \; p_j^k \right)$; furthermore we have $X_j^{k*} = X_j^{k\,(D)}$. Demand increase may have supply increase, so that we suppose supply increase will positive response to price level; as a result, we suppose $\partial X_j^{k\,(S)} / \partial X_j^{k\,(D)} = \delta_j^k p_j^k$. These assumptions, inserting to (4.20), will give us the following price determination equation in a final form for practical estimation.

$$p_j^k = \frac{c_{p3}^k c_{p4}^k + 1 - \beta_j^k}{\left(c_{p1}^k + c_{p3}^k\right)} + \frac{(c_{p1}^k c_{p2}^k + c_{p3}^k)}{(c_{p1}^k + c_{p3}^k)} p_{j,-1}^k + \frac{\beta_j^k \delta_j^k}{(c_{p1}^k + c_{p3}^k)} MC_j^k \quad (4.21)$$

The equation indicates; a) increase of marginal cost may cause increase of price in (4.21), b) increase of scale economy may decrease price by $MC_j^k = AC_j^k / SE_j^k$, and the Lerner's monopoly index $LX_j^k = \left(p_j^k - MC_j^k \right) / p_j^k$ will have positive impact on price increase by $MC_j^k = p_j^k \left(1 + LX_j^k \right)$.

<u>Definition of Price at Macro Level</u>

$$p^k = \sum_{i=1}^{N} \left(\frac{\overline{X}_i^k}{\sum_{\mu=1}^{N} \overline{X}_\mu^k} \right) p_i^k \quad (4.22)$$

$\overline{X}_j^k : X_j^k$ at base year

Price at macro level is weighted average of sector prices, in which sector productions in average weights are used at base year.

<u>Wage Rate</u>

Wage rate of j-th sector in k-th country is simply determined by productivity of labor and

expected price, which follows W. J. McKibbin & J. Nguyen (2004).

$$w_j^k = \left(p^{k(e)} \right)^{\beta^k} \left(\frac{X_j^k}{L_j^k} \right)^{\xi_j^k} \quad (4.23)$$

$p^{k(e)}$: expected price

<u>Definition of Non Occupation Ratio</u>

Labor force LF^k in k-th country less total occupation labor of j-th sector L_j^k in k-th country makes non occupation labor, and non occupation ratio UR^k is easily defined:

$$UR^k = \frac{LF^k - \sum_{j=1}^{N} L_j^k}{LF^k} \quad (4.24)$$

5. Other Variables

Fixed investment for each industry is already argued, which might be domestic one; yet, overseas investment of multi-national corporation via foreign direct investment (FDI) should be taken by having another cost function of overseas production. But, this enlarged framework is postponed for future study.

It would be possible to treat inventory investment for short-term behavior as exogenous variable; but, if one counts inventory cost to cost function, one could endogenize the behavior.

On government expenditure, four kinds of modeling could be suggested; a) exogenous variable, b) simple conventional modeling of fiscal policy response function, c) micro foundation of setting government utility function like household, and finally d) dealing government as the leader of Stackelberg game using optimal control theory by G. C. Chow (1975) Among the third approach, T. W. Hertel (1997) in GTAP assumes household has Cobb-Douglas utility allocating private consumption, saving and government expenditure simultaneously. The fifth possibility is, focusing defense spending of government expenditure, to endogenize military spending, which would unveil link of economic behaviors with international relation. (See L. R. Klein, M. Gronicki and H. Kosaka (1992), H. Kosaka (1993))

Export to the other region is promising; unfortunately, the export to EU and BRICS is on the way. (See A. R. Hoen (2002)) In the final step multi-country and multi-sector system cover the whole world.

6. Concluding Remarks

We finish developing multi-country and multi-sector model for the Asian international input output system of Institute of Developing Economies from micro foundation in demand oriented view.

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Alternative Measures of Economic Inequality and Poverty in Japan, Taiwan and Thailand

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Abstract

Using household surveys in Japan, Taiwan and Thailand, the paper estimates the degree of economic inequality and poverty with respect to income and consumption, with three major conclusions. First, the paper found that estimates of inequality are lower when measured by consumption, and the divergence was particularly large for Japan and Taiwan. Second, the paper provides new evidence that it is important to adjust for differences in household size when measuring economic inequality. In particular, I found spurious upward trends in economic inequality of Japan and Taiwan, which largely disappeared after adjusting for the number of equivalent household members. Third, I found a broad agreement between historical trends in economic inequality and poverty rate, with much lower poverty with respect to consumption expenditures compared with more widely-used measures that rely on disposable income.

Keywords: economic inequality, poverty

JEL classification: D63, I32

1. Introduction

While it is still most common to evaluate the degree of economic inequality with respect to income, this conventional approach has been criticized in recent years (Attanasio et al., 2011, Kohara and Ohtake (2011)). The use of income-based inequality measures has several serious problems, such as incomplete reporting of income in household surveys to avoid taxation (especially for incomes from the shadow economy), and the failure to account properly for living standards of aged household members, who may have low incomes, but still could afford relatively high standards of living, by running down the stock of previously accumulated savings.

These problems are less severe when inequality is examined with respect to consumption. The seminal paper by Cutler and Katz (1991) was among the first to pay attention to this alternative measure of economic well-being, and pointed out that economic inequality in the United States is much less severe when measured with respect to consumption, rather than income. Attanasio et al. (2011) also provided more recent inequality estimates for the United States, and basically confirmed the earlier results of Cuttler and Katz (1991) that consumption inequality in the United States is much less severe in comparison with income-based measures.

A number of studies have applied this comparative approach to Japanese household data. For example, Kohara and Ohtake (2010) studied changes in the poverty rate, defined by the headcount ratio of individuals who have less than one-half of median income (or median consumption). Similarly to previous studies with U.S. household data, the paper

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found that the degree of poverty in Japan was less severe with respect to consumption. For example, when the poverty rate was measured by consumption expenditures, the ratio remained stable at around 7.5 percent, while income-based calculations produced the poverty rate of almost 10 percent. Subsequently, Ohtake and Kohara (2011) used a different survey of Japanese households, and confirmed that economic inequality in Japan is lower with respect to consumption. They also considered the sensitivity of an alternative index of inequality, the Gini coefficient, and concluded that the Gini coefficient also shows a lower inequality when it is applied to consumption, rather than income.

In this paper, I will extend the approach of Ohtake and Kohara (2011) to international comparisons of economic inequality in Japan, Taiwan and Thailand, and examine the sensitivity of measured inequality with respect to alternative measures of economic well-being (such as disposable income or consumption expenditures). In addition, the paper will study the sensitivity of measured economic inequality to adjustments for differences in household size. Over the recent decades, Japan, Taiwan and Thailand have experienced a dramatic demographic transformation that greatly reduced the size of typical households, and this historical trend makes these countries well-suited for studying the possible bias in inequality measures when differences in household size are neglected.

This paper deals with three major gaps in previous studies of economic inequality and poverty in Japan, Taiwan and Thailand (a number of representative studies are summarized in Table 1). First, previous studies typically dealt with inequality or poverty in a single country; when international comparisons were made (like, for example, in Tachibanaki and Urakawa (2006)), they usually covered only developed economies. In consequence, there is a particular lack of studies that made international comparisons of Japan with other Asian economies. Second, while consumption inequality was examined for Japanese household data by Ohtake and Kohara (2010, 2011), there remains little evidence for other Asian economies, including Taiwan and Thailand. Hsieh (2004) estimated consumption inequality in Taiwan, but only with respect to housing expenditures. On the other hand, Kurita and Kurosaki (2011) estimated inequality for total consumption expenditures, but they used provinces, rather than households, as the unit of analysis. Third, while the adjustment for different household size were often used in studies for Japanese data (in particular, by

Table 1 Previous studies on inequality and poverty in Japan, Taiwan and Thailand

Paper	Unit of analysis	Income inequality	Consumption inequality	Adjustment for equivalence scales	Poverty rate
(a) Japan					
Ohtake (2005)	Households and income quintiles	Yes (disposable income)	Yes (total consumption)	Yes (square root of household members)	Yes (disposable income and total consumption)
Oishi (2006)	Households	Yes (disposable income)	No	Yes (square root of household members)	Yes (disposable income)
Tachibanaki, Urakawa (2006)	Households	Yes (disposable income)	No	Yes (various adjustment factors)	Yes (disposable income)
Ohtake (2008)	Households	Yes (disposable income)	Yes (total consumption)	Yes (square root of household members)	No
Ohtake, Kohara (2010)	Households and income quintiles	Yes (disposable income)	Yes (total consumption)	Yes (square root of household members)	Yes (disposable income and total consumption)
Ohtake, Kohara (2011)	Households	Yes (disposable income)	Yes (total consumption)	Yes (square root of household members)	Yes (disposable income and total consumption)
(b) Taiwan					
Hsieh (2004)	Households	Yes (disposable income)	Yes (housing consumption)	No	No
(c)Thailand					
Ikemoto (1991)	Households and income deciles	Yes (before-tax income)	No	No	No
Motonishi (2006)	Provinces	Yes (before-tax income)	No	No	No
Kurita and Kurosaki (2011)	Provinces	No	Yes (total consumption)	No	Yes (total consumption)

Ohtake (2005) and Tachibanaki and Urakawa (2006)), the adjustment was not widely used in previous inequality studies for Taiwan and Thailand.

This paper attempted to address the major gaps in previous studies, and calculated a number of alternative measures of inequality and poverty in Japan, Taiwan and Thailand. To preview main findings of this paper, first, I found that consumption inequality was substantially lower compared with income inequality, and the difference was particularly large for Japan and Taiwan. Second, the paper provides evidence that it is important to adjust inequality measures for differences in household size. In particular, without such an adjustments, inequality indices could produce a spurious upward trend, which diapered when income or consumption was normalized by the number of equivalent adults. Third, I found that there was a broad agreement between historical trends in economic inequality and poverty rate, with much lower poverty when it was calculated with respect to consumption expenditures, rather than disposable income.

The paper is organized as follows. Section 2 introduces two inequality measures that will be examined in this paper, the Gini coefficient and the poverty rate. Section 3 describes major adjustments for household size, including estimates of equivalence scales. Section 4 describes major features of household surveys for Japan, Taiwan and Thailand, while Section 5 reports alternative measures of economic inequality and poverty. Section 6 summarizes major conclusions of this study.

2. Measures of economic inequality.

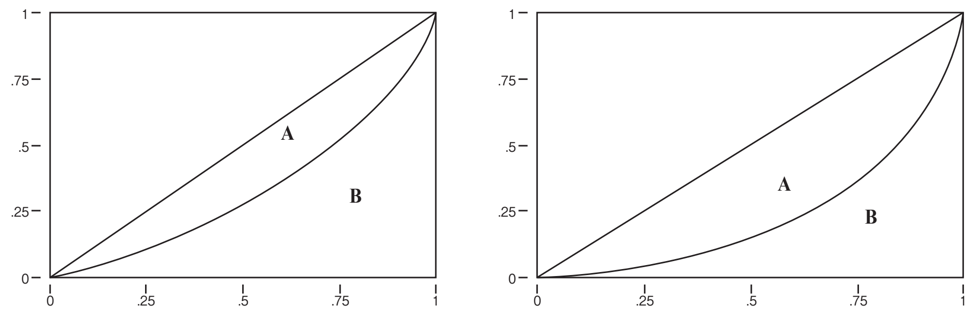
2.1 Gini coefficient

The Gini coefficient is one of the most common measures of economic inequality. The coefficient varies in the range between zero and one, which identify the opposite cases of perfect equality and inequality, respectively. The coefficient is derived from the Lorenz curve, which measures the distribution of economic resources across individuals or households.

