Leontief paradox and the role of factor intensity measurement

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Abstract

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J.E.L. Classification: F1; F11; D2; D5

Keywords: Leontief paradox, factor content of trade, relative factor price differences

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1 Introduction

The expansion of global trade receives so much attention largely because it has important influences on the factor markets of countries involved. This also explains why, after decades, the Heckscher-Ohlin (HO) theorem is still a mainstay of international economics. The HO theorem, which focuses on the relationship between production factors and trade, predicts that a country will export commodities that are intensive in the country's relatively abundant factors and will import commodities that are intensive in the country's relatively scarce factors. Consequently, theories about factor prices and about welfare of different production factors are developed based on this model.

The prediction of the HO theorem is conceptually convincing; however, its empirical applicability is in doubt. Leontief (1953) found that the capital-labor ratio embodied in US exports is smaller than the capital-labor ratio embodied in US competitive import replacements. Based on our belief that the US is capital abundant, this phenomenon seems contradict the HO's prediction of the pattern of trade. This is known as the Leontief paradox, which is commonly regarded as the earliest empirical finding that questions the practical validity of the HO theorem.

When measuring the capital-labor ratio embodied in US imports, Leontief (1953) did not examine the factor intensity techniques used by foreign industries that exported commodities to the US. Instead, he examined factor intensity techniques used by US industries that were producing import-competing commodities. Assuming foreign industries using the same factor intensity techniques as the US import-competing industries is valid if the factor price equalization (FPE) holds. However, a global comparison reveals large deviations in factor prices across countries.

The assumption of identical factor intensity techniques is questionable. Nevertheless, it is very difficult to relax it because of a lack of data. To relax the assumption and compute the actual factor intensity techniques applied in different countries, detailed input-output tables and factor usage data are required. However, these data are unavailable for many countries, especially the developing countries. Note that both input-output tables and factor usage data are required. Some countries publish one but not the other. Even for countries that publish these data, the data are sometimes not published frequently. Also, some published data are either expensive or not in satisfactory forms that are readily for use in HO analyses.[1]

This paper takes an alternative approach. Instead of collecting input-output tables and factor usage data and compute the actual factor intensity techniques, this paper uses an inferring method that can allow us to infer the factor intensity techniques of different countries based on our knowledge of the US factor intensity techniques and the relative factor prices across countries. The rationale is that, whichever country they are in, industries will employ factors to a level such that the marginal rate of substitution in production equals the relative factor price in that country. Therefore, by observing the US factor intensity techniques chosen by US industries in response to the US relative factor prices, we should be able to infer the factor intensity techniques chosen by other countries' industries in response to other countries' relative factor prices.

Empirical studies after Leontief's work found that the paradox comes and goes from time to time (e.g., Stern and Maskus, 1981; Trefler, 1993). Leamer (1980) demonstrate that, in certain circumstances, it is possible for a capital abundant country to have a higher capital-labor ratio in its imports than its exports. Nonetheless, this paper shows that the ambiguity of the paradox arises because the capital-labor ratios embodied in US imports and US exports are very close, and the reason for the close measured capital-labor ratio of US imports and US exports is that the US factor intensity techniques are used to compute the capital-labor ratio embodied in US imports. This paper shows that, if the "actual" factor intensity techniques of the

[1]Some studies had put efforts in collecting input-output data when revisiting the HO model (e.g. Davis and Weinstein, 2001 and Hakura, 2001); however, the country sample that provided input-output data in these studies were mostly rich OECD countries. Compared with the number of countries that export commodities to the US, the country sample was still small.

source countries of US imported goods are used to compute the capital-labor ratio embodied in US imports, a clear pattern of the paradox will be observed.

The measured capital-labor ratio of trade of 59 countries is computed using the inferred factor intensity matrices. The paradoxes are found to be either disappeared or eased. This shows that the assumption of identical factor intensity techniques plays an important role in causing the Leontief paradox.

2 The Leontief paradox

In the HO theorem, production functions exhibit constant returns to scale. Given the relative factor prices, industries will choose a set of cost-minimizing factor inputs. The *factor intensity matrix* is a matrix of total (direct plus indirect) factor input requirements of producing each unit of final good. Let $\mathbf{A}_c$ be the factor intensity matrix of country c. Its dimension is $(F \times I)$, where I is the number of goods and F is the number of factors. The HO model assumes that all countries have the same technology and the factor endowments of all countries lie within the cone of diversification. As a result, the FPE holds and the same factor intensity techniques is shared by all countries: $\mathbf{A}_c = \mathbf{A}$. In most of the previous studies, the US factor intensity matrix was chosen to be the international common matrix: $\mathbf{A} = \mathbf{A}_{us}$.

