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Development-Related Biases in Factor Productivities and the HOV Model of Trade

Keith E Maskus and Shuichiro Nishioka

University of Colorado at Boulder

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Center for Economic Analysis
Department of Economics

University of Colorado at Boulder
Boulder, Colorado 80309

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Abstract

Past empirical failures of the basic Heckscher-Ohlin-Vanek (HOV) model related to its restrictive assumptions, particularly identical international technologies and factor price equalization. Trefler (1993) resuscitated HOV by introducing a simple Hicks-neutral (HN) factor-productivity adjustment, an approach that was heavily criticized. In this paper, we reexamine the productivity question by estimating factor productivities from the individual technology data of multiple countries. Using a dataset of 15 OECD countries, we find positive evidence for Trefler's idea, but with factor augmentation. Further, we find that the ratios of factor productivities are strongly correlated with corresponding factor endowments. This systematic bias implies that the ability of HOV to explain North-South factor trade depends both on relative factor abundance and productivity gaps. We thus extend Debaere's (2003) conclusion that North-South trade is determined by HN-adjusted endowment differences.

Keywords: Heckscher–Ohlin-Vanek; Factor Trade, Productivity

1. Introduction

Early tests of the Heckscher-Ohlin-Vanek (HOV) model of international factor trade demonstrated that it failed to predict trade better than a coin toss (Maskus, 1985; Bowen, Leamer and Sveikausas, 1987). As noted by Maskus (1985), the assumptions of the strict HOV model are too unrealistic to expect them to generate actual data.[1] Later tests relaxed many of these assumptions to generate augmented HOV models that were more consistent with data (e.g., Trefler, 1995; Davis and Weinstein, 2001; Davis, et al, 1997; Hakura, 2001). Much of this analysis has focused on the unrealistic assumptions of internationally identical technologies and factor price equalization (FPE).

Trefler (1993) made a first important step to integrate international differences in factor-prices into the HOV model. He introduced a simple Hicks-neutral productivity modification to measure factor endowments in productivity-equivalent units. For example, if the labor supplies of the United States and Brazil were the same, but U.S. workers were twice as productive, the former nation would have twice as much labor at the productivity-equivalent level.[2] At the same time, the wage of U.S. workers would be twice that of Brazilian workers and ratios of factor prices could be used to infer relative productivities. This modification is consistent with the HOV model after adjusting for international differences in factor productivity.

Davis and Weinstein (2001) argued that Trefler's productivity modification is incomplete because it fails to introduce general differences in technology. With step-by-step relaxations of the standard HOV assumptions, they found substantial improvements in prediction power when national technologies are modified according to factor abundance measures.

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[1] The Strict version assumes: (1) identical constant returns to scale (CRS) technology and factor price equalization (FPE), (2) perfectly competitive markets in goods and factors, (3) identical and homothetic preferences, (4) factor endowment differences and (5) free trade in goods and services (product prices are identical across the countries) but not factors.

[2] This was Leontief's (1953) co

Though both studies focused on modifying FPE, the conceptual distinction between their empirical approaches is important. Is it differences in productivity of factors or underlying technology that is responsible for factor price disparity? If it is because of factor-productivity differences, the HOV model is fundamentally acceptable, for its failures would come from the inability to measure factors in productivity-equivalent units. However, if the failures occur because of general technology differences, bot

only relative factor abundance for South-North country pairs. Therefore, it is hard to conclude that the success of the relative factor-abundance model is purely derived from South-North differences in factor endowments. Rather, both differences in factor productivities and factor endowments are responsible, with the balance of each element being unclear.

We organize the paper as follows. In Section 2 we revisit Trefler's (1993) model and the criticism in Gabaix (1997). In Section 3 we set out our empirical results from the estimation of factor productivities and relates them to Trefler's model. In addition, we study the characteristics of estimated productivities, particularly the correlation between productivity and factor abundance. In section 4 we examine the potential biases occurred from factor productivities in the context of Debaere's (2003) relative factor-abundance model. Finally, we conclude the paper with a discussion of the link between factor productivity and technology.

2. The HOV Model and Factor-Augmenting Productivity

We begin by deriving the basic HOV prediction in a world with F factors, C countries, and N products (sectors). Assume that all countries have identical constant returns to scale production technology; markets for goods and factors are perfectly competitive; there are no barriers to trade and zero transportation cost; factors move freely within a country but do not move across countries; and the distribution of factors is consistent with integrated equilibrium so that factor prices are equalized across countries.

For each country the net-export vector can be obtained as the difference between net production and the final consumption:

$$= (-) - \qquad (1)$$

where is an N×1 vector of net exports, is an N×1 vector of gross output, and is an N×1 vector of final consumption. is an N×N input-output (indirect) matrix for the unit intermediate requirements so that equals the net output vector .