Figure 1 illustrates the dependence of the Gini coefficient on particular shapes of the Lorentz curves, using actual distribution of income among Taiwanese and Thai households in 2004 and 1992, respectively. The horizontal axis shows the cumulative proportion of

Figure 1 Derivation of the Gini coefficient from the Lorenz curve

(a) Taiwan (2004) **(b) Thailand (1992)**



households that ranges from 0 to 1. Similarly, the vertical axis shows the cumulative percentage of income that corresponds to a given population share on the horizontal axis.

In the extreme case of perfectly equal income distribution, the relationship between the cumulative shares in population and in income becomes linear (so, for example, 75 percent of households account for exactly 75 percent of the total income). In consequence, the Lorentz curve is located right on the main diagonal between the origin (0,0) and the upper-right point (1,1). With unequal distribution of income, a given percentage of individuals will correspond to a larger share of income, and the Lorentz curve will bend downwards from the main diagonal. Using the example above, 75 percent of households would account for a larger share (say, 90 percent) of the total income.

The Gini coefficient takes advantage of this property of the Lorenz curve, and measures inequality by how much the Lorentz curve deviates from the linear pattern of perfect equality. The coefficient compares the area between the main diagonal and actual Lorentz curve (denoted by area A in Figure 1), and compares it with the total area below the main diagonal (which in Figure 1 contains areas A and B):

$$Gini = 2 \times \frac{area\ A}{(area\ A + area\ B)} \quad (1)$$

In the case of perfect equality, area A is reduced to zero, and so the Gini coefficient also becomes zero. Conversely, in the case of perfect inequality, the Lorentz curve would stretch from the origin (0, 0) to point (0, 1) and then to point (1, 1), with area A coinciding with area B, so the Gini coefficient will approach one.

Actual Lorenz curve in Figure 1 show that the Lorentz curve is much closer to the main diagonal in Taiwan compared with Thailand, indicating a more equal income distribution in former case. In consequence, the Gini coefficient for Taiwan was 0.338, compared with 0.538 for Thailand.

Note that formula (1) gives only the intuition behind the Gini coefficient, and not the actual numerical formula to calculate the coefficient. Several alternative approaches are available, such as the following formula:

$$I_{Gini} = \frac{\sum_{i=1}^{n}\sum_{j=1}^{n}\left|y_i - y_j\right|}{2n^2\overline{y}} \quad (2)$$

with n denoting the sample size, i and j indexing for individuals or households, with y_i and y_j denoting corresponding income or consumption.

In this formula, all possible differences between individuals i and j are evaluated, and normalized by the sample average $\overline{y}$. The total number of comparisons between individuals i and j are given by n^2, while the multiplication by 2 in the denominator adjusts for the numerical identity between $|y_i - y_j|$ and $|y_j - y_i|$.

The standard calculation method in equation (2) is intuitive, but unfortunately the formula requires a large number of computations. For example, some household surveys in Thailand include around 35,000 households, which means that $n^2 = 35{,}000^2 \approx 1.2\times10^9$ differences in $|y_i - y_j|$ should be calculated, squared and summed up. Even with modern personal computers, this involves substantial computational cost.

$$I_{Gini} = \frac{2}{n^2\overline{y}}\sum_{i=1}^{n} i\left(y_{(i)} - \overline{y}\right) \quad (3)$$

Formulas (2) and (3) produce identical values of the Gini coefficient, but formula (3) has a major advantage of much smaller computational burden that is proportional to the sample size n, but not n^2, as in the case of formula (2).

The Gini coefficient can estimate economic inequality with different measures of economic welfare. Though the coefficient has been commonly used to study income inequality, for a number of reasons consumption may be a better indicator of economic inequality than income.

First, in terms of conceptual relevance to measuring welfare, consumption may be a better indicator, or actual living conditions of individuals or households (Deaton, 1997). In particular, the life cycle theory of saving distinguishes aged individuals that have reduced incomes after retirement, but nevertheless could relatively unchanged standards of living, which are fined from the stock of savings, accumulated before retirement. If income is used to measure economic inequality, the effect from the aged population would bias the Gini coefficient towards higher inequality, in comparison with inequality estimates that are calculated from consumption expenditures.

Second, it is common for income to be more volatile than consumption in household surveys. The problem is particularly serious for developing economies, where respondents may be unwilling to state their full incomes (especially their earnings in the shadow economies) to avoid taxation. In contrast, consumptions expenditures are generally not subject to taxation, and this greatly alleviates the problem of under-reporting among survey respondents.

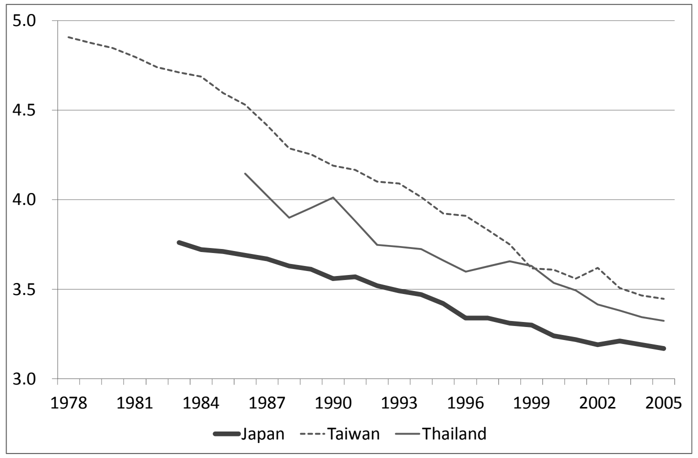
2.2. Poverty rate

In general, the Gini coefficient measures the overall distribution of economic resources among households and individuals, and provides little information whether rising inequality is due to either increased poverty among the poor, or increased wealth among the rich. In contrast, the poverty rate focuses on the poorest part of the population, and measures the share of the poor individuals in the total population. The poor are defined with respect to typical levels of income or consumption, using the median value across individuals or households. The poverty line is then defined by some ratio of the median income and consumption, with the most common choice of 50 percent of the median. Individuals or households with income or consumption below the poverty line are classified as the poor, and their number is counted. The poverty rate is simply the ratio of this count to the total population.

2.3. Adjustment for differences in household size.

As reported in Table 1, it is still very common to measure economic inequality across households, without adjustments for differences in household size. However, this approach may be highly misleading in countries that go through demographic transformations that reduce the size of typical household. Figure 2 illustrates such demographic changes in Japan, Taiwan and Thailand. For example, the size of average Taiwanese household decreased from around 5 to 3.5 household members between the late 1970s and the mid-2000s. Similar declines took place in Japan and Thailand, with all countries currently

Figure 2 Historical change in the size of average household



having less than 3.5 household members.

In general, this change reflects two demographic transitions: first, the declining birth-rate and second, the gradual disappearance of three-generation households which used to be a traditional family pattern in Asia. If these changes in household compositions are ignored, economic inequality may be measured with a serious bias. For example, suppose that relatively affluent households also have a relatively large size. If inequality is measured across households only, the differences in household size will create a positive bias in inequality compared with inequality measures that adjust for differences in household size. On the other hand, if poor households have tendency to be larger in size, then inequality measures per households will be smaller compared with corresponding indices across individuals.

There are two major ways to take into account differences in the household size. The first approach uses estimates inequality using income or consumption, normalized by the number of household members. This approach, however, tends to underestimate the economic well-being of larger families, because it essentially assumes the same living costs for each additional household member. However, some living costs may have a significant economy of scale (most notably, housing costs), which reduce the additional cost with each extra household member.

The second approach explicitly takes into account these economies of scale in living costs. Specifically, rather than assuming equal extra costs, the approach applies a set of decreasing factors that are the largest for the first member of household, but then decrease for successive household members.

Several equivalence scales have been proposed, with major alternatives summarized by Fernández-Villaverde and Krueger (2007). A common equivalence scale was suggested by the Organization of Economic Cooperation and Development (OECD), in which the first household member gets a factor of 1.0. The remaining adult members receive a factor of 0.7, while children receive a uniform factor of 0.5 (OECD, 2008). With this equivalence scale, the family of two adults and two children would include 2.7 equivalent members, rather than 4 in the first approach.

Unfortunately, it was not practical in this study to apply the OECD scale to all household data due to the lack of detailed information about the age composition of household members. Instead, I followed the approach of Ohtake and Kohara (2010, 2011), which normalizes income or consumption by the square root of household size. Like the OECD scale, this approach also assigns a progressively smaller factor for families with more members.

3. Data

Economic inequality is based on household surveys in Japan, Taiwan and Thailand that collect extensive information about household income and consumption. In general, consumption was the total expenditures of households on goods and services, while income was defined as after-tax income, most of which consist of wage income, social security payments and income from real estate and financial assets.

For Japan, I used annual data from the Family Income and Expenditure Survey (FIES), with sample period from 1983 to 2004. The survey is a representative sample of around 8,000 households. One limitation of the survey is that up to the late 1980s, it collected data only for workers' households with two or more members, effectively excluding two important household types households: singles, and households with retired household heads.

For Taiwan, I used annual household data from the Survey of Personal Income Distribution from 1978 to 2004. The survey had a larger sample size than the FIES, including about 16,000 households up to the early 1990s, and then declining only marginally to approximately 14,000 households in recent years.

Household data for Thailand were taken from the Socio-Economic Survey of Thailand between 1986 and 2004. The survey was conducted in irregular intervals over time, initially every two years between 1986 and 1998, then annually between 1999 and 2002, and once again every two years after 2002. Earlier surveys included around 12,000 households, and their number increased substantially in recent years, reaching more than 35,000 households in 2004.

While the Gini coefficient in Taiwan and Thailand was calculated with the raw household data, it was not possible in the case of Japan, where the publicly-available data are not for households per se, but 10 deciles of income, ranging from the poorest to the richest ones. Calculations with such measures produce the 'pseudo-Gini' coefficient of inequality, and are remain a common 'second-best' option when the original raw data are not available (as, for example, in Ikemoto (1991), Ohtake (2005), Khan and Sen (2006), Ohtake and Kohara (2010)).

4. Results

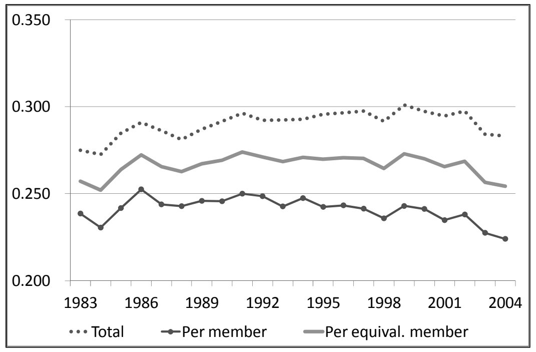
4.1. Estimates of economic inequality..

Figure 3 reports estimates of the Gini coefficient for three definitions of income: the unadjusted total household income, income per household member, and income per equivalent household member (namely, the square root of the number of household members).