Let $\mathbf{X}_{cc'}$ be the $(I \times 1)$ vector of country c's export to country c'. Under the assumption of identical factor intensity techniques, the factor contents of factor f in country c's exports and imports are $\mathbf{a}_{f,us}\mathbf{X}_c$ and $\mathbf{a}_{f,us}\mathbf{M}_c$, where $\mathbf{X}_c = \sum_{c',c'\neq c} \mathbf{X}_{cc'}$, $\mathbf{M}_c = \sum_{c',c'\neq c} \mathbf{X}_{c'c}$, and $\mathbf{a}_{f,us}$ is the fth row of $\mathbf{A}_{us}$.

Leontief computed the capital (k) and labor (l) contents of US exports and US competitive import replacements. He found that

$$\frac{\mathbf{a}_{k,us}\mathbf{X}_{us}}{\mathbf{a}_{l,us}\mathbf{X}_{us}} < \frac{\mathbf{a}_{k,us}\mathbf{M}_{us}}{\mathbf{a}_{l,us}\mathbf{M}_{us}}.$$

Since it is believed that the US is relatively abundant in capital in comparison to labor, Leontief's findings contradict the HO model's prediction of the factor trade direction.

3 Differentiated factor intensity technique

The assumption of identical factor intensity techniques across countries is suspected to be one of the major reasons that casued the poor performance of the HOV model. Countries will apply the same factor intensity techniques only when the FPE holds. However, when we look around the world, we see huge deviations in the factor prices of various countries.

Table 1 lists the *relative* factor prices of different countries compared to those experienced in the US, $[(w_{l,c}/w_{k,c})\,/\,(w_{l,us}/w_{k,us})]$, where $w_{f,c}$ is the factor price of factor f in country c. In Table 1, the relative factor prices of each country are expressed as the factor price of labor occupation category l relative to the factor price of capital k. Relative factor prices are important because they determine the choice of factor intensity techniques by industries in different countries. If FPE holds, all values in Table 1 should equal one. However, by comparing the mean, the median, and the quartiles results, it is evident that many ratios differed drastically from one. This indicates that the relative factor prices varied significantly across countries. The differences in relative factor prices will drive industries in different countries to adopt different factor intensity techniques rather than to share the same one.

A simple two-country model can be used to demonstrate that, when the actual factor intensity techniques are indeed differentiated across countries, assuming identical factor intensity techniques will underestimate the volume of factor services embodied in international trade.

Suppose there are only two countries, China (cn) and the US (us). China is relatively labor abundant and the US is relatively capital abundant. Assume the difference in the relative factor endowments between the two countries is so huge that it results in a difference in the relative factor prices: $w_{l,cn}/w_{k,cn} < w_{l,us}/w_{k,us}$.

Facing a lower relative factor price of labor, industries in China will choose factor intensity techniques that use more labor and less capital than industries in the US in producing each unit of industrial output. That means, with quasiconcave production functions for all industries, we have the following relationship:

$$a_{li,cn} > a_{li,us} \quad \text{and} \quad a_{ki,cn} < a_{ki,us} \quad \forall i. \tag{1}$$

where i is used to index industries and $a_{fi,c}$ is the ith element of $\mathbf{a}_{f,c}$.

In this two country model, $\mathbf{M}_{us} = \mathbf{X}_{cn}$. The actual capital and labor content of the US imports should be $\mathbf{a}_{k,cn}\mathbf{M}_{us}$ and $\mathbf{a}_{l,cn}\mathbf{M}_{us}$. With the relationship in (1), we can easily see that the difference between the capital-labor ratio embodied in the US exports and the capital-labor ratio embodied in the US imports will be underestimated if we assume China uses the US factor intensity techniques:

$$\frac{\mathbf{a}_{k,us}\mathbf{X}_{us}}{\mathbf{a}_{l,us}\mathbf{X}_{us}} - \frac{\mathbf{a}_{k,us}\mathbf{M}_{us}}{\mathbf{a}_{l,us}\mathbf{M}_{us}} < \frac{\mathbf{a}_{k,us}\mathbf{X}_{us}}{\mathbf{a}_{l,us}\mathbf{X}_{us}} - \frac{\mathbf{a}_{k,cn}\mathbf{M}_{us}}{\mathbf{a}_{l,cn}\mathbf{M}_{us}}.$$

