Relative Factor Abundance and Trade

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I develop a factor content of trade prediction for the Heckscher-Ohlin-Vanek model (HOV) that relates bilateral differences in country endowments to bilateral differences in factor contents. The results are striking. In comparisons of North-South factor contents or factor contents of countries with very different endowments (e.g., with very different capital-labor ratios), there is clear support for an HOV sign prediction. Thus countries with dissimilar endowment ratios also have very different factor content of trade differences as predicted by the HOV model.

I. Introduction

The question why countries trade is at the heart of international trade theory. In traditional, neoclassical models, differences between countries in terms of their technologies, their factor endowments, or their preferences determine countries' comparative advantage, and these differences, therefore, are essential to explain the international patterns of production and trade. In the Heckscher-Ohlin theory, still one of the major theories in international trade that has a long empirical tradition that started with the work of Leontief (1953), differences in factor en-

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dowments between countries are critical. For a world of many goods, many countries, and many factors, these differences predict the factors contained in a country's net trade. A capital-abundant country, for example, should, on net, export capital through the goods that it trades with the rest of the world, and a labor-abundant country should export labor. There is a huge gap between the capital-labor ratios and the skilled–unskilled labor ratios of developed and developing countries. Therefore, North-South trade should be the primary illustration of endowment-driven trade, and the factor content of trade from developed and developing countries should be very different.

However compelling these predictions may be, the recent empirical literature based on Vanek's (1968) extension of the Heckscher-Ohlin model into higher dimensions offers little evidence to support these predictions. Wood (1994) states that North-South trade has not been directly studied in a Heckscher-Ohlin-Vanek (HOV) setting. Davis and Weinstein (2001) test the HOV model only for the relatively similar OECD countries. And Trefler (1995), whose test includes both developed and developing countries, obtains the weakest results predominantly for countries from the South that mainly trade with the North and whose endowments are very different from the world endowments. These are precisely the countries for which we might think that the theory should be most relevant.

In the HOV literature, it is common to explain a country's factor content of trade by relating a country's endowment to the world endowments. In this paper I develop a prediction of the factor content of trade that relates bilateral differences in endowments to bilateral differences in factor contents. In particular, I introduce factor endowment ratios in the country pair approach that has been employed by Staiger, Deardorff, and Stern (1987), Brecher and Choudhri (1988), and Hakura (1995). This particular setup allows me to compare endowments and factor contents of developed and developing countries directly and to do so for two factors at a time. My prediction yields qualitative results that cast a different light on the literature and bear out the basic HOV intuition mentioned above.

The HOV literature has a history of poor performances that started with Maskus (1985) and Bowen, Leamer, and Sveikauskas (1987).[1] Trefler (1995) states that he can only half of the time ("a flip of a coin") predict the sign of a country's factor content of net trade on the basis of its own and the world's endowments, which is devastating for HOV. In addition, he reports how weighting the signs improves this (unweighted) sign test result from 49.5 to 71 percent. It has often been

[1] Davis and Weinstein (2001) have questioned the quality of the data used in Bowen et al. (1987).

overlooked that Trefler's weights depend on the size of the factor content. Therefore, the improvement is driven by the above-average performance of the six biggest industrial nations. At the same time, the weighting reveals the below-average performance of the countries for which endowment-driven trade was thought to matter most, that is, the non-OECD countries.

My results differ significantly from these findings. Using Trefler's data, I find that more than 70 percent of over 3,000 country pairs support an (unweighted) sign prediction of the HOV model that is based on endowment ratios. The results are even more striking in comparisons of pairs of developed and developing countries that are very different in terms of capital-labor and skilled–unskilled labor ratios. In about 80 percent of these country pairs the HOV sign prediction is confirmed. If one explicitly includes the factor content of North-South trade, the data match the sign prediction up to 90 percent of the time. Moreover, I also study factors such as land whose abundance does not coincide with the distinction between developed and developing countries. Therefore, my findings support the more general statement that whenever countries' factor endowments are very different, their trade will reflect very different factor contents.