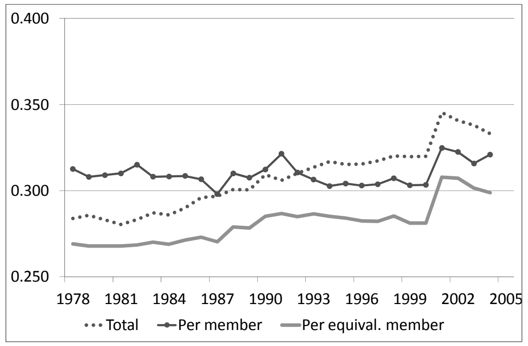
As shown in Panel (a), the Gini coefficient in Japan for the total household income was gradually increasing since the early 1980s, and reached 0.30 in the late 1990s, with only a slight decline in subsequent years. Eventually, the coefficient dropped to 0.28 in mid-2000s, which was close to its level in the mid-1980s. However, when income was normalized by the number of household members, the Gini coefficient moved downward and remained below 0.25 for most of the sample period. Moreover, the increasing trend in inequality

Figure 3 Estimates of the Gini coefficient for income

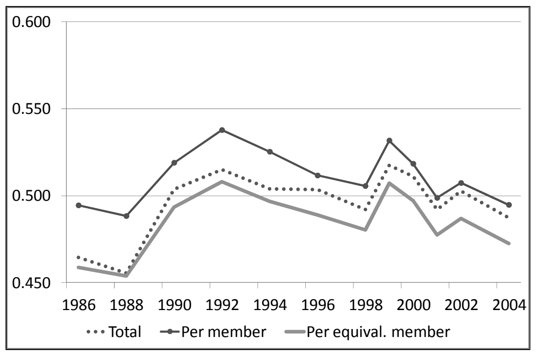
(a) Japan



(b) Taiwan



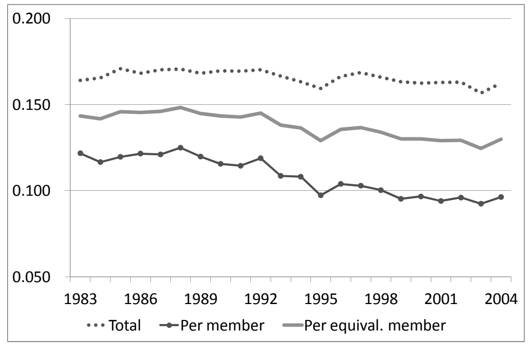
(c) Thailand



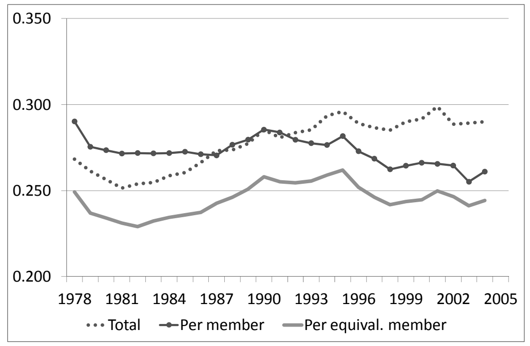
largely disappeared for the second definition of income, with the Gini coefficient even declining since the late 1990s. Finally, when income was adjusted for the number of equivalent adults, the Gini coefficient became largely flat, and did not deviate much from its long-term level of around 0.26. Overall, these divergent trends in income inequality demonstrate that it is important to make proper adjustments for the changing size of Japanese households. In particular, the use of unadjusted income data for total households resulted in spurious rise in income inequality, which completely disappeared after adjustments for differences in household size.

Figure 4 Estimates of the Gini coefficient for consumption

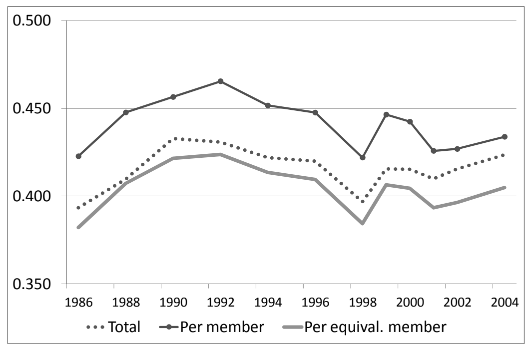
(a) Japan



(b) Taiwan



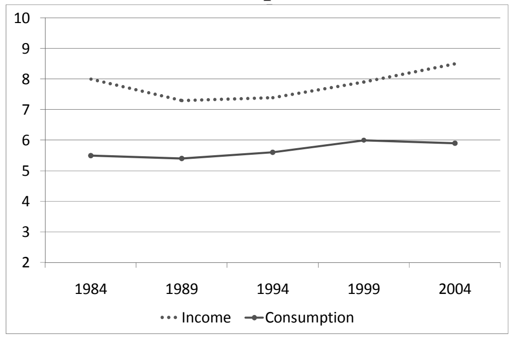
(c) Thailand



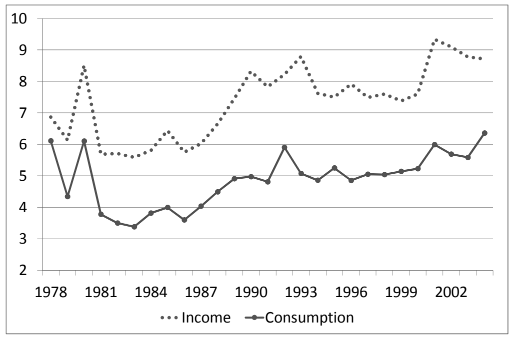
Panel (b) of Figure 3 reports alternative estimates of income inequality in Taiwan, with four noteworthy results. First, the Gini coefficient for the total household income showed a significant upward trend, from 0.27 in the late 1970s to 0.33 in the early 2000s. Second, the adjustment for equivalent household members greatly reduced the degree of income inequality, with the Gini coefficient dropping by about 0.030 (or by about 10 percentage points) over the most of the sample period. Third, the Asian financial crises produced a slight increase in all three alternative measures of income inequality, but the effect was alleviated by the mid-2000s. Fourth, when measured by income per equivalent

Figure 5 Poverty headcount ratio

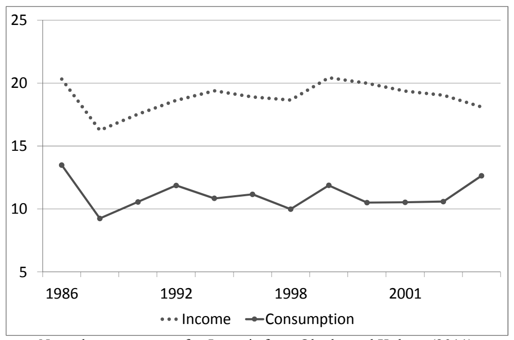
(a) Japan



(b) Taiwan



(c) Thailand



Note: the poverty rate for Japan is from Ohtake and Kohara (2011).

adult, the income inequality in Taiwan remained slightly higher (at around 0.28-0.30) compared with Japan, where the Gini coefficient continued to stay close to the long-term level at around 0.25.

Panel (c) of Figure 3 displays changes in alternative measures of income inequality for Thailand. Overall, not much difference is evident among three alternative Gini coefficients, all of which remained at much higher levels compared to both Japan and Taiwan. Like in Taiwan, the impact of Asian financial crises is evident, with inequality rapidly rising in 1998-1999. Also similarly to Taiwan, the effect of the financial crises turned out short-lived, and largely disappeared by the mid-2000s, with all three Gini coefficients reverting to their pre-crises levels.

Figure 4 reports estimates of the Gini coefficient for household consumption. Similarly to results in Figure 3, three definitions of consumption are used: for the total household, per household member, and per equivalent adult member.

Four major results are noteworthy in Figure 4. First, the extent of consumption inequality was the lowest in Japan, and was followed by Taiwan, with Thailand showing the highest inequality. Second, adjustments for household size were particularly important in Japan and Taiwan. For example, the Gini coefficient for the total household consumption produced an increasing trend, which was no longer evident when consumption was normalized by the number of households members, or by the number of equivalent adults. Third, the effect of the Asian financial crises was much smaller on consumption inequality, with a distinct increase evident only in Thailand. Fourth, while Gini coefficients for income and consumption were broadly similar in Taiwan and Thailand, this was not the case in Japan, where inequality was much lower in terms of consumption expenditures. This particular discrepancy may be attributed a higher proportion in Japan of aged households that have low incomes, but relatively high consumption expenditures, which are financed by running down the stock of life-time savings.

4.1. Estimates of economic inequality.

Figure 5 reports estimates for the poverty rate with respect to income and consumptions, both of which are normalized by the number of equivalent adults. Due to the lack of the raw household data for Japan, it was not possible to estimate the Japanese poverty rate; instead, the figure reports estimates of the poverty rate from Ohtake and Kohara (2011, p. 149).

Three noteworthy findings can be identified. First, in each of three countries, the poverty rate by consumption is consistently lower than the poverty rate by income. For example, Panel (a) shows that the Japan's poverty rate by income is around 8.0 - 8.5 percent, while the rate by consumption drops to around 5.5 – 6.0 percent. Second, the wedge between two alternative measures of poverty is particularly large in Thailand, by around 7-8 percentage points. Third, the rate of poverty in each country turned out remarkably stable over time, with little deviations of long-term values.

5. Conclusions

This paper examined relative changes in income and consumption inequality in Japan, Taiwan, and Thailand, and also changes in relative poverty rates with respect to income and consumption. Three major conclusions can be identified.

First, when calculating inequality indices, it is important to take into account the changing composition of households, in particular, the historical decline in the size of typical households. When the adjustment was not done, and Gini coefficients were calculated for incomes or consumption for households as a whole, there was often a spurious trend of increasing inequality, especially in Japan and Taiwan. However, when incomes or consumption were normalized by the number of household members, the increasing trend in the Gini coefficient often disappeared.

Second, the adjustment for the number of household members also showed that Japan and Taiwan are much more similar in their level of income inequality, especially for the adjustment with the square root of the number of household members. On the other hand, economic inequality in Thailand always remained higher than in Japan and Taiwan. Similarly, the poverty rate in Japan and Taiwan turned out quite similar, with much larger incidence of poverty in Thailand.

Third, results for consumption inequality in Japan, Taiwan and Thailand showed a broadly similar pattern to income inequality. The only noteworthy difference is that consumption inequality in Japan was much lower than income inequality, possibly due to a larger share in Japan of aged households that have low incomes, but which could afford high standards of living, which are financed by running down the stock of previously accumulated savings.

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Empirical Matching Functions and Job Search Competitions in China

Yang Liu*

Abstract

Our study bridges the gap of matching function estimation of the Chinese labor market, and provides empirical evidence for matching functions with three heterogeneous groups of job seekers in China. We find that new hires are not only determined by the contribution of job seekers and vacancies, but also by congestion externalities from other groups of job seekers. Moreover, the result highlights competition among the three groups of job seekers in the matching process, and indicates the potential influences of productivity, job-search services, and economic reform shocks on their matching efficiencies.

Keywords: China, job-worker matching function, congestion externalities, matching efficiencies, productivity

JEL classification: J64, O53

1. Introduction

The matching model has been used widely in labor market issues. It provides a tool for fractional unemployment analysis, and enables the modeling of the contribution of job seekers and vacancies to new hires in an incomplete labor market (See Diamond and Maskin (1979), Blanchard and Diamond (1989), and Pissarides (2000)). Although considerable effort has been made to estimate matching functions for numerous countries, China has been ignored. In order to fill this gap, we specify and estimate matching models for the Chinese labor market and consider heterogeneous job seekers in the matching process.

The segmentation of job seekers is usually based on whether they are employed or unemployed, depending on their employment status (van Ours (1995), Hynninen (2009), etc.). In the urban Chinese labor market, there is another group of job seekers: rural-urban migrants. They are different from employed and unemployed residents because of the strict household registration system. They do not receive unemployment benefits because they are employed for farm work in rural areas, and are not officially recognized as involuntary unemployed persons even if they are unable to find employment. These migrants are more likely to accept a job than permanent residents. Thus, numerous Chinese studies divide job seekers in urban areas into three groups: employed, unemployed, and migrant workers (Knight and Song (1995), Xie (2008), etc.) It must be noted that unemployed persons in urban China only include unemployed urban residents. The three above mentioned job-seeker groups seek employment in the same vacancy pool and possibly compete with each other. In our study, we examine the matching processes of each group as well as competition among the three groups.

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The theoretical background of our study is the job-worker matching model. The conventional aggregate matching function is a regression of new hires on unemployed persons and vacancies[1]. Recently, certain studies have found that biases could arise if employed job seekers and other non-unemployed job seekers are ignored (Broersma and van Ours (1999), Petrongolo and Pissarides (2001), Sunde (2007)). Further, other recent studies have noted that the conventional matching function is influenced by the proportion of heterogeneous job seekers (Hynninen 2009). Thus, in this empirical study of China, we introduce heterogeneous factors of Chinese labor market to the conventional matching function. Further, matching efficiencies are often influenced by exogenous factors; the estimated scales of the matching function enable us to examine the determinants of matching efficiencies of China.