This may explain why we observed the Leontief paradox and why it appeared in some times (Leontief, 1953; Baldwin, 1971) and disappeared in other times (Stern and Maskus, 1981; Trefler, 1993). When the difference between the capital-labor ratio embodied in US exports and US imports is considerably reduced, whether the capital-labor ratio embodied in the US exports is smaller (paradox) or larger (no paradox) may simply reflect the influence of data measurement errors.

4 Empirical investigations

It is widely believed that assuming all countries applying the US factor intensity techniques is unrealistic. However, because of the lack of national input-output tables and factor usage data, it is not easy to assess the different factor intensity techniques, $\mathbf{A}_c$, adopted in different countries. This paper adopts the factor intensity technique inferring method suggested in Kwok (2005). Based on the US factor intensity matrix,

$\mathbf{A}_{us}$, and the relative factor prices across countries, the inferring method allows us to infer the factor intensity matrices, $\mathbf{A}_c$, of other countries in the world.

4.1 Inferring factor intensity matrices

As defined in the previous section, the amount of factor f used by industry i in country c to produce one unit of output is $a_{fi,c}$. Assume the production functions $Q(\cdot)$ are Cobb-Douglas:

$$1 = Q_i (a_{1i,c}, a_{2i,c}, \ldots, a_{Fi,c}) = A_i \left[\prod_{l=1}^{F} a_{li,c}^{\theta_{li}} \right], \qquad \sum_{l=1}^{F} \theta_{li} = 1. \tag{2}$$

The marginal value product of factor k in industry i is $p_{i,c}\theta_{ki}a_{ki,c}^{-1}$, where $p_{i,c}$ is the price of commodity i in country c. By cost minimization, industry i chooses a combination of input of factor k and factor l such that

$$\frac{w_{k,c}}{w_{l,c}} = \frac{\theta_{ki}}{\theta_{li}} \left(\frac{a_{li,c}}{a_{ki,c}} \right), \tag{3}$$

where $w_{f,c}$ is the factor price of factor f in country c.[2]

Assume all countries are sharing the same technology. Same technology here means the values of the parameters, A_i and θ_{fi} are the same across countries. This should not be confused with the assumption of identical factor intensity techniques. Even if industries in all countries are operating under same production functions, they can still choose different factor intensity ratios, $(a_{li,c}/a_{ki,c})$. In fact, industries in each country will choose their own factor intensity techniques such that the marginal rate of substitution in production equals the relative factor prices in their own country (equation (3)).

Because equation (3) is true for all countries, the factor intensity ratios applied in country c and the factor intensity ratios applied in the US have the following relationship:

$$\frac{a_{ki,c}}{a_{li,c}} = \left(\frac{w_{k,us}}{w_{l,us}} \right) \left(\frac{a_{ki,us}}{a_{li,us}} \right) \left(\frac{w_{l,c}}{w_{k,c}} \right). \tag{4}$$

[2] Assume the factor prices in each country are the same across industries.

Based on equation (2), when industries of both country c and the US are on the same unit isoquant,

$$\prod_{l=1}^{F} a_{li,c}^{\theta_{li}} = \prod_{l=1}^{F} a_{li,us}^{\theta_{li}}. \tag{5}$$

Because $\prod_l a_{ki,c}^{\theta_{li}} = a_{ki,c}$, we can rewrite (5) as

$$a_{ki,c} = \prod_{l=1}^{F} a_{li,us}^{\theta_{li}} \prod_{l=1,l\neq k}^{F} \left(\frac{a_{ki,c}}{a_{li,c}}\right)^{\theta_{li}}.$$

Using (4), we have

$$a_{ki,c} = \prod_{l=1}^{F} a_{li,us}^{\theta_{li}} \left[\prod_{l=1,l\neq k}^{F} \left(\frac{w_{k,us}}{w_{l,us}}\right)^{\theta_{li}} \left(\frac{a_{ki,us}}{a_{li,us}}\right)^{\theta_{li}} \left(\frac{w_{l,c}}{w_{k,c}}\right)^{\theta_{li}}\right].$$