Let be the F×N direct technology matrix and its elements ( ) represent the amount of a factor needed to produce one unit of gross output in sector . Pre-multiplying equation (1) by direct and indirect technology matrix QA and applying the factor-exhaustion assumption where is an F×1 vector of factor endowments, we have that a country's factor contents of trade is the difference between factors absorbed in production (

model because fitted values for predicted factor contents of trade are identical to measured factor contents of trade. That is, all the HOV test statistics automatically would indicate a perfect fit.[5]

To deal with this issue Trefler set out two alternative methods to demonstrate the validity of his estimated factor productivities. One was to check the signs of the productivity parameters, with all expected to be positive. The other was to study the correlation between relative price ( ) and relative productivity (π π) in equation (6) for each factor, with the correlation expected to be unity. Trefler noted that the productivities estimated from equation (7) were positive and that equation (6) performed well, with the correlation for labor being 0.90 and that for physical capital being 0.68.

While the approach generated a number of comments, Gabaix (1997) in particular criticized this methodology for deriving the estimation method (equation (7)) testing factor productivities. His reasoning came from the “missing trade” phenomenon analyzed in Tm(m)THh.rŒ positive and correlated strongly with factor prices. In this context, Trefler's approach offered no independent validation for the empirical success of his productivity modification of HOV.

Although Gabaix's criticism does invalidate Trefler's methodology and statistical evidence, it does not necessarily mean the rejection of Trefler's model . Rather, if it were possible to estimate factor-productivity parameters independently of the equation system, incorporating them would not make HOV a truism and standard testing procedures would be valid. To this end, we develop unit total factor requirements (technologies and) for each country and estimate factor productivities for each country across sectors. These estimated parameters are then incorporated to test equations (5) and (6). This procedure escapes the problems Gabaix (1997) pointed out.

Within Trefler's framework, countries share identical production technologies at the productivity-equivalent level, making adjusted unit factor requirements identical across countries for each factor: for country and factor where is π . If firms minimize unit cost functions with CRS technology, the quantity of factor required in sector divided by corresponding output is the unit factor requirement: = for the United States and

π π = for country .

We estimate the productivity parameters (π) by regressing the unit factor requirements of the United States against those of individual countries. This approach was proposed by Maskus and Webster (1999) in developing their "factor-augm

where α is the measured relative factor contents of trade with c

(2001) who developed a 23-sector dataset of four European countries with seven factors. Because we combine input-output tables from different sources (OECD and Eurostat) in order to increase the number of countries, we were forced to aggregate to 23 sectors to maintain consistency in classification.[11] Aggregation is inevitable but, as has been noted by Feenstra and Hanson (2000) it raises the risk of systematic bias in the HOV predictions, a problem in all such studies.

Table 1 reports the estimated factor-productivity parameters and associated statistics for equation (9). All factor-productivities are positive and statistically significant.[12] The coefficients on physical capital for all 14 OECD countries are lower than unity, suggesting that the United States has the highest levels of capital productivity. Regarding labor, workers in Belgium, France, and Italy are more productive than those in the United States. For each country the R-squared coefficients measure the strength of the correlation between countries. In most cases the factor productivities fit well. For example, the R-squares for Canadian capital and labor are 0.847 and 0.590, indicating a strong concordance between Canadian and U.S. technologies. However, if the technology differed in a more complex way, as Davis and Weistein (2001) suggested, there are additional determinants that the basic approach taken here does not account for. This might be the case for capital productivities in Belgium, France and Japan, which do not perfectly correlate with the U.S. technology,

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[11] Overall there are 23 industries in the OECD STAN database. However, because the figures on gross fixed capital form

It is of interest to compare the national factor-productivity parameters developed using Trefler's (1993) method (equation (7)) and those using the method in equation (9) due to Maskus and Webster (1999). In Table 2 we list the parameters computed from Table 1 (the first two columns) and those in Trefler's paper (the next pair of columns). The correlations between the corresponding factors are very high, at 0.81 for physical capital and 0.96 for aggregate labor. Thus, Trefler's estimated factor-productivities are similar to those obtained from estimation based only on unit factor requirements.