Our data of job vacancies, job seekers, and new hires has been obtained from local labor agencies in China. Every city has its own labor agencies that are operated by the government, and certain cities also have privately-owned labor agencies. Labor agencies provide job services not only at their public halls but also through the internet and newspapers. The quarterly report of the Chinese labor market encompasses job agencies of 100 large cities in the country, and the annual report includes all the official and private job agencies in all the cities of China. In this study, we use provincial data from the annual report of the Chinese labor market. The time period for the data is 1996–2008, with a cross-section of 29 Chinese provinces.

2. Previous Studies

An empirical matching model for the Chinese labor market has not been previously attempted. However, the job-worker matching problem of China has been mentioned in certain studies. Although China is currently experiencing an unprecedented economic boom with high job creation, the unemployment rate continues to be high. Knight and Song (1999) found that the redundancy policies in the late 1990s lead to millions of unemployed urban workers who faced numerous difficulties in the labor market. They seemed to have many difficulties to adapt themselves to new jobs in the market economy. The competitions among job-seeker groups have also been observed (Xie, G. (2003)).

For the study of other countries, there has been considerable discussion on the heterogeneity of job seekers in previous studies. However, the studies that utilize empirical matching functions for this purpose are not common because of data limitations (Petrongolo and Pissarides (2001)). Burgess (1993) examined the competition provided by employed job seekers for the unemployed, using the replacement ratio, the proportion of employed aged 16–19, and other factors to measure the propensity of the employed to engage in search. Van Ours (1995) developed two types of matching function forms to distinguish the case that employed and unemployed job seekers search in the same pool of vacancies and the case that they search in different pools, using a dataset of pooled 24 observations (8 regions over discrete 3 years) in Netherlands. Further, Broersma and van Ours (1999) used approximations for the non-unemployed job seekers (for instance, it is assumed that 10% of the employed work force searches for another job). A more recent study, Hynninen (2009), although do not have data for new hires of each job-seeker group, they introduce composition of job-seeker groups into the total matching function, and found significant heterogeneity of job seekers in matching process. Using different methods to overcome data limitations, previous studies found that it is important to account for the behavior of non-unemployed job seekers in empirical matching functions. This is the starting point of our study.

It is noteworthy that using registered job seeker and vacancies in local labor offices and other public job exchanges is the most common method to collect data for matching function estimation. Although some studies pointed out that there could be workers and job flows outside the local labor office, a more complete dataset usually does not exist. The results obtained by those dataset highly support the theory and usually consist with each other even in different countries; therefore, they are widely accepted.

[1] In empirical literature, matches are usually assumed to be equal to new hires (Petrongolo and Pissarides (2001)). In our study, we do not consider the job-worker contacts that do not result in employment and assume the reject rate after contact is unrelated to job vacancy and job seekers.

3. Empirical Matching Functions of the Three Job-seeker Groups

In this section, we estimate matching functions for the three job-seeker groups in China, and further examine competition among these groups.

3.1 Model

The conventional aggregate matching function is $H^u = aU^{\alpha}V^{\beta}$, where H^u represents new hires from among the unemployed, U represents unemployed job seekers, and V represents the total notified job vacancies (Pissarides (2001)). It must be noted that the estimates could be biased if there are job seekers other than unemployed persons. Therefore, we not only consider the contributions of job seekers and vacancies to the matching result but also introduce variables of congestion externalities, which are important factors in the matching process. The terms of congestion externalities are based on Ibourk, etc. (2004).

The general matching functions for each job-seeker group are given below:

$$H^u = A_u U^{\alpha_u} EUV^{\beta_u},$$

$$H^e = A_e (S^e)^{\alpha_e} EEV^{\beta_e}, \text{ and}$$

$$H^m = A_m (S^m)^{\alpha_m} EMV^{\beta_m},$$

where H^u, H^e, and H^m represent new hires from unemployed, employed, and urban-rural migrant job seekers, respectively. U, S^e, and S^m represent unemployed, employed, and rural-urban migrant job seekers, respectively. Further, A_u, A_e, and A_m are matching efficiencies of unemployed, employed, and migrant job seekers, respectively.

EUV, *EEV*, and *EMV* are efficient job vacancies for unemployed, employed, and migrant job seekers, respectively; they are defined in the following manner: $EUV = V - \lambda^{ue} V \frac{S^e}{S} - \lambda^{um} V \frac{S^m}{S}$, $EEV = V - \lambda^{eu} V \frac{U}{S} - \lambda^{em} V \frac{S^m}{S}$, and $EMV = V - \lambda^{eu} V \frac{U}{S} - \lambda^{em} V \frac{S^m}{S}$, where λ is significantly positive if the other two groups of job seekers cause congestion in job vacancies. We take logarithms of the three general matching functions and use the Taylor approximation to assume that $\ln(1 - \lambda^{ue} \frac{S^e}{S} - \lambda^{um} \frac{S^m}{S}) \approx -\lambda^{ue} \frac{S^e}{S} - \lambda^{um} \frac{S^m}{S}$ in *EUV*, as well as similar terms in *EEV*, and *EMV*. Accordingly, the matching functions can be expressed in the following manner[2].

(a) $\ln H^u_{it} = \alpha_u \ln U_{iu} + \beta_u \ln V_{it} + \partial^{ue} R^e_{it} + \partial^{um} R^m_{it} + c^u_i + c^u_t + \varepsilon^u_{it}$,

(b) $\ln H^e_{it} = \alpha_e \ln S^e_{iu} + \beta_e \ln V_{it} + \partial^{eu} R^u_{it} + \partial^{em} R^m_{it} + c^e_i + c^e_t + \varepsilon^e_{it}$, and

(c) $\ln H^m_{it} = \alpha_m \ln S^m_{it} + \beta_m \ln V_{it} + \partial^{mu} R^u_{it} + \partial^{me} R^e_{it} + c^m_i + c^m_t + \varepsilon^m_{it}$,

where $R^u_{it} = \frac{U_{it}}{S_{it}}$, $R^e_{it} = \frac{S^e_{it}}{S_{it}}$, and $R^m_{it} = \frac{S^m_{it}}{S_{it}}$ (S_{it} is the total number of job seekers).

These variables can be explained as indices of the congestion externalities from other groups of job seekers. α_u, β_u, α_e, β_e, α_m, β_m, ∂^{ue}, ∂^{um}, ∂^{eu}, ∂^{em}, ∂^{mu}, *and* ∂^{me} are coefficients. If other groups of job seekers cause congestion in seeking jobs, the ratios of other groups will have negative effects on new hires; thus, their coefficients will be significantly negative.

3.2 Data

The data for this study has been sourced from approximately 30,000 public and private labor agencies in China (NBS (1999-2008)). The dataset provides the annual number of job seekers belonging to different groups, flow of new hires from each group, and job vacancies at the provincial level. The period is 1996–2008, and the analysis is conducted for a cross section of 29 Chinese provinces[3]. The data for migrants has not been reported separately for the period 1999–2004; thus, the adjusted periods are 1996–1999 and 2005–2008.

3.3 Results

In this study, we examined the endogeneity problem in the Chinese labor market using the Durbin and Wu-Hausman tests. The null hypothesis that the variable under consideration can be treated as exogenous is rejected in eq. (b), but not in eq. (a) and (c). Therefore, we estimate a 3SLS(1) specification with instruments in all equations and a 3SLS(2) specification with instruments only in eq. (b). Further, the relevance and exogeneity of instruments have been examined. For the sake of comparison, we also report the results of OLS, TSLS, GMM, as well as a specification where effects of other job-seeker groups are ignored (in the last column of 3SLS*). The results are reported in Table 1.

The results reveal that all the job-seeker groups and vacancies have statistically significant positive coefficients, and most of the congestion externality terms have significant negative coefficients. Further, it is indicated that a greater number of job seekers or vacancies lead to a greater number of new hires, which supports the matching theory. Moreover, the matching processes are often affected by the congestion externalities of other groups of job seekers, which is consistent with our expectation. Furthermore, it is evident that the comparative estimates in the last column of 3SLS* (effects of other groups of job seekers

2 $\log EUV = \log V + \log(1 - \lambda^{ue}\frac{S^e}{S} - \lambda^{um}\frac{S^m}{S}) \approx \log V - \lambda^{ue}\frac{S^e}{S} - \lambda^{um}\frac{S^m}{S}$, and the same as log*EEV* and log*EMV*.

3 Hong Kong, Macau, Xinjiang, Tibet, and Taiwan are not included.

Table 1 Results of Matching Function Estimation for the Chinese Labor Market

(1) Dependant variable: $\ln H^u_{it}$

Instruments*: $(\ln U_{it}, \ln V_{it})$ $\ln S_{it}$, $\ln S^e_{it}$, $\ln S^u_{it}$

	The Model		Comparison			
	3SLS(1)	3SLS(2)	OLS	TSLS	GMM	3SLS*
$\ln U_{it}$	0.31***	0.38***	0.38***	0.31***	0.30***	0.54***
	(4.7)	(7.4)	(7.4)	(4.2)	(4.4)	(5.0)
$\ln V_{it}$	0.42***	0.34***	0.34***	0.43***	0.43***	0.25**
	(4.6)	(6.5)	(6.5)	(4.1)	(4.3)	(2.7)
$\frac{S^m}{S}$	-0.56***	-0.42**	-0.42**	-0.56**	-0.53**	——
	(-3.0)	(-2.8)	(-2.7)	(-2.6)	(-2.7)	
$\frac{S^e}{S}$	-0.34**	-0.24**	-0.24**	-0.34**	-0.39**	——
	(-2.6)	(-2.3)	(-2.3)	(-2.3)	(-2.8)	
Adj.R^2.	0.95	0.96	0.96	0.95	0.95	0.96
Obsers.	179	183	183	179	179	179
p-value	0.00	0.00	0.00	0.00	0.00	0.00

$H_0: \alpha + \beta = 1$

(2) Dependant variable: $\ln H^e_{it}$

Instruments: $(\ln V_{it})$ $\ln S_{it}$, $\ln S^m_{it}$, $\ln S^u_{it}$

	The Model		Comparison			
	3SLS(1)	3SLS(2)	OLS	TSLS	GMM	3SLS*
$\ln S^e$	0.05***	0.06***	0.05***	0.05**	0.06***	0.11***
	(3.1)	(3.1)	(3.1)	(2.8)	(4.7)	(5.5)
$\ln V_{it}$	1.17***	0.89***	0.89***	1.18***	1.23***	1.29***
	(7.4)	(7.4)	(7.4)	(6.6)	(8.1)	(7.3)
$\frac{S^m}{S}$	-5.21***	-5.10***	-5.10***	-5.22***	-5.30***	——
	(-10.0)	(-8.8)	(-8.8)	(−8.9)	(-11.1)	
$\frac{U_{it}}{S}$	-4.69***	-5.02***	-5.01***	-4.72***	-4.95***	——
	(-8.5)	(-8.4)	(-8.4)	(-7.6)	(-9.3)	
Adj.R.	0.86	0.87	0.87	0.86	0.86	0.78
Obser.	184	184	184	184	184	184
p-value	0.16	0.67	0.67	0.20	0.05	0.02

$H_0: \alpha + \beta = 1$

(3) Dependant variable: $\ln H^m$

Instruments: ($\ln S_{it}^m, \ln V_{it}$) $\ln S_{it}$, $\ln S_{it}^e$, $\ln S_{it}^u$

	The Model		Comparison			
	3SLS(1)	3SLS(2)	OLS	TSLS	GMM	3SLS*
$\ln S^m$	0.40**	0.52***	0.52***	0.44**	0.38**	0.52***
	(2.6)	(7.1)	(7.1)	(2.5)	(2.1)	(3.4)
$\ln V$	0.45***	0.40***	0.40***	0.42**	0.44**	0.45**
	(2.9)	(5.2)	(5.2)	(2.3)	(2.2)	(2.3)
$\frac{U}{S}$	-1.15**	-0.74**	-0.74**	-1.04*	-1.20*	——
	(-2.1)	(-1.9)	(-1.9)	(-1.7)	(-1.7)	
$\frac{S^e}{S}$	-0.59	-0.26	-0.26	-0.44	-0.70	——
	(-1.3)	(-0.7)	(-0.7)	(-0.9)	(-1.6)	
Adj.R.	0.93	0.93	0.93	0.93	0.92	0.92
Obser.	181	185	185	181	181	181
p-value	0.08	0.31	0.32	0.14	0.26	0.64
$H_0: \alpha + \beta = 1$						

Notes: * endogenous variables are in parentheses.

are ignored) are biased, particularly in the unemployed and employed job-seeker groups. Therefore, we can conclude that in the case that congestion externalities are significant, the conventional matching function form could lead to misspecification.