By rearranging terms, we get

$$a_{ki,c} = a_{ki,us} \left(\frac{w_{k,us}}{w_{k,c}}\right) \left[\prod_{l=1}^{F} \left(\frac{w_{l,c}}{w_{l,us}}\right)^{\theta_{li}}\right].$$

Under profit maximization, industry i employs factor l until its marginal value product equals its factor price. Substitute $w_{l,c}$ and $w_{l,us}$ by corresponding marginal value products and rearrange the terms using (5), we can solve the factor intensity coefficient, $a_{ki,c}$, of industry i in country c:

$$a_{ki,c} = a_{ki,us} \left(\frac{w_{k,us}/p_{i,us}}{w_{k,c}/p_{i,c}}\right). \tag{6}$$

Equation (6) says that, when producing the *same* amount of outputs, the ratio of factor k employed in country c to factor k employed in the US is inversely related to the ratio of factor price of k in country c to factor price of k in the US. That is, if factor k is relatively abundant and has a lower factor price in country c than the US, industries in country c will employ more factor k than their US counterparts in producing the same amount of output.

Recall that $a_{ki,c}$ and $a_{ki,us}$ are just the elements in the factor intensity matrices $\mathbf{A}_c$ and $\mathbf{A}_{us}$; therefore, using equation (6), we can solve for all elements in $\mathbf{A}_c$ based on our knowledge of the elements in $\mathbf{A}_{us}$ and the cross country factor prices.

4.2 The data

The data used in this paper were pertained to 1992.[3] The US factor intensity matrix was computed using the US input-output tables and factor usage data from various industrial and population surveys published by the US Department of Commerce. Factor intensity matrices of other countries were inferred using the factor intensity technique inferring method (equation (6)). Production functions of all industries were assumed to take the Cobb-Douglas form. Although the actual production functions may not take this simple form, we believe that the factor intensity matrices inferred are still much closer to the actual factor intensity techniques used in different countries than the US factor intensity matrix. That is, we believe $\left|\hat{a}_{fi,c} - a^*_{fi,c}\right| << \left|a_{fi,us} - a^*_{fi,c}\right|$, where $\hat{a}_{fi,c}$ is the factor intensity coefficient inferred and $a^*_{fi,c}$ is the actual factor intensity coefficient.

Following Trefler (1993), factor price of capital was proxied by the PPP-adjusted investment price obtained from the Penn World Table. Wages by occupation were mainly obtained from the Occupational Wages around the World database, which is calibrated by Freeman and Oostendorp (2000) based on the ILO October Inquiry database.

Trade data in the form of total imports and exports by countries were obtained from the *International Trade Statistics Yearbook* published by the United Nations. The factor services embodied in exports were derived directly by premultiplying the exports data with the factor intensity matrix of the exporting country. The factor services embodied in imports were derived by premultiplying the imports data with a weighted average of factor intensity matrices of the origin countries of the imported goods. The weights are proportional to the volume of US imports from these origin

[3]If the 1992 data were unavailable, the data from the year that is closest to 1992 were adopted with proper adjustments. In the cases when data were missing for a couple of countries, the missing data were proxied by data of a similar adjacent country with suitable adjustments. See the data appendix for details.

countries.

4.3 Results and explanations

The factor content of exports and imports of 52 countries were computed using two different ways. The first one, which is corresponding to the first column of table 2 and table 3, is computed based on the assumption of FPE. That is, all countries are assumed to share the same US factor intensity techniques. The second one, which is corresponding to the second column, is computed without the assumption of FPE. That is, countries are using differentiated factor intensity techniques. The factor intensity techniques used in each country was inferred using the inferring method described in the previous section.

Based on the inferred factor content of exports and imports without FPE, countries were divided into two groups. Countries that have a higher capital-labor ratio in their exports than their imports are classified as the capital services exporting countries (table 2). Countries that have a higher labor-capital ratio in their exports than their imports are classified as the labor services exporting countries (table 3).

Comparing with the second column, we can see that the values in the first column of table 2 and table 3 are very close to 1. That means, under the assumption of FPE, there is not much difference in the capital-labor ratio between exports and imports. Because the measured capital-labor ratio of exports is so close to the measured capital-labor ratio of imports, data measurement errors may dominate and, as a result, we observed Leontief paradox for some countries at some periods of time in the history.