In addition, we compare these factor productivities with total factor productivities (TFP), which are estimated from a Cobb-Douglas production function applied to 13 manufacturing sectors in these OECD countries.[13] The correlations between TFP and individual factor productivities are not perfect (around 0.6) and the values of TFP generally lie between those for capital and labor. This would suggest that the empirical success of the factor-productivity adjustments in Trefler (1993) are attributable to systematic productivity differences across factors that the Hicks-neutral form (e.g., TFP) cannot account for. This confirms previous findings in the literature that Hicks-neutral productivity adjus.3.3597 Tm(nts.)TjE4EMC/P /<MC3D 3 >>008 T

However, once the estimated factor productivities are introduced, these numbers improve considerably. For the HOV specification, as shown in the bottom panel, the sign fit improves to 76.7 percent, the slope coefficient rises to 0.231, and the variance ratio increases to 0.233. Furthermore, Figures 1-1 and 1-2 depict the correlation between factor productivities and factor prices as in equation (6). Both correlates positively with capital abundance.[15] As shown in Figures 2-1 and 2-2, this feature characterizes the data, but weakly. Using unadjusted input requirements, capital-productivities decline with capital abundance (correlation equals -0.25) and labor productivities rise with capital abundance (correlation equals 0.24). One reason for these correlations to be weak might be the limitation of our data to just two factors, with other elements such as knowledge capital and human capital being partially responsible for varying productivities.

However, when we incorporate the adjusted productivity ratios (π /π), they correlate strongly with corresponding factor endowments as shown in Figure 3. For example, capital-abundant Japanese workers are productive relative to Japanese capital because they have good access to abundant capital (machines and computers). It seems that Trefler's original explanation holds well in this "relative" sense. This observation suggests that, similar to the approach of Davis and Weinstein (2001), who adjusted technologies according to factor abundance, our adjusted factor productivities also capture the link between technology, productivity, and factor-abundance that the Hicks-neutral form cannot accommodate.

4. The Relative Factor Abundance Model and Factor-Productivities

The strong correlation between factor abundance and factor productivity is particularly relevant to the relative factor-abundance model of Debaere (2003). Debaere developed a factor content of trade prediction for the HOV model that relates bilateral differences in endowments to bilateral differences in factor trade. Our objective here is to reexamine his conclusion that the trade of South-North country pairs is consistent with HOV but that of North-North country pairs is not. Weers) 12 72.0002 15723 Tw 12 0 0 12 3weM9dnot.o30.0032ha1mrlogy, endowments, which is the issue he emphasized, but also by South-North differences in factor productivity. Specifically, because unskilled labor, the abundant factor in the South, has limited access to skilled labor and capital, the productivity of unskilled workers there is systematically lower than that in the North. This difference is an additional important reason that only South-North country-pairs perform well in his examination of HOV.

To develop Debaere's relative factor abundance model, take equation (4) with U.S. technologies and impose identical and homothetic preferences:

$$= \; - \quad (\; - \quad)^{-1} \tag{13}$$

Divide both sides of equation (13) by the scalar expenditure share to obtain:

$$* \; = \; * \; - \quad (\; - \quad)^{-1} \tag{14}$$

where and . Now consider equation (14) for two countries, and , and take the difference between their expressions:

$$* \; - \; *_{,} \; = \; * \; - \; *_{,} \tag{15}$$

Equation (15) may be expressed for a particular factor ( ) and divided by the sum of factor endowments, :

$$\frac{* \quad *_{,}}{* \quad *_{,}} \quad \frac{* \quad *}{* \quad *_{,}}$$

Here, the relative difference in measured factor content of trade is on the left-hand side and the relative difference in predicted factor cont

$$\frac{*}{*} > \frac{*}{*} \Leftrightarrow \frac{'/\pi}{'/\pi} > \frac{'/\pi}{'/\pi} \Leftrightarrow \frac{'}{'}\frac{\pi}{\pi} > \frac{'}{'}\frac{\pi}{\pi} \qquad (18)$$

Equation (18) explains that relative factor-abundance ratio without productivity adjustments (or) is a product of the productivity-equivalent relative factor abundance ratio (or) and the factor-productivity ratio (π /π or π /π). If, as Debaere assumed, the Hicks-neutral form (π /π =π /π) is realistic, then relative factor abundance and productivity-equivalent factor abundance are identical and his basic conclusion holds. However, if productivity adjustments are more general, then both elements matter. For example, if is labor ( ) and is physical capital ( ) for the South ( ) and the North ( ), we expect that labor in the South is less productive than in the North because it operates with a smaller relative capital endowment. As a result, we have an inequality in relative productivity ratios: π /π >π /π or π /π >π /π .

It is important, therefore, to study South-North differences in factor productivities in addition to relative factor endowments. For this purpose, we use Trefler's dataset, divide countries into the South and the North according to Debaere (2003), and develop the South-North productivity ratios for factors. The parameters (π) are obtained by estimating equation (7) for physical capital, skilled labor, unskilled labor, and aggregate labor. If Hicks-neutral productivity differences were realistic, we would expect these productivity ratios to be identical across any factor pair (π /π =π /π). However, this is not the case as shown in Figures 4-1 through 4-8. Rather, we find the interesting tendency that the productivity ratio of the South to the North for unskilled labor is always smaller than that for skilled labor and physical capital. There is not a similar tendency for the North-North pairs. Therefore, the systematic tendency in factor productivities supports the inequality in equation (18) only for the South-North country pairs of particular factor combinations: unskilled labor/skilled labor, unskilled labor/capital, and labor/capital. This evidence implies that Debaere's conclusion could be delivered by interplay between endowment differences and factor-productivity differences.