In this study, we also examined returns to scale since it is often of interest in studies of matching functions. We found that the null hypothesis of constant returns to scale is rejected decisively in the matching function of unemployed job seekers; however, it cannot be rejected in the matching functions of employed job seekers and migrants. The estimates and test results indicate that there could be decreasing returns to scale for unemployed job seekers (the sum of coefficients of and is less than one) and constant returns to scale for employed job seekers and migrants.

Further, the results of our model (Specifications (1) and (2)) offer the following indications as empirical evidence of China's labor market. First, among the three groups, the group of rural-urban migrants have the largest impact on the other two groups (–0.56*** and –0.42** in eq. (1) of $\ln H_{it}^u$, and –5.21*** and –5.10*** in eq. (2) of $\ln H_{it}^e$, Specs. (1) and (2), respectively). Second, the group of employed job-seekers is most greatly influenced by congestion externalities (–5.21*** and –4.69*** in Spec. (1) and –5.10*** and –5.02*** in Spec. (2)). Third, externalities of employed job seekers reduces new hires from among the unemployed job-seekers, while there is no significant effect on rural-urban migrants (–0.34** and –0.24** in eq. (1) of $\ln H_{it}^u$ and –0.59 and –0.26 in eq. (3) of $\ln H_{it}^m$).

It is not surprising that rural-urban migrants in China greatly influence other job-seeker groups and receive few congestion externalities from employed job seekers. Firms prefer migrants because of their lower labor and monitor costs. The survey in Guihua Xie (2008) reported that 66% of interviewed urban residents (including 63% employed residents

and 71% unemployed residents) stated that competition from migrants reduces their job opportunities. Further, congestion externalities to migrants particularly from unemployed urban residents also exist. The reason for this could be that city policies protect their residents and occasionally make it compulsory for enterprises to employ a certain proportion of unemployed residents (Knight and Song (2005)).

In this section we estimated the empirical matching functions of China, and confirmed the competitions among job-seeker groups. It must be noted that the matching process is not only influenced by congestion externalities of other job seekers, but also determined by the efficiency of job-worker matching within the group. In the next section, we examine the matching efficiencies of the three job seeker groups.

4. Determinants of Matching Efficiencies of Each Job-Seeker Group

Matching efficiency is defined as the technology variable in matching functions (variables A_u, A_e, and A_m in our model). There is no existing theoretical framework for determining matching efficiency, and previous studies often examined potential determinants on the basis of the actual situation (Destefanis, S. and R. Fonseca (2007)). In China's case, the potential determinants could be labor productivity growth—ΔPRO—(Cahun and Zylberberg 2004), job search services provided by government and private agencies—*SEV*—(Petrongolo and Pissarides 2001), and economic reform shocks—*RES*.

Further, the determinants of matching efficiency may also differ among the three job-seeker groups. Productivity growth could lead to difficulties in finding appropriate jobs if the group of workers undergoes little training; on the other hand, it could benefit the group that undergoes special training that is demanded by new jobs. In China, an important employment policy is to provide job training to unemployed residents. However, on the other hand, the economic reform in late 1990s destroyed millions of inefficient jobs of urban residents, and created new jobs. This threatened the original resident workers, while providing opportunities to migrant workers. We use regression to examine the possible determinants of matching efficiency for each job-seeker group.

In empirical literature, matching efficiency is usually estimated through dummy variables of period, regions, or both (Blanchard and Diamond 1989, etc.). Accordingly, we obtain the matching efficiency of each job-seeker group as $A_u = e^{c_i^u + c_t^u}$, $A_e = e^{c_i^e + c_t^e}$, and $A_m = e^{c_i^m + c_t^m}$ for employed, unemployed and migrant job seekers, respectively. We chose specification (1) for our empirical matching functions.

The data pertaining to job search services is obtained from regional job agencies, and we use annual layoff and unemployment inflow during the economic reform period as the proxy variable of economic reform shocks. Note that economic reform came to an end in the early 2000s; thus, the reform shocks do not influence matching efficiency after 2004. Therefore, we divide our work into two periods: 1997–1998, which is the peak period of economic reform with reform shocks, and 2005–2008 when the period of reform was over and there were no economic reform shocks. The observations have been recorded for a cross section of 29 Chinese province and the results are reported in Table 2.

Coefficients of ΔPRO_{it} in the equations of A_{it}^M are significantly negative, which indicates that the productivity growth has a rather significant negative effect on the matching efficiency of migrants in both the periods. The reason for this could be that the education

Table 2 Determinants of Matching Efficiency in the Chinese Labor Market

Period: 1997–1998			
Dependent Variables	A_{it}^{U}	A_{it}^{E}	A_{it}^{M}
Indep. Varia.			
ΔPRO_{it}	5.4×10^{-5} *	7.9×10^{-5}	-6.4×10^{-5} ***
	(1.8)	(0.6)	(-2.9)
SEV_{it}	4.0×10^{-4} ***	-5.0×10^{-4}	2.0×10^{-4} ***
	(4.4)	(-1.2)	(5.7)
RES_{it}	-3.8*	18.1 **	2.4
	(-1.9)	(2.0)	(1.6)
$RES_{i,t-1}$	4.4**	-18.1 **	-4.0**
	(2.8)	(-2.6)	(-3.6)
Constant	1.1***	2.4***	1.4***
	(5.7)	(3.0)	(10.5)
Adj.R^2.	0.26	0.11	0.37
Period: 2006–2008			
Dependent Variables	A^{U}	A^{E}	A^{M}
Indep. Varia.			
ΔPRO_{it}	3.1×10^{-5} **	-6.1×10^{-5} **	-2.6×10^{-5} ***
	(2.6)	(-2.1)	(-2.4)
SEV_{it}	2.1×10^{-4} ***	-2.0×10^{-4} **	1.3×10^{-4} ***
	(5.3)	(-2.8)	(3.7)
Constant	0.9**	2.2***	1.2***
	(11.3)	(11.2)	(16.3)
Adj.R^2.	0.27	0.10	0.17

level of rural migrants is rather low, and most of them do not receive sufficient job-training; thus, they may find it difficult to adapt to new jobs that require higher skills and greater productivity. However, ΔPRO_{it} has significant positive coefficients in the equations of A_{it}^{U}. It is indicated that higher productivity growth leads to a higher level of matching efficiency of urban residents, which could be a result of the job-training subsidy provided to residents. For the employed job-seeker group, although the productivity growth does not have a significant effect on matching efficiency in the period 1997–1998, it causes a significant reduction in the matching efficiency after the economic reform. This is because when there is a growth in productivity, employed workers may find it difficult to adapt to skills demanded by new jobs.

Further, job search services—SEV_{it}—has rather significant positive coefficients in the unemployed and migrant job-seeker groups, which indicates that job search services in China contribute to an increase in matching efficiency in these groups. However, it appears that job search services do not increase matching efficiency of employed job-seekers and have even led to a decrease in matching efficiency for this group in the period 2006–2008. One possible reason for this is that more job-searching services encourage more on-the-job searches, which leads to congestion within the group of employed job seekers.

Finally, the result indicates that economic reform shocks also influence matching efficiencies. The direct impact is a significant negative effect on the matching efficiencies of unemployed residents (–3.8*). The reason for this could be that residents are not able to adapt to new jobs immediately. However, the effect of reform shocks becomes positive (4.4**) over a period of time. The most important reason for this could be the re-employment promotion policy for unemployed urban residents during the economic reform process. On the other hand, reform shocks have an immediate positive effect on employed and rural-urban migrant job-seekers (18.1** and 2.4) as they are not threatened by job destruction and could benefit from newly created jobs. However, this effect becomes negative over a period of time (–18.1 ** and –4.0**) for the possible reason that the job-seekers in these groups do not receive job-training subsidies and new jobs are given to trained unemployed residents through government policies.

5. Conclusion

We estimated matching functions of unemployed, employed, and migrant job seekers in urban China. We find that the number of new hires is not only determined by the contribution of job seekers and vacancies, but also by congestion externalities from other groups of job seekers. The estimates of congestion externalities are rather significant, and not considering these externalities could lead to misspecification.

Further, we observed heterogeneities of the three job-seeker groups in the matching process. First, the degrees of congestion externalities differ among the three groups: rural-urban migrants cause the greatest congestion externalities in other groups, and employed job seekers receive larger congestion externalities than the other two groups. Second, the influences of matching efficiencies also vary greatly. Although unemployed job seekers underwent job relocation during the economic restructuring in the 1990s, they received most government support for skill training and re-employment. Both productivity growth and job-search services improve their matching efficiency. Moreover, migrant job seekers also benefit from job-search services; however, their matching efficiencies decline as productivity grows because of their low skills and inadequate job training. Further, productivity growth had a negative effect on employed job seekers in the 2000s, and the reason for this could be the lack of further job training to adapt to new jobs.

Overall, we conclude that it is important to incorporate non-unemployed job seekers into the matching process and consider the heterogeneities of job-seeker groups in China. Future research could include a more detailed segmentation of job seekers, effect of endogenous job creation, and determinants of equilibrium unemployment of China.

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Estimating the Local Economic and Environmental Impacts of Two Carbon Tax Policies: the Production and Consumption-based Accountings

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Abstract

We estimate effects of two carbon tax policies on economy and CO_2 emissions in Ibaraki Prefecture by combining a regional computable general equilibrium model and a two-region input-output model. The carbon tax is levied on the basis of Producer Pays Principle (PPP) and User Pays Principle (UPP) which corresponds with the production-based accounting and the consumption-based accounting respectively. The revenue from the carbon tax is recycled to reduce a direct tax. Three main results are obtained from the study. First, although the carbon tax based on the PPP attains higher CO_2 emissions reduction and lower economic loss within the prefecture than the carbon tax based on the UPP, it is found that these are attained through carbon leakage. Second, carbon tax based on the UPP prevents carbon leakage and reduces CO_2 emissions more largely at national level in consumption-based accounting. Third, the carbon tax corresponding with the accounting method reduces CO_2 emissions more largely. This study has an important implication for future local emissions accounting methods and corresponding policies.

Keywords: emission account, carbon tax, carbon leakage, interregional trade, regional computable general equilibrium model, two-region input-output model

JEL classification: C68, D58, H71, H73, P25, Q54, Q58, R15

1. Introduction

Local governments are responsible for stimulating industries and households to reduce CO_2 emissions. This is especially true in Japan where the sources of national CO_2 emissions necessarily fall under the local government. When environmental policies are implemented unilaterally by a local government, the policy may result in increased emissions in the rest of the country, in what is referred to as “carbon leakage”. Although Barker et al. (2007) show that carbon leakage from six EU member states that implemented an environmental tax is unlikely to be substantial, carbon leakage is more likely to occur at the local level where there are lower transport costs and more comparable local market conditions.