For the US, when assuming FPE, the ratio of the capital-labor ratio of exports to imports is 1.01. That means there is no Leontief paradox in our 1992 trade data. But the value is still too small in view of the US as the leading developed country with huge endowment of capital. When we relaxed the assumption that countries producing the US imported commodities are using US factor intensity techniques, the capital-labor ratio of the US imports decreases significantly and the ratio of the capital-labor ratio of exports to imports increases almost four times to 5.60.

Though the Leontief paradox is not observed in the US trade data, it appears in many other countries. When assuming FPE, developed countries such as Japan, Germany, France, Denmark, Belgium, Italy, and Spain are all found to be labor exporting countries with the capital-labor ratio embodied in exports smaller than the capital-labor ratio embodied in imports; developing countries such as Indonesia, Mexico, Colombia, Costa Rica, Honduras, Egypt, and Zimbabwe are all found to be capital exporting countries with the capital-labor ratio embodied in exports larger than the capital-labor ratio embodied in imports. When we relaxed the assumption of FPE, countries grouped into capital exporting countries and labor exporting countries are basically conform to our belief.

When the factor content of exports and imports is measured without the FPE assumption, both the capital-labor ratios of capital exporting countries and the labor-capital ratios of labor exporting countries increase significantly. This implies that countries engaged in the world trade are trading commodities with differentiated factor intensities, not commodities with similar factor intensities.

Data Appendix

Factor intensity techniques applied in the US were computed using the US input-output (I-O) table and factor usage data. I-O data were obtained from the *Benchmark Input-Output Accounts of the United States, 1992.* 2-digit I-O data, for which establishments were grouped into 96 industries, were used. Although data in a finer 6-digit I-O industry classification are available, they were not used because data in other classifications were to be converted into I-O classifications, and conversions at finer levels are not reliable. Direct capital input is the tangible wealth estimates provided by the Bureau of Economic Analysis (BEA). As the industry classifications of the BEA estimates are not detailed enough (equivalent to 2-digit SIC level only), assets data provided by Bureau of the Census and the Internal Revenue Service were used to prorate the BEA estimates to detailed SIC levels. The data were then converted into I-O codes using the concordance provided in the *Benchmark IO Accounts*. Direct labor input is the labor employment by occupation in each industry extracted from the *Current Population Survey*. Personal data under 3-digit CPS industry code and occupation major recode were adopted. They were first converted into SIC, and then into I-O classifications. Employment data published in corresponding industry and government censuses, which are not divided into different occupations, were used as weights if needed.

Factor price of capital is the 1992 PPP-adjusted investment price index obtained from the Penn World Table Mark 5.6 and 6.0 (PWT). Factor price of labor by occupation is mainly the base calibration with lexicographic weighting obtained from the Occupational Wages around the World (OWW) database. Exchange rates from the IMF were used to convert the wage rates of all countries into US dollar. Since the ratio of wage rates between other countries and the US is needed, we need wage rate data of the same occupation in both the US and the country in concern. If there is no matching occupation, the ratio of wage rates between the country in concern and Germany, which has more detailed occupational wage data than the US, was taken. The ratio was then multiplied with the ratio of wages rates in the same ISCO group between Germany and the US to get the ratio between that country and the US. If wage rates of a particular ISCO group are not available, the ratio of another ISCO group that is close to that group was used. For countries that wages were unavailable in the OWW, their wages were proxied by the wages of a similar adjacent country adjusted to either the wages in manufacturing (from the International Labour Office (ILO) database) or the PPP-adjusted GDP per capita (from the PWT). It should be noted that the wage data of different countries collected in the ILO are not based on the same working time horizon, hourly rates and daily rates were multiplied with estimated working hours per month and working days per month respectively.

Trade data were obtained from issues of *International Trade Statistics Yearbook*.

Because the commodity trade data are published at different digit levels of SITC, the commodity items published in the *Trade Yearbook* are not mutually exclusive. Differences between every two different levels of aggregation were taken to get trade data of mutually exclusive commodity classifications. The trade data are in SITC rev.2. They were first converted into SITC rev.3. The concordance between SITC rev.2 and SITC rev.3 was constructed using the concordance of 10-digit HS to 5-digit SITC rev.2 and the concordance of 10-digit HS to 5-digit SITC rev.3, which are collected by Jon Haveman from the NBER Trade Data CD. The data under SITC rev.3 were then converted into SIC using the concordance provided in the *U.S. Exports History* CDROM. Finally, the trade data were converted into IO classifications.

