Purchasing Power Parities and Multilateral Comparison of Input-Output Structures - 2000 Real Input-Output Tables of Japan, China and Republic of Korea

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1. Introduction

We are researching on international comparisons of labor productivities and energy efficiencies. For this purpose, we need not only nominal input-output tables but also real input-output tables. National input-output tables are in national currencies at national price levels. Nominal input-output tables are in a common currency at national price levels. They are converted from national input-output tables by using official exchange rates. Real input-output tables are in a common currency at a uniform price level. They are converted from national input-output tables by using purchasing power parities.

We tried to estimate binary purchasing power parities between Japan and China and between Japan and Republic of Korea several times. This time we try to estimate multilateral purchasing power parities among Japan, China and Republic of Korea. And by using them, we try to convert from national input-output tables of these three countries to real input-out tables.

There are many methods to calculate purchasing power parities, which preceding researchers invented. Of these methods, we think Geary-Khamis method is the best for the purpose of converting input-output tables. Therefore first we try to calculate purchasing power parities by using Geary-Khamis method. Secondary we bring up our original method - expression of purchasing power parities based on international average total labor model, and by using this method we calculate new unique purchasing power parities. At the end, by using these purchasing power parities, we convert national input-output tables to real input-output tables and compare them.

2. Desirable properties of purchasing power parities and real input-output tables

We think that the following three properties are important.

Additivity: real value of aggregated item = the total of real values of disaggregated item

Base-Country Invariance: When base-country is changed, relative sizes among countries are not changed.

Transitivity: a/b and b/c are consistent with c/a

Especially additivity is very important to keep merit of input-output tables.

Real input-output tables of multi-countries must be expressed in a set of common prices. We can express them in three kinds of common prices.

i. Prices of base country: This method is called Paasche method. This method satisfies additivity and transitivity, but does not satisfy base-country invariance.

ii. Average prices of multi-countries: A representative of these methods is Geary-Khamis method. These methods satisfy additivity, base-country invariance and transitivity.

iii. Prices based on economic theory: These methods satisfy additivity and transitivity. And if relative prices based on economic theory are not affected by choice of base-country, then that method also satisfies base-country invariance. We bring up our original unique method based on international average total labor model. Our method is one of these methods.

EKS method does not satisfy additivity. For this reason, we think EKS method is not good as purchasing power parities by using which we convert input-output tables.

3. Our procedures for estimation of purchasing power parities and real input-output tables

We have aggregated Japanese, Chinese and Korean input-output tables into common 28 sector classification. These input-output tables have 28 domestic sectors (rows and columns) and 1 import row. We estimate purchasing power parities by this 28 sector. Our procedure consists of two stages like ICP.

i. First stage: Estimation of purchasing power parities of individual industries

i-1. Estimation of binary purchasing power parities of individual industries

We collected price data which are available in each both countries, namely Japan and China, Japan and South Korea, and China and South Korea. We calculated purchasing power parities by commodity, and classify them into the above-mentioned 28 sector, and calculate geometric mean of them in every sector. These results satisfy base-country invariance, but do not satisfy transitivity. In order to satisfy transitivity, next procedure is necessary.

i-2. Estimation of multilateral purchasing power parities of individual industries

In order to satisfy transitivity, we apply EKS method to the above results.

$$\mathrm{EksPPP}_{JPN/CHN} = \left[\left(\mathrm{BinaryPPP}_{JPN/CHN}\right)^{2} \times \left(\mathrm{BinaryPPP}_{JPN/ROK}\right) \times \left(\mathrm{BinaryPPP}_{ROK/CHN}\right) \right]^{1/3}$$

$$\mathrm{EksPPP}_{ROK/JPN} = \left[\left(\mathrm{BinaryPPP}_{ROK/JPN}\right)^{2} \times \left(\mathrm{BinaryPPP}_{ROK/CHN}\right) \times \left(\mathrm{BinaryPPP}_{CHN/JPN}\right) \right]^{1/3}$$

$$\mathrm{EksPPP}_{ROK/CHNN} = \left[\left(\mathrm{BinaryPPP}_{ROK/CHN}\right)^{2} \times \left(\mathrm{BinaryPPP}_{ROK/JPN}\right) \times \left(\mathrm{BinaryPPP}_{JPN/CHN}\right) \right]^{1/3}$$