To prevent carbon leakage at the local level, CO_2 emissions should be accounted on the basis of the consumption accounting principle, wherein a consuming region is responsible for the CO_2 emitted in the process of producing the energy, goods and services it consumes. However, carbon leakage is likely to occur, given that the current accounting method for CO_2 emissions is based on the production accounting principle, wherein the producing

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region is responsible for the CO_2 it emits through the production of energy, goods, and services. Princen (1999) discusses how consumption ranks among population and technology as a major driver of global environmental change. CO_2 emissions are generated through the final use of all goods and services even imported ones and in this context, a number of studies discuss the consumption-based accounting method for setting climate policy at the national level (Kondo and Moriguchi, 1998; Machado et al., 2001; Munksgaard and Pedersen, 2001; Ferng, 2003; Sánchez–Chóliz and Duarte, 2004; Mongelli et al., 2006; Peters and Hertwich, 2008). This accounting method is suitable for use at the local level because the emissions produced in a prefecture differ from those generated to satisfy consumption within the prefecture as a result of interregional and international trade. Thus, discussion on consumption-based accounting has been emerging at the local level (Dodman, 2009; Larsen and Hertwich, 2009, 2010).

Environmental policy should be implemented in accordance with CO_2 emissions accounting methods. While the aforementioned references apply consumption-based accounting, they set aside environmental policy implementation in consumption-based accounting. A carbon tax is one of the most cost-effective public interventions in reducing CO_2 emissions, and it is simple to implement in accordance with the accounting methods (Peters and Hertwich, 2008). The carbon tax is generally levied on the basis of the Polluter Pays Principle (PPP) according to which, the polluter should pay environmental costs. Although the PPP has been accepted as a background principle with regard to environmental policy, this acceptance does not reflect the idea that environmental change is a matter of consumption rather than solely of production. PPP is unfair for municipalities that export a significant volume of energy-intensive goods; particularly, carbon leakage is likely to take interregional trade into account, along with PPP to reduce production costs.

As a consequence of distinguishing production and consumption responsibilities, there arises the idea of the User Pays Principle (UPP), which advocates that the user of commodities should pay the environmental costs arising from their production. Thus, products should be taxed in the region where they are consumed rather than in the region where they are produced, unless they are also consumed there. Levying a carbon tax based on different principles impacts economic and CO_2 emissions in different way. Therefore, a consideration of UPP points to other new issues in municipal areas, such as the emissions embodied in interregional trade, carbon leakage, and an analysis of regional consumption versus emissions.

In this context, this study evaluates two carbon tax policies along with a reduction in a direct tax implemented unilaterally by Ibaraki Prefecture; this study applies a regional computable general equilibrium (CGE) model to estimate their economic and environmental impacts on Ibaraki Prefecture in the year 2005. Revenue from the carbon tax is used to reduce a direct tax to maintain constant tax revenue. The replicated results are input in a two-region input-output (IO) model for Ibaraki Prefecture and the rest of Japan (ROJ), to estimate the impacts on CO_2 emissions according to two accounting methods. The first carbon tax policy is based on the PPP, which places a burden on production processes; the second one is based on UPP which places a burden on the entire supply side, including imports and transfers from the ROJ. CO_2 emissions are indicated under the two accounting methods namely, production-based accounting and consumption-based accounting to identify carbon leakage that derives from the two carbon tax policies. This paper

complements the existing literature from a policy perspective by providing a set of results derived by combining accounting methods and carbon taxation methods.

2. Methodology

In the context of this study, economic and environmental impacts associated with a carbon tax, calculated on the basis of PPP and UPP are estimated. CO_2 emissions are accounted on the basis of production-based accounting and consumption-based accounting. Turner et al. (2007) argue that a multi-region input-output (MRIO) model is the most appropriate method by which to estimate CO_2 emissions when using consumption-based accounting. Wiedmann et al. (2007) and Wiedmann (2009) review MRIO models used with consumption-based emissions. However, Kainuma et al. (2000) find that the IO model overestimates CO_2 emissions caused by structural changes, whenever demand and supply behaviors change simultaneously due to an assumedly passive supply and the universal Leontief technology. A CGE model is a more suitable tool for estimating the impacts of taxes and recycling revenue, both of which stimulate supply and demand simultaneously and provoke structural changes. Thus, many research studies apply a CGE model to estimate the impacts of a carbon tax and carbon leakage (Gerlagh and Kuik, 2007) and there are several applications to Japan at the national level (e.g. Park, 2004; Takeda, 2007). Partridge and Dan (1998, 2007) review applications of the CGE model to a wide range of regional economic development policy at the local level but there has been a dearth of study of the environmental application of regional CGE models. Although André et al. (2005) and De Miguel-Vélez et al. (2009) each examine the application of the regional CGE model to a carbon tax, they neglect impacts on other parts of the country.

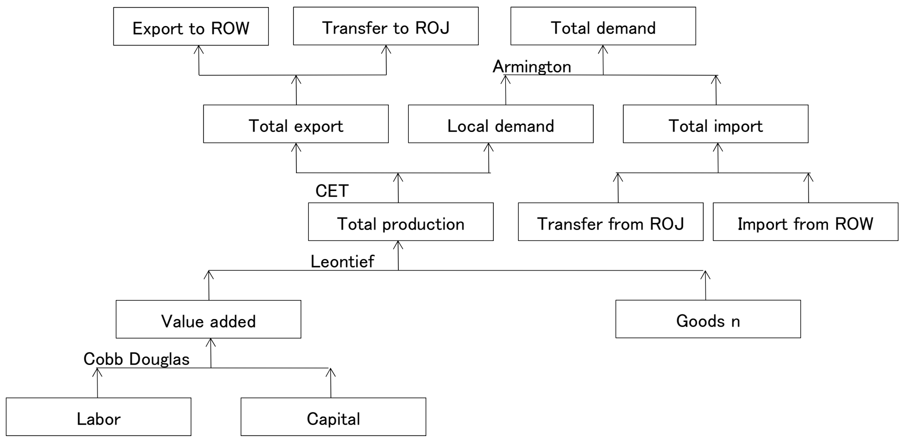
Given this background, we apply two models, a regional CGE model and a two-region IO model in this study. First, we apply the regional CGE model to estimate the economic impacts of a carbon tax and recycling revenue at the prefectural level. Second, the calculated results are input into a two-region IO model to estimate the impacts of a carbon tax on interregional CO_2 emissions. In the following subsections, the models used in this study are explained.

2.1 Regional CGE model

The CGE model is ideally suited to estimate the impacts of a carbon tax, owing to its multi-sector scope and sensitivity to changes in an economy's supply-side dimension. The CGE theory employed in this study is based on the work of Dervis et al. (1982), and It assumes that the market is fully competitive; that is, all economic entities are price takers. The model demands market equilibrium, a relationship of perfect equality between demand and supply in each market. Fig. 1 provides an overview of the flow of goods and related factors in the regional CGE model.

The producer makes decisions driven by his pursuit of profit maximization conditioned by his technological capacity. On the first nest level, the combination of labor and capital is determined by the Cobb Douglas function which takes into account substitution. This is expressed in equation (1)

Figure 1 Overview of the flow of goods and related factors in the regional CGE model



$$\mathbf{QA_{act} = ad_{act} L_{act}^{\alpha_{act}} K_{act}^{1-\alpha_{act}}} \quad (1)$$

where $\mathbf{QA_{act}}$ represents the quantity of output in activity **act; $\mathbf{ad_{act}}$**, the Cobb-Douglas function shift parameter for the production factor in activity **act; $\mathbf{L_{act}}$**, the quantity of the labor in activity **act; $\mathbf{K_{act}}$**, the quantity of the capital in activity **act;** and α_{act}, the Cobb-Douglas parameter for the production factor in activity **act,** which presents consistently with the share of $\mathbf{L_{act}}$ in value-added. Labor units can float among sectors, and their wages are set as the adjustment variable. On the other hand, capital cannot float among sectors; increased capital demand is absorbed by the concomitant increase in the capital price.

On the second nest level, the combination of value-added and goods is determined by way of the Leontief function, in which the intermediate input among sectors is not substitutable and only the primary input-intermediate input ratio changes.

On the third nest level, total production is supplied to either local demand or exports that comprise exports to the rest of the world (ROW) and transfers to the ROJ as determined by the Constant Elasticity Transformation (CET) function. These are explained in equations (2) and (3);

$$\mathbf{QX_{com} = at_{com}\left[deltat_{com} \times QED_{com}^{\tau_{com}} + (1-deltat_{com}) \times QD_{com}^{\tau_{com}}\right]^{\frac{1}{\tau_{com}}}} \quad (2)$$

$$\mathbf{QED_{com} = au_{com}\left[deltau_{com} \times QEC_{com}^{\nu_{com}} + (1-deltau_{com}) \times QE_{com}^{\nu_{com}}\right]^{\frac{1}{\nu_{com}}}} \quad (3)$$

where $\mathbf{QX_{com}}$ represents the quantity of commodity **com; $\mathbf{at_{com}}$**, the CET function shift parameter of commodity **com; $\mathbf{deltat_{com}}$**, the CET function share parameter of commodity **com;** τ_{com}, the CET function substitution elasticity of commodity **com; $\mathbf{QED_{com}}$**, the sum of the exports of commodity **com** to the ROW and the transfers of commodity **com** to the ROJ; $\mathbf{QD_{com}}$, the local demand for the local production of commodity **com; $\mathbf{au_{com}}$**, the CET function shift parameter for the exports of commodity **com** to the ROW and the transfers of commodity **com** to the ROJ; $\mathbf{deltau_{com}}$, the CET function share parameter for the exports of commodity **com** to the ROW and the transfers of commodity **com** to the ROJ; ν_{com}, the CET function substitution elasticity for the exports of commodity **com** to the ROW and the transfers of commodity **com** to the ROJ; $\mathbf{QED_{com}}$, the quantity of the transfers of commodity **com** to the ROJ; and $\mathbf{QE_{com}}$, the quantity of the exports of commodity **com** to the ROW.

On the fourth nest level, total demand is supplied by the local supply, which comprises both local demand and total imports that in turn comprise transfers from the ROJ and imports from the ROW as determined by the Armington function (Armington, 1969). These are explained in equations (4) and (5)

$$\mathbf{QQ_{com} = aq_{com}\left[deltaq_{com} \times QMD_{com}^{-\theta_{com}} + (1-deltaq_{com}) \times QD_{com}^{-\theta_{com}}\right]^{-\frac{1}{\theta_{com}}}} \quad (4)$$

$$\mathbf{QMD_{com} = ar_{com}\left[deltar_{com} \times QN_{com}^{-\rho_{com}} + (1-deltar_{com}) \times QM_{com}^{\rho_{com}}\right]^{-\frac{1}{\rho_{com}}}} \quad (5)$$

where $\mathbf{QQ_{com}}$ represents the quantity of the supply; $\mathbf{aq_{com}}$, the Armington function shift parameter; $\mathbf{deltaq_{com}}$, the Armington function share parameter of commodity **com;** θ, the Armington function substitution elasticity of commodity **com; $\mathbf{QMD_{com}}$**, the sum of the imports of commodity **com** from the ROW and the transfers of commodity **com** from the ROJ; **ar**, the Armington function shift parameter for the imports of commodity **com** from the ROW and the transfers of commodity **com** from the ROJ; $\mathbf{deltar_{com}}$, the Armington function share parameter for the imports of commodity **com** from the ROW and the transfers of commodity **com** from the ROJ; ρ_{com}, the Armington function substitution elasticity for the imports of commodity **com** from the ROW and the transfers of commodity **com** from the ROJ; $\mathbf{QN_{com}}$, the quantity of the transfers of commodity **com** from the ROJ; and, $\mathbf{QM_{com}}$, the quantity of the imports of commodity **com** from the ROW.