References

[1] Bowen, Harry P.; Leamer, Edward E.; and Sveikauskas, Leo, "Multicountry, Multifactor Tests of the Factor Abundance Theory." American Economic Review, December 1987, 77(5), pp. 791-809.

[2] Davis, Donald R. and Weinstein, David E., "An Account of Global Factor Trade." American Economic Review, December 2001, 91(5), pp. 1423-1453.

[3] Davis, Donald R.; Weinstein, David E.; Bradford, Scott C.; and Shimpo, Kazushige, "Using International and Japanese Regional Data to Determine When the Factor Abundance Theory of Trade Works." American Economic Review, June 1997, 87(3), pp. 421-446.

[4] Estevadeordal, Antoni and Taylor, Alan M., "A Century of Missing Trade?" American Economic Review, March 2002, 92(1), pp. 383-393.

[5] Freeman, Richard B. and Oostendorp, Remco H., "Wages Around the World: Pay Across Occupations and Countries", NBER Working Paper No. 8058, December 2000.

[6] Hakura, Dalia S., "Why Does HOV Fail? The Role of Technological Differences within the EC." Journal of International Economics, August 2001, 54(2), pp. 361-382.

[7] Helpman, Elhanan, "The Structure of Foreign Trade." Journal of Economic Perspectives, 13(2), Spring 1999, pp. 121-144.

[8] Kwok, Yun-kwong, "Global factor trade with differentiated factor prices and factor intensities." Mimeo, Deakin University, Australia, 2005.

[9] Leamer, Edward E., Sources of International Comparative Advantage: Theory and Evidence, Cambridge, MA: MIT Press, 1984.

[10] Leamer, Edward E. and Levinsohn, James, "International Trade Theory: The Evidence." in Gene Grossman and Kenneth Rogoff, eds., Handbook of International Economics, Vol. 3, Amsterdam: North-Holland, 1995, pp. 1339-94.

[11] Leontief, Wassily W., "Domestic Production and Foreign Trade: The American Capital Position Re-examined." Proceedings of the American Philosophical Society, September 1953, 97(4), pp. 332-49. Reprinted in Richard E. Caves and Harry G. Johnson, Readings in International Economics, Homewood, Ill.: Irwin, 1968.

[12] Maskus, Keith E., "A Test of the Heckscher-Ohlin-Vanek Theorem: The Leontief Commonplace." Journal of International Economics, 19, November 1985, pp.201-12.

[13] Summers, Robert and Heston, Alan, "The Penn World Table (Mark 5): An Expanded Set of International Comparisons, 1950-1988." Quarterly Journal of Economics, 106, May 1991, pp. 327-68.

[14] Trefler, Daniel, "International Factor Price Differences: Leontief was Right!" Journal of Political Economy, December 1993, 101(6), pp. 961-87.

[15] Trefler, Daniel, "The Cases of the Missing Trade and Other Mysteries." American Economic Review, December 1995, 85(5), pp. 1029-1046.

[16] U.S. Department of Commerce, Bureau of Economic Analysis, Economics and Statistics Administration, Benchmark Input-Output Accounts of the United States, 1992. Washington, DC: U.S. Government Printing Office, September 1998

[17] Vanek, Jaroslav, "The Factor Proportions Theory: The N-Factor Case." Kyklos, October 1968, 21(4), pp. 749-56.

Table 1: Relative Factor Prices Relative to the US
$[(w_{l,c} / w_{k,c}) / (w_{l,us} / w_{k,us})]$

