Factor Content of World Production and Trade

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The factor content of trade has long been studied in order to examine the plausibility of trade theories. The factor content of trade, or that of output/demand more precisely, is related with the factor endowment in pure theory models of international trade. However, the conditions for the relation to hold are stringent and not believed to hold generally. Recent contributions show that the magnitude of actual trade is smaller than the one predicted by the theory under the standard assumptions employed in the textbook version of neoclassical trade theory.[2] This finding led researchers to turn to identifying the sources of the discrepancy between the actual and the predicted trade flows. Focus is placed on international differences in productivity, the input-output structures, consumption tastes and transactions costs.[3]

In this paper, we calculate the factor content of world production and trade using an international input-output table that includes some of Asian developing countries. The international input-output table that we use presents data on production and on trade flows within and across countries with a consistent sector-classification scheme. Use of this table permits us to evaluate the factor content of production and trade based on the respective countries/regions' own technology. This procedure is expected to lead to more accurate inference of factor abundance than by the conventional method that uses technology of a representative country as the base. In addition, the inclusion of the Asian developing countries allows us to compare the factor content thus derived between developed and developing countries.

1 . Method and Data

We use the standard method of obtaining the factor content of a bundle of commodities. By applying the Leontief inverse matrix, the vector of the value of production factors that are needed to produce a vector of the value of commodities can be derived [4].

As is well-known, linking between the relative factor abundance of a country and the relative factor

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[1] An earlier version of this article is presented at the 11th annual conference of the Pan Pacific Association of Input-Output Studies in Sendai in November 2000. I thank Norihisa Sakurai for helpful comments. I also thank Nobuo Teramachi for comments on my earlier paper with a related topic. Remaining errors are solely mine.

[2] See Trefler (1995).

[3] Bowen, Leamer and Sweikauskas (1987), Trefler (1993, 1995), and Davis and Weinstein (2001).

[4] Details are in the below.

content of the export and the import vectors is possible only when restrictive conditions are met if there are more than two goods and production factors, and the linkage is not tight in general (Leamer, 1980). A more generally valid way, according to him, is to compare the factor content between the total output and the total demand.

The international input-output table enables us to overcome a shortcoming that undermines the conventional method of factor content studies. The method used originally by Leontief, and in many following studies, is to use the production technology used in a country as the base, then compare the factor content between exports and imports (or output and demand in the Leamer method).[5] This practice is adequate if the production technology is indeed the same across countries, which is a precondition for interpreting the result of factor content studies as indicating relative factor abundance between countries. However, it is a condition that is difficult to believe to be satisfied between countries if they are at diverse levels of economic development. Using the international input-output table, we are able to avoid this practice, because we have access to data on the input-output structure of different areas directly.

The actual calculation of factor content is based on the following resource-balance identity,[6]

$$Aq + c + i + x - m = q, \qquad (1)$$

where there are n goods, A is the n × n matrix of the coefficients of physical (intermediate) input, and c, i, x, m and q are the n-dimensional vectors of the physical volume of consumption, investment, exports, imports and gross production respectively.[7] Letting P be the n × n diagonal matrix whose diagonal elements are the prices of n goods and off-diagonal elements are all zero, and defining $B = PAP^{-1}$, we can convert (1) into the value terms as

$$[I - B](Pq) = Pc + Pi + Px - Pm. \qquad (2)$$

Since the revenue from the production of each goods equals the sum of the value of intermediate goods, value added, and indirect taxes minus subsidies,

$$p'[I - A] = wF + t', \qquad (3)$$

where there are k factors, w is the k-dimensional vector of factor prices and t be the n-dimensional vector of indirect taxes minus subsidies (per unit volume of output), F is the k × n matrix of physical factor input. Letting ℓ_h be the h-dimensional vector of ones, W be the k × k diagonal matrix of factor prices, and T be the diagonal matrix of net indirect tax rates, the price equation (3) can be transformed as

$$\ell_n'[I - B] = \ell_k' WFP^{-1} + \ell_n' TP^{-1}. \qquad (4)$$

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5 Trefler (1995) adopts the method of using the US technology as the base, then introduces parameters that designate divergences from the US technology. Davis and Weinstein (2001) uses the input-output structure of different countries, but does not include that of developing areas.