Sign tests are an integral part of the empirical evaluation of HOV. They are meant to provide basic evidence in support of HOV. Therefore, getting sign predictions right is important. There are two critical reasons for the better performance of HOV in my specification. First, my prediction is much less sensitive to technological differences between countries than the specification that Trefler chooses. Therefore, I can test whether the very different endowments of developed and developing countries are related to the differences in their factor contents in a systematic way, irrespective of the significant Hicks neutral technological differences between them. Second, Trefler compares for one factor at a time the level of a country's endowment with that of the world to predict a country's factor content of trade. My HOV prediction, however, is based on a comparison of the ratio of two factor endowments from two countries. Note that there is far more variation in endowment ratios across country pairs than there is between a country's endowment and that of the world for one factor at a time. Therefore, by investigating two factors at a time, I can test the theory where the signal from the endowments is strongest. This is a plus since the work by Trefler (1995) and Davis and Weinstein (2001) has shown how difficult it is to account for noise in the HOV model.

The rest of the paper is structured as follows. In Section II, I develop a factor content of trade prediction that considers two factors and two countries at a time. In Section III, I present the empirical support and

interpret the results. In Section IV, I place the results in the context of the empirical research on HOV.

II. Relative Factor Abundance in a Country Pair Approach

The HOV model predicts factor contents of net trade for F factors, M sectors, and C countries. It assumes for all the countries of the world (1) identical homothetic preferences, (2) identical constant returns to scale production functions, (3) perfect factor mobility between sectors in a country, (4) free and frictionless trade with perfect competition, and (5) factor price equalization across the world. Note that I shall relax the second and the fifth assumptions in the implementation.

The starting point of the analysis is the following identity:

$$T_c = Q_c - C_c, \tag{1}$$

where **T**, **Q**, and **C** are, respectively, $M \times 1$ vectors of net exports, output, and consumption.

The equation states that a country c trades the part of its production that is not consumed. With identical homothetic preferences, perfect competition, and free and frictionless trade, countries consume a constant fraction s_c of world production Q_w, that is, $C_c = s_c Q_w$.[2] With F factors and M sectors, there is also an $F \times M$ technology matrix **A** whose elements a_{fm} indicate how much of a factor f is needed to produce one unit of output in sector m. That matrix should be the same for all countries when there is factor price equalization and when all countries have identical constant returns to scale production functions. In that case, the vector of a country's factor content of net trade F_{fc}^* that indicates how much capital, labor, and so forth its net exports contain equals $\mathbf{F}^* = \mathbf{AT}$. Also, with factor price equalization, identical technology, and full employment, the factor content of production **AQ** equals the endowment $\mathbf{V}^*$. Consequently, under the HOV assumptions, equation (1) can be transformed into the standard HOV equation when the vectors **T**, **Q**, and **C** are premultiplied by **A**:

$$F_{fc}^* = V_{fc}^* - s_c V_{fw}^*. \tag{2}$$

Equation (2) relates for each factor f a country's net factor content of trade to its own and the world's endowments. I divide expression (2) by the income shares s_c and define $F_{fc} = F_{fc}^*/s_c$ and $V_{fc} = V_{fc}^*/s_c$ to obtain the following equation:

$$F_{fc} = V_{fc} - V_{fw}^*. \tag{3}$$

[2] The term $s_c = (Y_c - B_c)/Y_w$, where Y_c and Y_w are country c's and the world's gross domestic product and B_c is country c's trade balance.