Countries	Labor by occupation in ISCO-1968					
	0/1	3	4	5	6	7/8/9
Algeria	0.08	0.11	0.13	0.16	0.20	0.12
Argentina	0.33	0.24	0.39	0.33	0.28	0.43
Australia	0.92	1.18	1.28	1.36	1.01	1.33
Austria	0.98	0.99	0.66	0.75	0.94	0.82
Bangladesh	0.05	0.05	0.04	0.05	0.07	0.04
Belgium	0.58	1.09	1.01	1.01	1.37	1.31
Brazil	0.46	0.33	0.33	0.41	0.32	0.24
Bulgaria	0.07	0.15	0.14	0.14	0.23	0.15
Canada	1.43	1.20	1.58	1.58	1.26	1.26
Chile	0.77	0.25	0.42	0.18	0.46	0.46
China	0.04	0.09	0.10	0.09	0.05	0.05
Colombia	0.38	0.15	0.16	0.22	0.19	0.20
Costa Rica	0.12	0.14	0.25	0.24	0.25	0.13
Cyprus	0.90	1.09	0.76	1.22	0.86	1.02
Czech Republic	0.13	0.20	0.26	0.31	0.23	0.23
Denmark	0.83	1.10	1.18	1.71	0.87	0.97
Dominican Rep.	0.12	0.09	0.10	0.20	1.00	0.15
Ecuador	0.36	0.15	0.15	0.21	0.18	0.19
Egypt	0.05	0.08	0.07	0.09	0.06	0.05
El Salvador	0.07	0.09	0.15	0.15	0.15	0.08
Finland	0.83	0.99	1.17	1.31	1.09	1.31
France	0.93	0.59	0.97	0.86	1.06	0.99
Germany	1.24	0.79	1.29	1.14	1.40	1.32
Greece	0.53	0.34	0.55	0.49	0.60	0.56
Guatemala	0.07	0.08	0.14	0.14	0.14	0.07
Honduras	0.19	0.14	0.20	0.12	0.13	0.10
Hong Kong	0.42	0.86	0.50	0.70	0.94	0.94
Hungary	0.19	0.15	0.24	0.27	0.23	0.14
India	0.11	0.11	0.05	0.06	0.05	0.14
Indonesia	0.25	0.27	0.13	0.25	0.10	0.10
Iran	0.32	0.37	0.53	0.53	0.40	0.32
Ireland	1.00	1.14	0.85	1.14	1.19	1.09
Israel	0.73	0.47	0.77	0.67	0.83	0.78
Italy	0.90	1.29	1.15	1.44	1.22	1.42
Japan	1.45	0.72	0.69	1.35	1.99	1.11
Korea	0.86	0.70	0.81	0.95	0.83	0.83
Malaysia	0.11	0.23	0.23	0.22	0.12	0.22
Mexico	0.22	0.25	0.20	0.27	0.29	0.25
Morocco	0.11	0.17	0.15	0.19	0.13	0.11
Netherlands	0.74	0.74	1.23	1.23	1.22	1.04
New Zealand	1.08	1.10	0.92	1.10	0.74	1.10
Nigeria	0.08	0.02	0.04	0.04	0.01	0.02
Norway	0.61	1.23	1.29	1.22	1.08	0.82
Pakistan	0.17	0.17	0.07	0.10	0.08	0.23
Panama	0.75	0.31	0.32	0.43	0.37	0.40
Paraguay	0.43	0.11	0.42	0.20	0.49	0.49

Table 1: Relative Factor Prices Relative to the US (cont.)

	Labor by occupation in ISCO-1968					
Countries	0/1	3	4	5	6	7/8/9
Philippines	0.10	0.21	0.21	0.20	0.11	0.20
Poland	0.21	0.31	0.33	0.41	0.38	0.21
Portugal	0.65	0.60	0.45	0.48	0.47	0.42
Romania	0.10	0.10	0.14	0.16	0.21	0.12
Singapore	1.33	0.73	0.81	0.65	0.54	0.54
Slovenia	0.29	0.49	0.58	0.66	0.65	0.35
South Africa	0.88	0.31	0.78	0.31	0.23	0.25
Spain	1.05	0.67	1.10	0.97	1.19	1.12
Sri Lanka	0.05	0.09	0.05	0.09	0.04	0.04
Sweden	0.49	1.17	1.34	1.34	1.38	1.17
Switzerland	1.37	0.87	1.43	1.26	1.55	1.46
Syria	0.26	0.26	0.26	0.26	0.26	0.26
Taiwan	0.58	0.47	0.54	0.63	0.56	0.56
Thailand	0.47	0.49	0.24	0.46	0.18	0.18
Trinidad	0.45	0.49	0.21	0.24	0.41	0.53
Tunisia	0.11	0.17	0.16	0.20	0.13	0.12
Turkey	0.39	0.71	0.33	0.33	0.78	0.78
UK	1.09	1.24	0.92	1.23	1.29	1.18
Uruguay	0.66	0.18	0.66	0.32	0.76	0.76
USA	1.00	1.00	1.00	1.00	1.00	1.00
USSR, Former	0.03	2.06	1.72	1.87	3.43	0.10
Venezuela	0.19	0.25	0.14	0.16	0.14	0.23
Zimbabwe	0.60	0.22	0.53	0.22	0.16	0.17
Mean	0.51	0.51	0.55	0.58	0.62	0.54
St. Dev.	0.40	0.43	0.45	0.49	0.58	0.45
(1 - Mean)/SD	1.21	1.13	1.01	0.85	0.66	1.04
Median	0.43	0.31	0.42	0.33	0.41	0.35
(1 - Median)/SD	1.42	1.58	1.31	1.36	1.01	1.44
1st Quartile	0.12	0.15	0.16	0.20	0.18	0.15
(1 - 1st Q)/SD	2.18	1.94	1.89	1.62	1.41	1.91
3rd Quartile	0.83	0.79	0.85	1.00	1.00	0.97
(1 - 3rd Q)/SD	0.41	0.49	0.34	0.00	0.00	0.06