6 For detailes, see Yokokawa(1994).

7 Consumption and investment include those by the public sector, and gross production includes intermediate output.

The i-j element of WFP^{-1} is the value of factor i that is needed to produce a unit value of goods j, and the i-j element of TP^{-1} is the net indirect tax rate per unit value of output j.

In order to produce a unit value of final output of goods i, the monetary value of gross production $[I-B]^{-1}$ ei is necessary, where ei is the i-th unit vector. Hence, in order to accommodate a final (physical) demand vector d, the value of gross production of $Pq=[I-B]^{-1}(Pd)$ is required, and the value of factor input that is necessary for this is given by

$$(WFP^{-1})(Pq) = (WFP^{-1})[I - B]^{-1}(Pd). \qquad (5)$$

We may calculate the factor content of any mix of the monetary value of products by replacing Pd in (6) by the vector of the mix.

The data we use are the 1985 international input-output data compiled by the Management and Coordination Agency of the government of Japan. This splits the world into four production/trade areas, Japan, Asia, the US, the EU, and the Rest of the World (ROW). Asia includes eight Asian economies, i.e., China, Indonesia, Korea, Malaysia, the Philippines, Singapore, Thailand, and Taiwan, and the EU includes only France, former West Germany and the UK. Only trade is reported for the ROW, not the input-output structure for obvious difficulties. The aggregate input-output data of each of the four areas are separately estimated in this compilation project, although combining all the eight Asian economies, fairly diverse among themselves, can be a possible source of miscalculation.

The factor content of a vector of commodities, derived in the method here, is the nominal sum of labor and capital input that is necessary to produce the vector as (the nominal sum of) final output. Therefore, if the relative factor price differs across the areas, it makes little sense to compare the factor content, say of the Asian output and of the EU demand.

However, as long as we compare the factor content of the output and the demand of the same country, the distortion in the comparison is less serious. For example, let $(r_i K_i, w_i L_i)$ and $(r_j K_j, w_j L_j)$ be the factor content of production mix i and j, where K_i and L_i are the volume of capital and labor input for mix i, and r_i and w_i are the prices of labor and capital input that are prevalent in the relevant sectors producing (directly and indirectly) the mix i (respectively with j). Then, if we compare the factor content by relative factor intensity, then the measure we will be employing is

$$\text{relative factor intensity} = (r_i K_i / w_i L_i) / (r_j K_j / w_j L_j). \qquad (1)$$

This measure approximates the true capital intensity ratios if (r_i / w_i) is approximately equal to (r_j / w_j), even when there are disparities between the level of r_i (w_i) and r_j (w_j) [8].

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[8] I owe Nobuo Teramachi for pointing this out to me. Of course, relative factor price equalization is a strong condition in itself. For example, if technology exhibits constant returns to scale, and factor movement across sectors is perfect, then relative factor price equalization is the same as the equalization of the factor prices themselves.

On the other hand, we cannot arrive at an accurate measure of even nominal capital input that is available for all these areas unfortunately, due to diverse treatment of the value-added components (especially taxes and depreciation) in the original input-output information supplied from each country, on which the project of compiling the international version is based. For this reason, we use two measures of capital input, and attempt to extract results that are robust to the choice of the measure.

2 . Factor Content of Output-Demand and International Trade

In order to perform the relative factor content comparisons, we first obtain the nominal factor input for a unit value of exports, imports, final output and demand by replacing Pd on the right-hand side of equation (4) by each output/demand vector. Then we take the ratios of capital input to labor input, and divide the capital-labor input ratio on the output side by that on the demand side. Comparison is made between exports and imports, between final output and demand, and between gross output and demand. Exports and imports are those of each region with outside the region, excluding the intra-regional trade. The factor content of gross output (demand) is obtained through multiplying the output (demand) vector by the vector of direct factor use (i.e., by replacing Pq on the left hand side of equation (4) by the gross output (demand) vector, in other words without applying the Leontief inverse), because gross output (demand) already includes intermediate output (demand).

Table 1 reports the results when we use the part of the value-added other than labor compensation as the measure of capital input. Because this measure includes not only rewards to capital but also indirect taxes minus subsidies, it is an imperfect measure of capital input. A better measure is gross profit (profit and depreciation), and this is used in obtaining the results in Table 2, but we do not have the result for the US, since the value-added section of the US part of the input-output table does not distinguish profit and indirect taxes and subsidies.