5. Concluding Remarks

In this paper we reexamine Trefler's (1993) factor-productivity model. Departing from his procedure, which was criticized by Gabaix (1997), we estimate factor-productivity parameters from each country's actual technologies. This approach permits use of the standard evaluations of the HOry's actu within different cones. This is especially the case as regards labor in developing countries. As a result, Debaere's (2003) finding th

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Appendix A: Construction of Data

1) Input-Output Data

Input-output tables (total use) for Australia (1994-1995), Canada (1997), Denmark (1997), Finland (1995), France (1995), Germany (1995), Japan (1997), the Netherlands (1997), Norway (1997), the United Kingdom (1998), and the United States (1997) are from the OECD I-O database (2002). Belgium (1995), Italy (1995), Spain (1995), and Sweden (1995) are from the Statistical Office of the European Communities (Eurostat). The I-O tables from the OECD I-O database employ ISIC Rev.3 classification containing 41 industrial groups and the I-O tables from the Eurostat employ NACE/CLIO classification containing 59 groups. These two classifications are aggregated into 23 industrial groups of ISIC Rev.3. The number of industrial groups is smaller than the 35 sectors used by Davis and Weinstein (2001) but is the same as Hakura (2001). Both the input-output matrices and final consumption, gross output, and net exports are derived from the I-O tables for 1997. Final consumption is the sum of final consumption of households, final consumption and investment of government, gross fixed capital formation, and changes in inventory.[17] Therefore, the total use table of country always satisfies the equation: where is a 23×23 indirect technology matrix for the unit intermediate requirements and vector equals net output ( ). is obtained by taking input-output data from the I-O tables and dividing inputs in each se

STAN database (2004). Therefore, we take the total GFCF series from the OECD National Accounts Statistics (2006) and Japan's sectoral shares are obtained from the nominal investment matrix tables of the ESRI-Histat database.

(B) Labor

Sectoral labor inputs (total employments are derived from the OECD STAN databases (1998 and 2004), the Eurostat, and the OECD Employment by Activities and Status (2006). To interpolate unreported data, we use the available share of the nearest year to allocate aggregated sector totals to each detailed sector. Country-level average working hours from the OECD Employment and Labor Market Statistics (2006) are used to adjust international differences in average working hours, normalized by U.S. working hours.

Appendix B: Relative Abundance and Factor-Productivity Adjustment

Here we introduce factor-augmenting productivity to the right hand side of equation (17). First, we show that the inequality in relative factor abundance for the factor-productivity model does not coincide with that for the strict (or Hicks-neutral) model, as shown in the following equation. Thus, the empirical prediction of Debaere's model with factor-productivity parameters differs from

Tables and Figures

Table 1: The Results of SUR estimations

	Physical Capital			Aggregate Labor		
	π	s.e. of πcf	r-square	π	s.e. of πcf	r-square
Australia	0.706	0.029	0.758	0.780	0.028	0.662
Belgium	0.660	0.054	0.105	1.127	0.022	0.896
Canada	0.761	0.024	0.847	0.859	0.034	0.590
Denmark	0.654	0.022	0.822	0.867	0.038	0.476
Finland	0.644	0.036	0.563	0.766	0.026	0.692
France	0.817	0.063	0.211	1.079	0.043	0.591
Germany	0.702	0.027	0.788	0.858	0.031	0.666
Italy	0.692	0.031	0.691	1.084	0.032	0.740
Japan	0.505	0.040	0.158	0.733	0.030	0.546
Netherlands	0.702	0.037	0.548	0.926	0.033	0.607
Norway	0.598	0.029	0.667	0.990	0.038	0.625
Spain	0.614	0.039	0.438	0.721	0.021	0.774
Sweden	0.803	0.038	0.663	0.861	0.027	0.738
UK	0.737	0.042	0.517	0.739	0.033	0.457

Note: (1) Dependent variables are the US technology
(2) Sector 1 "Agriculture" is excluded

Table 2: Estimated Factor Augmenting Productivities

	Maskus and Webster (1999)		Trefler (1993)		TFP
	(1) capital	(2) labor	(3) capital	(4) labor	(5)
Australia	0.706	0.780	0.707	0.819	0.655
Belgium	0.660	1.127	0.641	1.072	0.911
Canada	0.761	0.859	0.852	0.861	0.945
Denmark	0.654	0.867	0.800	0.931	0.705
Finland	0.644	0.766	0.620	0.726	0.670
France	0.817	1.079	0.739	1.085	0.953
Ger					

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