Sources: Following Trefler (1993), factor price of capital was proxied by the PPP-adjusted investment price obtained from the Penn World Tables. Wages by occupation were estimated based on the Occupational Wages around the World database calibrated by Freeman and Oostendorp (2000), the LABORSTA database by International Labor Office, and the GDP per capita from the Penn World Tables.

Notes: Occupations are classified by International Standard Classification of Occupations ISCO-1968. Class 0/1 is professional and technical workers; class 3 is clerical workers; class 4 is sales workers; class 5 is service workers; class 6 is agriculture and forestry workers, fishermen and hunters; and class 7/8/9 is production workers, transportation equipment operators, and laborers.

Table 2
Ratios of Exported Factor Services to Imported Factor Services:
Capital Services Exporting Countries

Countries	FPE $\frac{(K/L)_{EX}}{(K/L)_{IM}}$	No FPE $\frac{(K/L)_{EX}}{(K/L)_{IM}}$	Difference in %
Hong Kong	0.86	8.12	841.22
Australia	1.50	7.17	379.00
Finland	1.01	5.60	456.15
USA (+Puerto Rico)	1.01	5.00	396.53
Norway	1.83	4.63	153.50
Japan	0.71	4.47	528.12
Germany	0.96	3.93	308.28
Canada	1.21	3.62	199.06
Italy	0.78	3.61	360.36
Spain	0.96	3.57	273.94
New Zealand	1.07	3.17	195.51
Sweden	1.04	3.03	190.65
France	0.96	2.91	201.98
Belgium (+Luxemburg)	0.99	2.88	189.02
Netherlands	1.09	2.85	162.18
UK	1.03	2.84	175.15
Singapore	0.96	2.81	194.47
Switzerland	1.01	2.67	163.55
Korea	0.67	2.64	292.00
Denmark	0.95	2.63	176.92
Austria	0.99	2.52	155.18
Turkey	0.70	2.09	196.83
Ireland	1.00	2.01	101.36
Greece	0.92	1.57	70.26
Uruguay	0.82	1.43	74.77
Panama	1.05	1.21	15.41
Poland	0.91	1.21	32.91
Slovenia	0.77	1.04	35.91
Portugal	0.76	1.00	31.53

Table 3
Ratios of Exported Factor Services to Imported Factor Services:
Labor Services Exporting Countries

Countries	FPE $\frac{(L/K)_{EX}}{(L/K)_{IM}}$	No FPE $\frac{(L/K)_{EX}}{(L/K)_{IM}}$	Difference in %
Bangladesh	2.18	7.61	249.52
China	1.36	6.07	347.68
Sri Lanka	1.60	6.04	278.22
El Salvador	1.15	4.71	308.80
Guatemala	1.07	3.80	256.06
Egypt	0.73	3.32	352.90
Tunisia	1.20	3.26	172.53
India	1.66	3.15	89.39
Indonesia	0.93	2.36	153.06
Mexico	0.86	2.34	171.66
Honduras	0.95	2.30	142.81
Philippines	1.28	2.20	72.29
Morocco	1.21	2.19	80.86
Costa Rica	0.97	2.10	114.99
Pakistan	1.68	1.80	6.84
Colombia	0.89	1.77	99.70
Romania	1.28	1.76	37.57
Zimbabwe	0.95	1.76	85.02
Malaysia	1.03	1.76	70.29
Thailand	1.33	1.41	5.97
Brazil	1.11	1.28	15.13
South Africa, C.U.	0.78	1.11	41.17
Paraguay	0.93	1.01	8.59