Panel I of each table shows the result when we use the regional input-output structure when evaluating the factor content (for the EU and Asia, the average input-output structure for the countries included in the region).[9] Panel II shows the results when we use the world average input-output structure, obtained by summing up the sector-wise input vectors (intermediate goods as well as factor input) over the four regions. Thus, for example, the first (second) column of the upper-left section of Table 1 shows the nominal capital-labor input ratios of exports (imports), final output (demand) and gross output (demand), and the third column shows the relative capital intensity of the output side over the input side, interpreted as the physical capital-labor ratios under the assumption of factor price equalization inside each region.

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[9] Not the national input-output structure, but only the regional average is available for the regions.

Table 1. Capital Intensity Ratios (Capital Input = Other Value Added)

I. Evaluation based on the input-output structure of each country/region

	All Sectors			Manufacturing		
	Exports	Imports	Exports/Imports	Exports	Imports	Exports/Imports
Japan	0.87	1.07	0.81	0.94	1.01	0.93
USA	0.69	0.70	0.98	0.57	0.56	1.01
EU	0.70	0.89	0.79	0.56	0.64	0.88
Asia	1.31	1.40	0.94	1.33	1.48	0.90
	Final Output	Final Demand	Final Output/Demand	Final Output	Final Demand	Final Output/Demand
Japan	0.84	0.86	0.98	0.91	0.91	1.00
USA	0.41	0.56	0.73	0.46	0.51	0.89
EU	0.39	0.65	0.60	0.44	0.51	0.85
Asia	1.16	1.31	0.89	1.11	1.38	0.80
	Gross Output	Gross Demand	Gross Output/Demand	Gross Output	Gross Demand	Gross Output/Demand
Japan	0.84	0.86	0.98	0.94	0.95	0.99
USA	0.50	0.54	0.93	0.34	0.33	1.03
EU	0.56	0.81	0.69	0.31	0.37	0.85
Asia	1.36	1.45	0.94	1.38	1.60	0.86

II. Evaluation based on the average world input-output structure

	All Sectors			Manufacturing		
	Exports	Imports	Exports/Imports	Exports	Imports	Exports/Imports
Japan	0.69	1.25	0.55	0.68	0.84	0.80
USA	0.76	0.85	0.90	0.69	0.71	0.98
EU	0.82	1.00	0.82	0.74	0.81	0.91
Asia	0.93	0.91	1.01	0.78	0.79	0.98
	Final Output	Final Demand	Final Output/Demand	Final Output	Final Demand	Final Output/Demand
Japan	0.74	0.79	0.93	0.66	0.69	0.97
USA	0.45	0.71	0.63	0.54	0.65	0.84
EU	0.50	0.75	0.67	0.60	0.67	0.90
Asia	0.74	0.67	1.10	0.59	0.63	0.94
	Gross Output	Gross Demand	Gross Output/Demand	Gross Output	Gross Demand	Gross Output/Demand
Japan	0.75	0.80	0.94	0.56	0.58	0.97
USA	0.59	0.71	0.83	0.48	0.50	0.96
EU	0.69	0.95	0.72	0.52	0.56	0.93
Asia	0.78	0.77	1.01	0.52	0.56	0.93

Table 2. Capital Intensity Ratios (Capital Input = Gross Profit)

I. Evaluation based on the input-output structure of each country/region

	All Sectors			Manufacturing		
	Exports	Imports	Exports/Imports	Exports	Imports	Exports/Imports
Japan	0.74	0.99	0.75	0.80	0.85	0.93
USA	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
EU	0.60	0.79	0.76	0.48	0.53	0.91
Asia	1.08	1.14	0.94	1.06	1.19	0.90
	Final Output	Final Demand	Final Output/Demand	Final Output	Final Demand	Final Output/Demand
Japan	0.73	0.75	0.97	0.77	0.77	1.00
USA	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
EU	0.28	0.54	0.51	0.40	0.45	0.90
Asia	0.97	1.07	0.90	0.89	1.11	0.80
	Gross Output	Gross Demand	Gross Output/Demand	Gross Output	Gross Demand	Gross Output/Demand
Japan	0.73	0.75	0.97	0.74	0.74	1.00
USA	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
EU	0.46	0.71	0.65	0.25	0.25	0.99
Asia	1.11	1.17	0.95	1.04	1.23	0.85