The model uses one representative household as a factor of private consumption. The household income comes from labor wage, capital income, a government transfer and a remittance from the ROJ and the ROW. The household pursues utility maximization in consumption, subject to budgetary constraints. The households' demand is determined according to its disposable income and marginal savings rate, while a ratio of sectoral demand is fixed in nominal terms. The household demand is estimated by equation (6)

$$\mathbf{P_{com}^{Q} H_{com}} = \beta_{com}(1-mps)\left[(1-ty)\,Y - prpay - remitpay\right] \quad (6)$$

where $\mathbf{P_{com}^{Q}}$ represents the supply price of commodity **com; $\mathbf{H_{com}}$**, the demand of the household of commodity **com;** β_{com}, a ratio of sectoral demand of the household to total demand of the household of commodity **com;** *mps*, the marginal propensity to save; *ty*, the direct tax rate; *Y*, the income of the household; *prppay*, the property payment; and, *remitpay*, the remittance to the ROJ and the ROW. The sectoral investment and the government expenditure ratio is fixed in real terms.

2.2 Carbon taxes

A carbon tax is included in this model to estimate its impacts. The carbon price is differentiated among commodities in accordance with the different CO_2 emissions generated by producing each commodity. The tax is levied on production prices in the case of PPP, based on the CO_2 emissions of each industry; this indicates the increase of the local production price, the price of transfers to the ROJ, and the price of exports to the ROJ. Thus, the responsibility for reducing emissions falls on the producing region. This is expressed in equation (7);

$$\mathbf{PX_{com}QX_{com}\ (1+tt_{com}) = PD_{com}QD_{com} + PED_{com}QED_{com}\ (1+tt_{com})} \tag{7}$$

where $\mathbf{PX_{com}}$ represents the production price of commodity **com; tt**, the carbon tax rate of commodity **com;** $\mathbf{PD_{com}}$, the local production price of commodity **com;** $\mathbf{QD_{com}}$, local demand for the local production of commodity **com;** and $\mathbf{PED_{com}}$, the price of the exports of commodity **com** to the ROW and transfers of commodity **com** to the ROJ. In the case of UPP, the tax is levied on purchase prices that correspond to the sum of the local production price, the price of the transfers from the ROJ, and the price of the imports from the ROW. This indicates that the carbon tax is transferred among domestic commodities, the import of commodities from the ROW, and the transfer of commodities from the ROJ according to the IO coefficients. The responsibility for reducing emissions thus falls on the consuming region. This is expressed in equation (8);

$$\mathbf{PQ_{com}QQ_{com}\ (1+tq_{com}+tt_{com}) = (PD_{com}QD_{com}+PMD_{com}QMD_{com})\ (1+tq_{com}+tt_{com})} \tag{8}$$

where $\mathbf{tq_{com}}$ represents the indirect tax rate of commodity **com**, and $\mathbf{PMD_{com}}$ the price of the sum of the imports of commodity **com** from the ROW and the transfers of commodity **com** from the ROJ. Thus, the regions that transfer to the ROJ and export to the ROW rebate taxes levied on the products when they are exported, while the regions that transfer from the ROJ and import from the ROW levy the carbon tax on imported products.

2.3 Two-region IO models

The IO model is a widely applied and useful tool for economic analysis at many geographic levels, including local, regional, national and international. The interregional IO model allows us to capture interregional and intersectoral flows of CO_2 emissions associated with products and services. We apply a two-region IO model to estimate CO_2 emissions in the prefecture namely, those driven by the ROJ and those driven into the ROJ to substitute the value calculated by the regional CGE model. Miller and Blair (2009) provide a complete description of the method and the detail of the mathematics of the regional IO model. In this study, the method for calculating total CO_2 emissions is indicated as in equation (9)

$$\mathbf{CO_{2ind} = C_{ind}X = C_{ind}\ (I-TA+\hat{M}A)^{-1}\ (TF-\hat{M}F+E)} \tag{9}$$

where $\mathbf{C_{ind}}$ represents CO_2 emissions per unit of production; **I**, the unit matrix; **T**, the interregional trade coefficient; **A**, the input coefficient; $\mathbf{\hat{M}}$, the import coefficient; **F**, the final demand; and **E**, the quantity of exports to the ROW. We add direct CO_2 emitted from households and private automobiles through the use of electricity, heating oil, and gasoline to the direct CO_2 emissions of the prefecture. We estimate changes in household and private automobile CO_2 emissions as being in proportion to changes in the private consumption of the power generation, gas and heat supply sector; and the petroleum sector. The product of **C** and $\mathbf{TF-\hat{M}F+E}$ corresponds to direct CO_2 emissions. The difference between total CO_2 emissions and direct CO_2 emissions corresponds to indirect CO_2 emissions in this study.

"Total emissions" indicates only emissions in the prefecture associated with activity in the prefecture; CO_2 emissions generated from exports to the ROW are included in both types of production-based CO_2 emissions. This excludes CO_2 emissions driven by the ROJ and driven into the ROJ. In the same way, CO_2 emissions generated by imports from the ROW are excluded in consumption-based CO_2 emissions; this relates to international negotiations, such as those inherent in the Kyoto Protocol, the reduction targets of which are accounted in production-based accounting. Thus, both consumption-based accounting and production-based accounting refer to domestic CO_2 emissions in this study.

2.4 Households CO_2 emissions

CO_2 is emitted by a household through the consumption of kerosene for heating and gasoline for private car uses. This consumption is affected by the carbon tax and the use of revenue from the carbon tax. Household CO_2 emissions are estimated from private consumption in the corresponding sector; as shown in equation (10)

$$\mathbf{CO_{2hou} = C_{hou} \times P^{Q}Q} \tag{10}$$

where $\mathbf{C_{hou}}$ represents CO_2 emissions per unit of private consumption. Thus, household CO_2 emissions change in accordance with changes in the private consumption of electricity and petroleum products that are driven by the carbon tax and the use of revenue from the carbon tax.

2.5 CO_2 emissions from electricity generation

CO_2 emitted from electricity generation is distributed to each final consumer according to the amounts of electricity consumed under laws that help promote measures to mitigate global warming. We represent this in equation (11)

$$\mathbf{CO_{2ele} = \varepsilon \times ele} \tag{11}$$

where $\mathbf{CO_{2ele}}$ represents CO_2 emissions from electricity for each industry and household; ε, CO_2 emission coefficients for electricity; and **ele**, the electricity consumption of each industry and household.

3. Data and cases

The objective region is set as Ibaraki Prefecture. Given the location of an adjacent area of the metropolis, the prefecture mainly comprises energy-intensive industries that satisfy the demands of the ROJ and the ROW. The strong energy-intensive base of the economy generates a high concentration of CO_2 emissions in a production process that originates from transfers to the ROJ and exports to the ROW. The emissions accounting method is largely relevant to the prefecture. The following subsections explain the data used and the cases developed in this study.

3.1 Economic data

The base year is 2005, the year of the most recent available IO table. The base data consist of a prefectural social account matrix (SAM) that depicts monetary interactions among whole economic entities, and comprises an IO table. The SAM is constructed by combining an Ibaraki Prefecture IO table with prefectural economic accounting, both of which are derived from the Ibaraki Prefectural Government (2005 and 2006, respectively). The IO tables for Japan cover the fiscal year, whereas the economic accountings cover the calendar year. Combining these two datasets requires adjustments, if one is to keep the sum of raw goods and the SAM column consistent. This study first derives the total value of intermediate inputs, value-added, intermediate demand and final demand from the prefectural economic accounting. Second, it derives their sectoral share from the prefecture IO table, in order to estimate each sectoral value. Finally, it uses the RAS method to make the sum of raw consistent with the sum of the column for all sectoral interactions. The industry is disaggregated into 28 sectors in accordance with the prefectural economic accounting.

There exist no data concerning substitution elasticity between the ROJ and the ROW. Therefore, the Armington and CET substitution elasticity of local and ROJ commodities; the ROJ and ROW commodities are obtained from Lee (1999). This study applies the rule of two, in which the elasticity of substitution across imports by sources is set to equal twice the elasticity of substitution between domestic goods and imports, as validated by Liu et al. (2003); this serves as the substitution elasticity between the ROJ and the ROW. Although this assumption seems *ad hoc*, these parameters do not affect the analytical results, since the relative price between the ROJ and the ROW is constant. The indirect tax rate, the marginal propensity to save, and the direct tax rate are calculated from the SAM data. Non household consumption is integrated into household consumption for the demand side and into labor for the supply side. The net operating surplus is integrated into the capital, and in the SAM, the sum of the indirect tax and the current subsidy is expressed as an indirect tax. The local government, the social security funds, the outpost agency, and the central government are aggregated as a single government body since they behave in economically analogous ways. This study does not employ data concerning borrowing from the ROJ and the ROW, or foreign investment; rather, these are calculated as the difference between raw and column of the SAM.

3.2 Environmental data

The national amount of sector-based energy consumption is available from the energy balance table compiled by the Agency for Natural Resources and Energy (2007). To convert energy consumption into CO_2 emissions, we multiply the CO_2 emissions coefficients compiled by the Ministry of Environment (2010). CO_2 emission coefficients of lubrication are set to zero, under the assumption that no lubrication is used as energy. Also, CO_2 emissions coefficients of naphtha are set to zero since the consumption of naphtha occurs in

non energy-related contexts. We use region specific information for the CO_2 emission coefficients of electricity. The CO_2 emission coefficients of electricity of Ibaraki Prefecture are derived from the Tokyo Electric Power Company which supplies electricity to the prefecture. We apply national average coefficients of electricity to derive the CO_2 emission coefficients of electricity for the ROJ. We adopt a short-term approach, so that the production technology and pollution intensity of all sectors are assumed to be fixed.

3.3 Carbon tax and cases

A carbon tax forces the market to internalize the cost of generating CO_2 emissions. The total cost is minimized with the internalized external cost of CO_2 emissions because each polluter is free to choose the most efficient way of complying with environmental targets. In Japan, discussions of the rate of a carbon tax are as wide-ranging as those of how it should be implemented. At the local level, the Canadian province of British Columbia in 2008 introduced a carbon tax of CAD 30 per ton of CO_2 emissions (Duff, 2008). Japan has discussed the introduction of a carbon tax at both the national and prefectural levels. The nonprofit organization Japan Center for a Sustainable Environment and Society (JACSES) maintains that an efficient carbon tax rate ranges from JPY1,600 to JPY 4,000 yen per ton of CO_2 emissions. On the basis of these discussions, we set a tax rate of JPY 3,000 per ton of CO_2 emissions in this study.

As to the use of carbon tax revenue, we select a reduction of a direct tax. According to current law, direct tax is relevant to the local tax system. We expect that the carbon tax would create negative incentives for production, particularly among energy-intensive industries, and that revenue from the carbon tax would have positive effects on the disposable incomes of households.

We examine two different policies namely, the PPP case and the UPP case to identify the economic and environmental impacts of the different taxation methods. The cases introduce two different carbon taxation methods by two different payer principles. In the PPP case, the carbon tax is levied on the commodities that the industries in Ibaraki Prefecture produce. In the UPP case, meanwhile, the carbon tax is levied on the commodities that the industries and households in Ibaraki Prefecture consume.

4. Results

Economic and environmental impacts are evaluated by combining the regional CGE model and the two-region IO model when the carbon tax is imposed on Ibaraki Prefecture, based on the two different payer principles. First, we focus on the impacts of the carbon tax on the prefectural economic. Second, we identify the impacts of the carbon tax on CO_2 emissions in Ibaraki Prefecture and interregional CO_2 emissions with ROJ.

4.1 Economic impacts

Table 1 shows the economic impacts on Ibaraki Prefecture. While private consumption and investment increase by JPY 1,790.8 and JPY 8,342.2 million, respectively in the PPP case, they decrease by JPY970.8 and 40,946.5 million in the UPP case. This difference occurs for two reasons. First, in the UPP case, the share of taxation is large for the tertiary industries, which largely supply private consumption and investment. Energy-intensive industries mainly export to the ROW and transfer to the ROJ, whereas the tertiary industries largely transfer from the ROJ in the prefecture. Second, reducing the direct tax increases the disposable income of a household and thus contributes to an increase in private consumption. Revenue from the carbon tax is higher in the PPP case than in the UPP case in accordance with the share of the taxation among industries.