By using these results, we can convert national input-output tables of these three countries from prices of each country into prices of base-country. In this method, relative sizes of gross domestic products of total industries in these three countries vary according to choice of base-country. Namely, concerning each industry, base-country invariance and transitivity are satisfied, but concerning more aggregated industry and total industries, they are not satisfied. In order to satisfy them, next procedure is necessary.

ii. Second stage: Estimation of purchasing power parities of total industries

If input-output tables of all the countries are expressed in common prices which do not vary according to choice of base-country, then base-country invariance and transitivity are satisfied. There are some alternative sets of such prices. First, weighted averages of actual prices in all the countries. This is called Geary-Khamis method. Second, prices which are proportion to international average total labor quantity inputted in the commodity.

A. Geary-Khamis (GK) method

We calculate GK purchasing power parities by using results of **i-2** and input-output tables.

π: average price (unknown)
ppp: purchasing power parity (unknown)
p: price (price in each currency for the volume which is priced at a unit of base-country-currency in base-country.)
q: quantity (domestic product and import valued in base-country-currency)
i:commodity (28 sectors and import)
j:country (Japan, China, Republic of Korea)

$$\pi_i = \sum_{j=1}^{n} \frac{p_{ij}}{ppp_j} \left[\frac{q_{ij}}{\sum_{j=1}^{n} q_{ij}} \right] \qquad (i=1,\ldots,m) \qquad (1)$$

$$ppp_j = \frac{\sum_{i=1}^{m} p_{ij} q_{ij}}{\sum_{i=1}^{m} \pi_i q_{ij}} \qquad (j=1,\ldots,n) \qquad (2)$$

$$\sum_{i=1}^{m} \pi_i q_{ib} = \sum_{i=1}^{m} p_{ib} q_{ib} \qquad (b=\text{base country}) \qquad (3)$$

B. Our new method based on international average total labor model

We usually measure volumes of individual product by using each physical unit, for example, iron: ton, rice: ton, electricity: watt-hour etc. We can not measure volumes of aggregate of products which have different physical characteristics and different uses by using usual physical unit. We can measure them by using the special unit which is the international average volume one person produces of each aggregate of various products in one year. In this case, the change in aggregate volume is the average of changes of individual product volumes, in which weight is international average labor quantity inputted in products.

1) By using national input-output tables in national currency, we calculated total labor quantity

t: total labor, row vector
A: input coefficient of domestic material, matrix
D: consumption coefficient of domestic fixed capital, matrix
e: share of commodity in export, column vector
m: input coefficient of import material + consumption coefficient of import fixed capital, row vector
r: direct labor, row vector

$$\mathbf{t} = \mathbf{t}(\mathbf{A} + \mathbf{D}) + \mathbf{t} \cdot \mathbf{e} \cdot \mathbf{m} + \mathbf{r} \qquad (4)$$

If we solve (4) concerning t

$$\mathbf{t} = \mathbf{r}(\mathbf{I} - \mathbf{A} - \mathbf{D} - \mathbf{e} \cdot \mathbf{m})^{-1} \qquad (5)$$

'**t**' is total labor quantity per national currency unit.

2) By using results of **i-2**, we converted total labor quantity from per national currency unit into per base- country currency unit.
3) We calculated international average total labor quantity per base- country currency, by using supply as weight. It is international average total labor price that is proportion to international average total labor quantity. International Labor Yen is the international average total labor price where Japanese total supply in International Labor Yen = Japanese total supply in Japanese Yen.
4) By using results of 3), we converted national input-output tables from in national currency into in International Labor Yen.

4. Concerning calculation results

Table 4 shows that in the case we use Japanese prices as common prices, China's GDP is 1.793 times as large as Japan's GDP, but in the case we use China's price, China's GDP is 1.028 times as large as Japan's GDP. In the former case, China's size is much larger than Japan's size, but in the latter case these two sizes are nearly the same. This is because relative sizes of China to Japan in agriculture and light industries are larger than those in heavy chemical industries, while prices of agriculture and light industries in China are much lower than those in Japan, but prices of heavy chemical industries in China are not so much lower than those in Japan, then ratios (=weight) of agriculture and light industries in China's prices are larger than those in Japan' prices and ratios (=weights) of heavy chemical industries in Chin's prices are smaller than those in Japan' prices. Republic of Korea's relative size to Japan's size does not varied so much as China's relative size with which country's prices.