II. Evaluation based on the average world input-output structure

	All Sectors			Manufacturing		
	Exports	Imports	Exports/Imports	Exports	Imports	Exports/Imports
Japan	0.31	0.49	0.63	0.31	0.36	0.87
USA	0.33	0.37	0.91	0.30	0.32	0.94
EU	0.35	0.42	0.85	0.33	0.35	0.94
Asia	0.39	0.39	1.01	0.34	0.35	0.98
	Final Output	Final Demand	Final Output/Demand	Final Output	Final Demand	Final Output/Demand
Japan	0.32	0.33	0.95	0.30	0.30	0.99
USA	0.22	0.32	0.69	0.23	0.30	0.78
EU	0.25	0.34	0.73	0.29	0.30	0.94
Asia	0.32	0.30	1.06	0.27	0.29	0.93
	Gross Output	Gross Demand	Gross Output/Demand	Gross Output	Gross Demand	Gross Output/Demand
Japan	0.32	0.33	0.95	0.27	0.28	0.99
USA	0.28	0.33	0.85	0.23	0.26	0.91
EU	0.32	0.41	0.78	0.27	0.27	0.97
Asia	0.35	0.35	0.98	0.27	0.29	0.92

A general tendency emerging from Table 1 and Table 2 is that the Japanese and the Asian output is more capital intensive relative to the respective demand than the EU and the US output is relative to the demand there (the second and the third block of the third column on Panel I and II in Tables 1-2). This tendency is observed regardless of which of the two measures we use as capital input (compare Table 1 and 2), and regardless of whether the national input structure or the world average input-output structure is used as a basis for the comparison. The exception is the gross output/demand comparison using the national input-output structure in the upper-left section of Table 1.

This tendency is mainly due to non-manufacturing activities because it becomes less visible when we restrict the attention to manufacturing only. Then the relative capital-labor input ratio between the output side and the demand side varies less across regions (the last columns of Table 1 and 2). This means that the capital-labor input ratios in non-manufacturing production is higher relative to that in non-manufacturing demand in Japan and Asian by greater margines than in the EU and the US. This gap, in turn, can be said to be due more to the production side than to the demand side, when assuming the same technology and judging based on final production/demand comparisons.

The prediction of relative factor endowment from this exercise given the standard assumptions of neoclassical trade theory is that Asia is most abundant in capital, next Japan, and the EU and the US are less abundant in capital. This is certainly at odds with the existing measures of capital-labor endowment. For example, the capital-worker ratios of some of the Asian countries are lower than the other regions in our sample (see Table 3).

Table 3. Capital-Worker Ratios

Thailand	4051
Phillipines	4087
Korea	12036
Japan	28106
UK	17636
US	29925
Germany	47695
France	31796

Source: Penn World Table Mark 5.6.

An explanation of this conflicting finding is that technology is not the same across regions. Comparing item-wise between Panel I and II in Table 1, the nominal capital-labor ratios of the final output from the EU and the US are lower when the regional technology is applied compared to the case in which the world average technology is applied. The opposite is true with Japan and Asia. This means that goods are produced

by more labor-intensive technology in the EU and the US than in Japan and Asia (the finding is common to both all sectors and manufacturing).

This can mean that relatively higher labor intensiveness of the EU and the US may reflect higher input of the skilled labor in these regions.[10] [11] Another explanation is the presence of distorting factors such as differential rates of taxes and subsidies since capital input in Table 1 include indirect taxes and subsidies. However, the result from Table 2 (which uses gross profit only as a measure of capital input) also suggests that Japan and Asia uses more capital-intensive technology on the output side than the demand side relative to the EU for the same logic.[12]

We also note that the output side is more labor intensive than the demand side in many of the cases in Table 1 and 2. Since world final demand equals final demand, if one area's output is more capital-intensive than demand, then the output of the rest of the world must be more relatively labor-intensive if the production technology is the same and if no taxes exist. Therefore, the finding of relatively higher labor intensity in these four regions must reflect either relatively higher capital intensity under the assumption of the neoclassical trade theory. Since our data do not include the input structure of the rest of the world, we do not have a direct answer to the validity of this interpretation; again, the explanation can be technological differences if the phenomenon observed between the EU and the US vs. Japan and Asia prevails in the comparison between the four regions vs. the rest of the world.