While labor decreases by JPY16,200.0 and JPY22,471.0 million in the PPP case and UPP case respectively, the real gross regional production (GRP) decreases more moderately, by JPY60.0 and JPY5,571.5 million, respectively. The carbon tax decreases both the real GRP and labor, through by incrementally increasing the production costs. The reduced direct tax contributes to an increase in private consumption and GRP; however, it also contributes a small amount to labor. Although the carbon tax and the recycling carbon tax revenue stimulate a structural switch from energy-intensive industries to tertiary industries, the overall real GRP decreases in both cases.

Table 2 shows the trade impacts on Ibaraki Prefecture. While transfers to the ROJ and exports to the ROW decrease by JPY10,501.5 and JPY2,071.5 million in the PPP case, they increase by JPY20,178.9 and JPY4,269.1 million in the UPP case, respectively. The increased production costs associated with the carbon tax reduce the prefecture's competitiveness in the PPP case. In the UPP case, however, local demand including

Table 1 Economic impacts on Ibaraki Prefecture (JPY million)

	PPP	UPP
Private consumption	1,790.8	-970.8
Investment	8,342.2	-40,946.5
Real GRP	-60.0	-5,571.5
Labor	-16,200.0	-22,471.0

Table 2 Trade impacts on Ibaraki Prefecture (JPY million)

	PPP	UPP
Transfers to ROJ	-10,501.5	20,178.9
Exports to ROW	-2,071.5	4,269.1
Transfers from ROJ	-1,582.3	-13,555.6
Imports from ROJ	-1,105.6	-259.4

intermediate demand decreases on account of the carbon tax. This encourages industries to transfer to the ROJ and export to the ROW given the relatively higher demand in the UPP case.

The transfers from the ROJ and the imports from the ROW decrease by JPY1,582.3 and JPY1,105.6 million in the PPP case and JPY13,555.6 and JPY259.4 million in the UPP case. The reduced local demand induced by the carbon tax, leads to lower demand outside the prefecture, in both cases. While the lower rate of imports from the ROW is larger in the PPP case, the rate of the transfers from the ROJ is larger in the UPP case. The imported goods from the ROW comprise mainly material and machinery goods consumed by industries as intermediate goods; on the other hand, the goods transferred from the ROJ comprise mainly the tertiary industries that are mainly consumed by the household. The intermediate demand decreases in the PPP case, and production costs are higher. Private consumption decreases, as explained for the UPP case. Thus, different propensities are shown between imports from the ROW and transfers from the ROJ between the two cases.

4.2 CO_2 emissions

Table 3 shows changes in CO_2 emissions in Ibaraki Prefecture. Total CO_2 emissions decrease by 6,773.5 tCO_2 and 3,048.6 tCO_2 in the PPP case and UPP case respectively, owing to the carbon tax. The carbon tax and recycling revenue derived from the carbon tax clearly bring about a decrease in total CO_2 emissions. In the UPP case, indirect CO_2 emissions increase by 6,620.1tCO_2, whereas the direct CO_2 emissions decrease by 9,668.7tCO_2. Increased prices of imports from the ROW on account of the carbon tax bring about a relatively lower demand for imported goods than local goods in the production sectors. Increased intermediate demand for local goods results in a lower import ratio and a higher self-sufficiency rate, both of which increase indirect CO_2 emissions in the UPP case. While the imports from the ROW decrease in the PPP case, the indirect CO_2 emissions

Table 3 Changes in CO_2 emissions in Ibaraki Prefecture (tCO_2)

	PPP	UPP
Total CO_2 emissions	-6,773.5	-3,048.6
Direct CO_2 emissions	-5,690.4	-9,668.7
Indirect CO_2 emissions	-1,083.0	6,620.1
CO_2 emissions driven by ROJ	-598.4	720.9
CO_2 emissions driven into ROJ	3,865.8	-15,477.9

decrease in the UPP case. Local goods used to satisfy intermediate demand decrease in volume to a relatively greater extent than import goods from the ROW owing to the carbon tax and based on the PPP; consequently, the import ratio increases in the PPP case. Although the GRP falls more markedly in the UPP case, the decrease in CO_2 emissions is lower than in the PPP case. This indicates that the carbon tax on the basis of the UPP is more distorted and inefficient with the current accounting method.

Changes in the CO_2 emissions, as driven by the ROJ, are determined by changes in transfers to the ROJ. Thus, with regard to changes in transfers to the ROJ, CO_2 emissions driven by the ROJ decrease by 598.4 tCO_2 in the PPP case while they increase by 720.9 tCO_2 in the UPP case (Table 2). Changes in CO_2 emissions driven into the ROJ are determined by changes in transfers from the ROJ. However, while transfers from the ROJ decrease in the PPP case -as is shown in Table 2- the CO_2 emissions driven into the ROJ increase. The machinery industry, which intrinsically induces CO_2 emissions across borders through intermediate inputs from energy-intensive industries, increases transfers from the ROJ. The machinery industry impacts on the transfers from ROJ in monetary terms, but to only a very small extent. CO_2 emissions driven into the ROJ increase, in contrast with the decrease in transfers from the ROJ. Increases in CO_2 emissions in the ROJ on account of the carbon tax in the prefecture indicate that carbon leakage occurs in the PPP case. On the other hand, carbon leakage is prevented in the UPP case, as CO_2 emissions driven into the ROJ decrease.

Table 4 shows the change in CO_2 emissions in Ibaraki Prefecture based on two different types of accountings; production-based accounting and consumption-based accounting. In production-based accounting, the prefecture is responsible for the sum of the total CO_2 emissions and CO_2 emissions driven by the ROJ. In consumption-based accounting, the prefecture is responsible for the sum of the total CO_2 emissions and CO_2 emissions driven into the ROJ. CO_2 emissions decrease by 7,371.9 tCO_2 in the PPP case and 2327.7 tCO_2 in the UPP case, when we account for CO_2 emissions through the use of production-based accounting; with consumption-based accounting, these items decrease by 2,907.7 tCO_2 and 18,526.6 tCO_2 respectively. Thus, we find that a larger decline in CO_2 emissions is observed when a carbon tax is imposed in line with the emissions accounting. When a carbon tax is imposed in a way different than that consistent with emissions accounting, the reduction effect is decreased to one-third in the production-based accounting and one-seventh in consumption-based accounting. This is due to the fact that transfers from the ROJ increase in the PPP case and transfers to the ROJ increase in the UPP case.

Local governments are required to choose a method of accounting for prefecture-level CO_2 emissions and take appropriate actions. The decrease in CO_2 emissions in the

Table 4 Changes in CO_2 emissions based on different forms of accounting (tCO_2)

	PPP	UPP
Production-based accounting	-7,371.9	-2,327.7
Consumption-based accounting	-2,907.7	-18,526.6

consumption-based accounting and in the UPP case is larger than that seen in production-based accounting and in the PPP case. Since regions outside the prefecture remain unchanged, the change reflects only the impacts of the carbon tax imposed by the prefecture. This explains how a decision by one prefecture can have knock-on effect on other prefectures.

4.3 Varying Armington function substitution elasticity and CET function substitution elasticity

In this analysis, Armington function substitution elasticity and CET function substitution elasticity are key determinants of the impacts of two different carbon tax policies. However, these parameters are borrowed from a previous study (i.e., Lee,(1999)). These parameters are estimated differently, and the resulting uncertainty might affect the results obtained above. Sensitivity analysis is conducted for these parameters. CO_2 emissions for two tax policies, based on two accounting principles, are calculated with a 10% increase in these parameters and are shown in Table 5 and Table 6.

CO_2 emissions decrease as Armington function substitution elasticity increases, since the imports from the ROW increase. However, the impacts thereof are negligible since the Armington function substitution elasticity of all sectors, as estimated by Lee (1999), exceeds 1.0. On the other hand, a 10% increase in CET function substitution elasticity affects CO_2 emissions to a greater extent due to the fact that CET function substitution elasticity never exceeds 1.0, as estimated by Lee (1999). CO_2 emissions increase as per both accounting methods when exports increase, as they respond more to the carbon tax. The increase in the UPP case is larger, due to a larger increase in exports; this is consistent with the results of analysis in subsection 4.1.

The sensitivity analysis generates the same observation as that in the analysis in subsection 4.2. This implies that the discussed results can be found regardless of Armington function substation elasticity or CET function substitution elasticity.

Table 5 Impacts of a 10% increase in the Armington substitution elasticity (tCO_2)

	PPP	UPP
Production-based accounting	-7,372.0	-2,328.4
Consumption-based accounting	-2,907.8	-18,527.4

Table 6 Impacts of a 10%increase in the CET substitution elasticity (tCO_2)

	PPP	UPP
Production-based accounting	-7,320.1	-1,976.3
Consumption-based accounting	-2,847.4	-17,927.3

5. Conclusion

This study addresses issues relating to carbon leakage in order to evaluate two alternative carbon tax policies at the local level. We develop a theoretical methodology to estimate the effects of a carbon tax based on the two different emissions accounting methods by combining a regional CGE model and a two-region IO model for the case of Ibaraki Prefecture. In addition, we take into account recycling revenue from the carbon tax. The following three observations are drawn from the results.

First, real GRP decreases more moderately and total CO_2 emissions decrease to a greater extent in the PPP case. This reflects the industrial characteristic of Ibaraki Prefecture which contains a high share of energy-intensive industries and where the tax would be imposed on a relatively larger scale in the PPP case. This would contribute to a decrease in CO_2 emissions there. Moreover, revenue from the carbon tax would be used to reduce the direct tax; as a result, private consumption would increase, which would in turn accelerate a structural switch to tertiary industries ultimately leading to a moderate decrease in real GRP.

Second, although the PPP case indicates higher real GRP and lower total CO_2 emissions than the UPP case, these are attained through carbon leakage. While transfers to the ROJ decrease in the PPP case, they increase in the UPP case, moreover, transfers from the ROJ decrease on a larger scale in the UPP case than in the PPP case. Accordingly, CO_2 emissions driven by the ROJ decrease in the PPP case and increase in the UPP case, and CO_2 emissions driven into the ROJ increase in the PPP case and decrease in the UPP case. In this sense, it is identified that the total CO_2 emissions are reduced through carbon leakage, making unilateral policies vulnerable in the PPP case. In addition, it has been proved that imposing a carbon tax based on UPP prevents carbon leakage.

Third, CO_2 emissions decrease to a greater extent with consumption-based accounting in the UPP case. CO_2 emissions in consumption-based accounting in the UPP case are lower than those in production-based accounting in the PPP case. In this sense, imposing a carbon tax based on the UPP is more effective than that based on the PPP, when a carbon tax is imposed in accordance with the accounting methods; this is due to the fact that carbon leakage is prevented in consumption-based accounting. This occurs irrespective of Armington substitution elasticity and CET substitution.

The results have important implications, not only from economic and environmental viewpoints, but also from the political viewpoint. CO_2 emissions are currently accounted on a PPP basis at the local level, although this entails carbon leakage. This is due to the fact that a carbon tax on the basis of UPP incurs high political costs. Moreover, any decision by one prefecture will have a knock-on effect on other prefectures. Since the consumers of a prefecture where a local carbon tax is imposed on a UPP can easily travel to other prefectures to acquire high carbon content commodities, the carbon tax cannot prevent carbon leakage at the local level, unlike with international trade. To prevent carbon leakage, first, consumption-based accounting should be established in collaboration with other local governments. Second, local governments need to implement policy that reduces CO_2 emissions on the basis of UPP to decrease national CO_2 emissions.

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