Gk's results show that China's GDP is 1.356 times as large as Japan's GDP. Relative size of China's GDP in GK is intermediate between the relative size in China's prices and the relative size in Japan's prices or in Republic of Korea's prices. It is natural because GK's prices are weight-averages of these three country's prices. Republic of Korea's relative size in GK is also intermediate between the relative size in China's prices and the relative size in Japan's prices or in Republic of Korea's prices.

Labor model's results show that China's GDP is 2.517 times as large as Japan's GDP. Relative size of China's GDP in labor model is still larger than the one in Japan's prices. This is because ratios (=weights) of agriculture and light industries in labor model is still larger than the one in Japan's prices. Relative size of Republic of Korea's GDP in labor model is also still larger than the one in Japan's prices.

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Table 1 Purchasing Power Parities by Industry

Official Exchage Rate	Yen/Yuan	13.02
	Won/Yen	10.49
	Won/Yuan	136.6

	Binary Comparison			EKS			G-K			International Average Labor Model		
	JPN/CHN	ROK/JPN	ROK/CHN	JPN/CHN	ROK/JPN	ROK/CHN	JPN/JpCnRk	CHN/JpCnRk	ROK/JpCnRk	JPN/JpCnRk	CHN/JpCnRk	ROK/JpCnRk
	Yen/Yuan	Won/Yen	Won/Yuan	Yen/Yuan	Won/Yen	Won/Yuan	Yen/GkYen	Yuan/GkYen	Won/GkYen	Yen/LaborYen	Yuan/LaborYen	Wo/LaborYen
1 Agriculture	148.79	5.07	418.0	122.18	4.17	509.0	2.42	0.020	10.07	2.21	0.0037	1.89
2 Energy Mining	28.91	5.34	223.1	32.67	6.04	197.4	0.71	0.022	4.29	1.65	0.0186	3.67
3 Non-Energy Mining	28.98	4.42	111.7	27.69	4.22	116.9	0.69	0.025	2.90	2.39	0.0151	1.77
4 Manufacture of Foods	66.37	5.55	423.1	69.51	5.81	404.0	1.28	0.018	7.43	1.64	0.0087	3.53
5 Textiles	41.97	7.32	348.8	43.78	7.64	334.3	0.93	0.021	7.13	2.46	0.0093	3.11
6 Wearing Apparel	51.42	6.17	214.3	45.10	5.42	244.3	0.98	0.022	5.30	2.00	0.0111	2.70
7 Sawmills and Furniture	53.51	7.93	424.1	53.51	7.93	424.1	1.04	0.019	8.24	1.56	0.0120	5.07
8 Paper and Printing	38.34	7.59	167.9	31.92	6.32	201.7	0.83	0.026	5.24	1.51	0.0208	4.19
9 Petroleum Processing and Coking	13.69	10.94	293.2	17.13	13.68	234.4	0.50	0.029	6.89	1.95	0.0299	7.00
10 Chemicals	32.60	6.12	185.9	31.84	5.98	190.4	0.79	0.025	4.71	1.66	0.0189	3.60
11 Nonmetallic Mineral Products	27.06	5.83	230.9	30.73	6.62	203.3	0.75	0.024	4.94	1.84	0.0177	3.59
12 Metals Smelting and Pressing	18.34	7.32	156.2	19.29	7.70	148.5	0.60	0.031	4.63	1.89	0.0274	4.06
13 Metal Products	20.32	1.94	188.5	34.25	3.27	111.8	0.95	0.028	3.10	1.18	0.0248	2.77
14 General Machinery	14.66	5.02	73.6	14.66	5.02	73.6	0.67	0.046	3.38	1.57	0.0435	3.20
15 Transport Equipment and Repair	22.61	6.08	254.8	27.78	7.46	207.4	0.79	0.029	5.92	1.09	0.0331	6.87
16 Electronic and Electric equipment	31.85	6.02	236.2	34.14	6.45	220.4	0.83	0.024	5.35	1.42	0.0206	4.53
17 Other Manufacture	44.94	3.08	138.3	44.94	3.08	138.3	1.04	0.023	3.21	1.02	0.0218	3.02
18 Electricity, Gas, Water	54.06	5.47	265.6	52.17	5.27	275.2	1.08	0.021	5.69	0.84	0.0228	6.28
19 Construction	147.58	4.30	528.8	138.88	4.05	562.0	2.08	0.015	8.42	0.50	0.0143	8.06
20 Transport and storage	60.89	4.54	504.5	74.42	5.55	412.8	1.24	0.017	6.87	0.68	0.0197	8.13
21 Communication	46.79	3.09	155.2	47.90	3.16	151.6	1.10	0.023	3.49	0.72	0.0291	4.42
22 Commerce	43.66	3.59	156.9	43.66	3.59	156.9	1.02	0.023	3.65	0.86	0.0265	4.16
23 Eating and Drinking Places	33.44	4.22	141.1	33.44	4.22	141.1	0.95	0.028	3.99	1.53	0.0195	2.75
24 Finance, Insurance, Real Estate	23.04	3.57	82.1	23.04	3.57	82.1	0.96	0.042	3.44	0.34	0.1293	10.62
25 Other Services	64.95	3.68	429.9	79.02	4.47	353.4	1.21	0.015	5.40	0.56	0.0227	8.01
26 Medical Service, Social Security	153.82	3.57	549.9	153.82	3.57	549.9	1.46	0.009	5.22	0.40	0.0162	8.90
27 Educating Cultural services	175.75	4.96	872.5	175.75	4.96	872.5	1.89	0.011	9.38	0.41	0.0139	12.16
28 Public Administration	120.64	4.12	497.0	120.64	4.12	497.0	1.65	0.014	6.78	0.55	0.0151	7.50
Inports	13.02	10.49	136.6	13.02	10.49	136.6	0.54	0.041	5.65	2.18	0.0352	4.82
Average							1.00	0.022	5.17	1.00	0.0135	4.89