The factor content of trade confirms similar patterns as discussed above concerning the comparison of Asia with the EU and the US, although it is a less valid means of inferring factor abundance. A striking reversal of the relative ranking is observed between Japan vs. the EU and the US, when exports/imports comparisons are contrasted with output/demand comparisons. That is, Japan's imports are much more capital-intensive than imports compared to the EU and the US, especially when we focus on trade in all sectors (not so much in manufacturing only). This is observed under both measures of capital input. The observation is due to both capital-intensiveness of Japan's imports and labor-intensiveness of Japan's exports. The former is in part attributable to its imports of natural resources (e.g., petroleum and natural gas), production of which is capital-intensive than many other sectors, especially under the world average production technology. The latter can be explained if Japan's exports are more skilled labor-intensive goods relative to national output as confirmed in our earlier study.[13]

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[10] This can explain, for example, the high US labor content in aircraft production, although not the EU factor content of the same industry (Chart 1-2) below.

[11] This has been verified for Japan, in the sense that the inferred Japan's abundance ranking is skilled labor>capital>unskilled labor (Yokokawa, 1994b). Results here suggest that this phenomenon is even more pronounced in the EU and the US.

[12] The EU capital-labor ratios in Panel I are marginally larger than those in Panel II in Table 2. This is because the intermediate input part is the average of the four regions while the value-added part is the average of the three regions excluding the US.

[13] See footnote 11.

3 . Cross-sector comparisons of factor uses

One of the persistent finding in the above exercises is that in Asian countries, nominal capital input occupies much higher proportion of the value-added than in other areas, both on the output (exports) side and the demand (imports) side. Although our data inhibit the decomposition of nominal capital input into physical capital input and the factor reward to capital, there appear to be reasons to believe that both are relevant given cross-sector comparisons of (nominal) capital-intensity.

On the one hand, in "light" and light processing industries, such as textile, apparel and food, which are generally believed to employ relatively labor-intensive technology in developing countries, the relative proportion of reward to capital is higher in Asia than in developed economies (Chart 1-1). If technology is the same between Asia and the other regions, the latter fact means that the rental-wage ratio is higher in Asia. If technology is more labor-intensive in Asia, then the rental-wage ratio in Asia must be higher by an even larger margin. This can be a reflection of the scarcity of capital in these Asian economies at the time of the data sample, i.e., 1985 (and international non-equalization of factor prices).

On the other hand, the nominal capital input ratio is even higher in relatively "heavy" industries that are considered to use capital-intensive technologies. If this is due to intensive use of physical capital, then it is consistent with the perception that enterprises in technologically more sophisticated industries in (especially multinationals' foreign direct investment to) developing economies sometimes employ production technology that is less reliant on the skill of labor. If the higher relative capital input in sophisticated manufacturing industries indicates high rate of returns to capital, then it indicates that the prices of capital services is not equalized even domestically across sectors (or monopoly rent accrues to capital in these industries).

Chart 1-1 Capital Intensity Ratios in Each Industry (1)

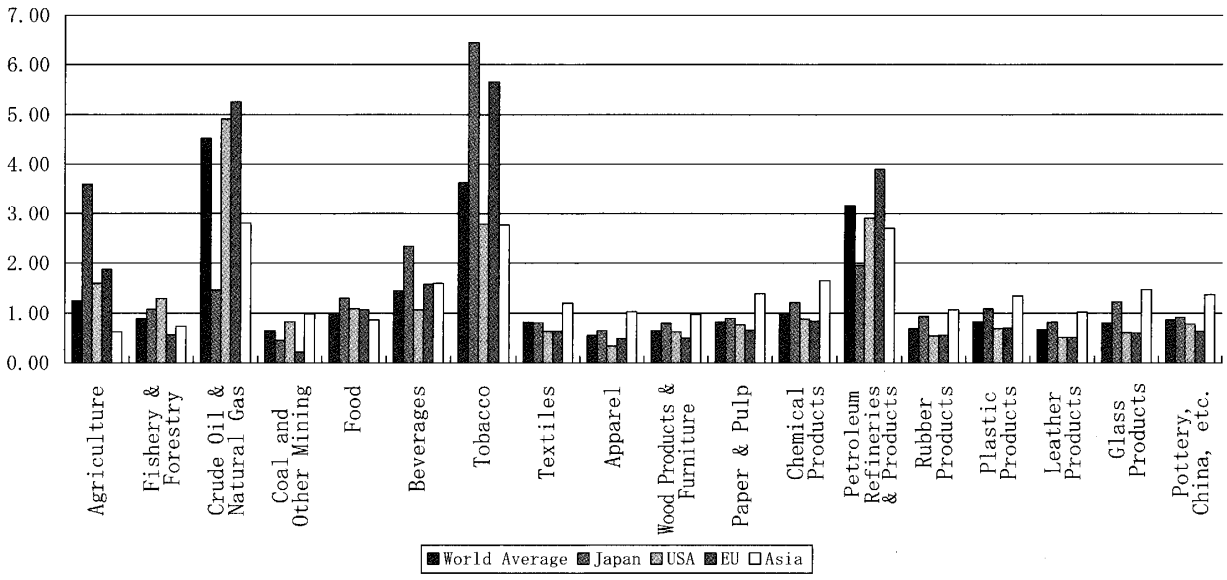
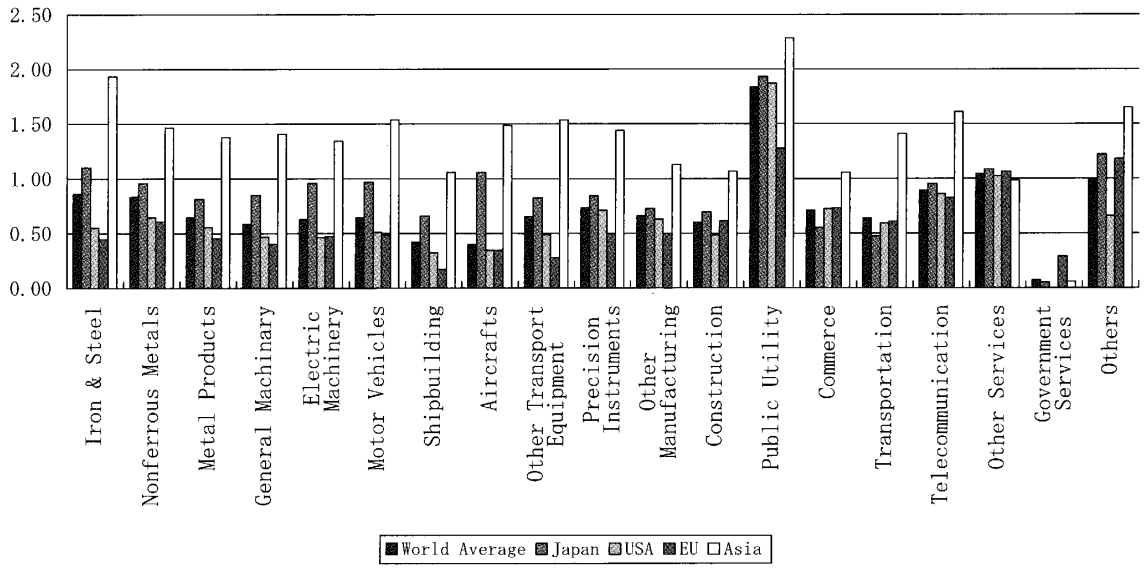


Chart 1-2 Capital Intensity Ratios in Each Industry (2)



4 . Conclusion

We utilized an international input-output table in order to perform the Leontief-Leamer tests on trade and output-demand patterns in four major areas in the world. The results show that Asian and Japanese output is more capital-intensive relative to demand than the EU and the US output is. This is at odds with existing measures of factor endowments and can be interpreted as reflecting international differences of technology. Asian countries are found to employ higher ratios of nominal capital input. Given scarcity of capital in Asia, this finding indicates possibility of factor price non-equalization across countries. We also found that nominal capital-labor input ratios differ across sectors in the same region and this can be attributable to cross-sector non-equalization of factor prices.

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