Simple Geometric Mean of 25~27 Sectors

Simple Geometric Mean of All Other Sectors

Calculated from Yen/Yuan and Won/Yen on the assumption that transitivity is satisfied.

Table 2 Purchasing Power Parities of total Industry

		Laspeyres	Paasche	Fisher	EKS	GK	Labor model
(1)	Yen/Yuan	59.1	36.9	46.7	45.8	46.1	73.9
(2)	Won/Yen	5.23	5.30	5.26	5.16	5.17	4.89
(3)	Won/Yuan	295.8	181.3	231.6	236.2	238.1	361.4

Table 3 International Comparison of Total Demand or Total Supply

	unit	National Price × Exchange Rate billion yen	Japanese Price billion yen	Chinese Price 10 million yuen	Korean Price 100 billion won	GK-International Price billion yen	Lobor-Model-International Price billion yen
absolute	Japan	991080	991080	2685855	51789	991080	991080
	China	360890	1638395	2772343	82015	1271474	2048273
	South Korea	153296	303434	887359	16088	311130	328891
JPN=1	Japan	1.000	1.000	1.000	1.000	1.000	1.000
	China	0.364	1.653	1.032	1.584	1.283	2.067
	South Korea	0.155	0.306	0.330	0.311	0.314	0.332

Table 4 International Comparison of GDP

	unit	National Price × Exchange Rate billion yen	Japanese Price billion yen	Chinese Price 10 million yuen	Korean Price 100 billion won	GK-International Price billion yen	Lobor-Model-International Price billion yen
absolute	Japan	488097	488097	898355	20615	397539	354862
	China	120213	875309	923469	38889	539107	893107
	South Korea	57138	146438	244094	5996	115159	109693
JPN=1	Japan	1.000	1.000	1.000	1.000	1.000	1.000
	China	0.246	1.793	1.028	1.886	1.356	2.517
	South Korea	0.117	0.300	0.272	0.291	0.290	0.309