Now consider equation (3) also for country c' and subtract it from (3), which yields, after division of both sides by $V_{fc} + V_{fc'}$,[3]

$$\frac{F_{fc} - F_{fc'}}{V_{fc} + V_{fc'}} = \frac{V_{fc} - V_{fc'}}{V_{fc} + V_{fc'}}. \tag{4}$$

In a final step, I take the last equation for a different factor f' and subtract it from (4) to obtain the expression that constitutes the basis for our analysis:

$$\frac{F_{fc} - F_{fc'}}{V_{fc} + V_{fc'}} - \frac{F_{f'c} - F_{f'c'}}{V_{f'c} + V_{f'c'}} = \frac{V_{fc} - V_{fc'}}{V_{fc} + V_{fc'}} - \frac{V_{f'c} - V_{f'c'}}{V_{f'c} + V_{f'c'}}. \tag{5}$$

I shall base a sign test on equality (5). In other words, I shall test whether the double difference in the factor contents of trade for two countries that is found on the left-hand side of the equality has the same sign as the double difference of their endowments on the right-hand side. Note that expression (5) is particularly appealing since, as is shown in Appendix A, it is directly related to relative factor abundance:

$$\frac{F_{fc} - F_{fc'}}{V_{fc} + V_{fc'}} - \frac{F_{f'c} - F_{f'c'}}{V_{f'c} - V_{f'c'}} = \frac{2V_{fc'}}{V_{f'c} - V_{f'c'}}\left(\frac{V_{f'c'}}{V_{fc'}} - \frac{V_{f'c} - V_{f'c'}}{V_{fc} - V_{fc'}}\right). \tag{6}$$

For any two factors f and f', a country c is said to be relatively abundant compared to country c' in the factor f when $V_{fc}/V_{f'c}$ is larger than $V_{fc'}/V_{f'c'}$. It is easy to show that relative abundance uniquely determines the sign of the right-hand side of equation (6), since $V_{fc}/V_{f'c} > V_{fc'}/V_{f'c'}$ holds if and only if $V_{f'c'}/V_{fc'} > (V_{f'c} + V_{f'c'})/(V_{fc} + V_{fc'})$. In other words, my sign test that is based on (5) should show whether or not the relative abundance of one country versus the other is revealed in the double difference of their factor contents. Because of this link with relative abundance, I shall refer to equation (5) as the relative abundance equation.

Note that the relative abundance equation opens an interesting op-

[3] As emphasized by Brecher and Choudhri (1988), such a country pair approach requires only that the assumptions of the HOV model hold for the two countries involved. They show (see their pp. 8–9) how one can derive a comparison of the net factor contents and the endowments between two countries (not unlike my eq. [4], except for the division by the consumption share s_c and by the sum of the endowments $V_{fc} + V_{fc}$) by assuming that only two countries have the same constant returns to scale technology, identical homothetic preferences, perfect competition, free trade, and the same factor prices. Note that instead of the assumption that $C_c = s_c C_w = s_c Q_w$, in the two-country case it is sufficient that $C_c = \beta C_{c'}$, where β is just a scalar. Note also that if one focuses on two countries, the domestic factor content of consumption (and trade) is based on the domestic input requirements of one of the countries, regardless of where the goods are produced. As Brecher and Choudhri remark, these Leontief-type measures generally differ from the "true" measures that are based on the actual input requirements in the country of production. See also Staiger et al. (1987).

portunity to extend the analysis to groups of countries. Equations (5) and (6) compare the multilateral factor content of two countries only. More specifically, if one is a developing country and the other a developed country, the factor content of their trade includes their trade with other developed and developing countries. Working with groups makes it possible to more directly study North-South trade excluding any trade among developed and among developing countries. For a group G, define its factor content of trade as $F^*_{fG} = \sum_{c \in G} F^*_{fc}$, its share of world consumption as $s_G = \sum_{c \in G} s_c$, and its endowments as $V^*_{fG} = \sum_{c \in G} V^*_{fc}$.[4] In a world in which HOV holds, $F^*_{fc} = V^*_{fc} - s_c V^*_{fw}$, and hence, the factor content for group G should equal $F^*_{fG} = V^*_{fG} - s_G V^*_{fw}$, or $F_{fG} = V_{fG} - s_G V_{fw}$, after multiplication by s_G. For any G and G' the familiar equation (5) for these groups of countries is

$$\frac{F_{fG} - F_{fG'}}{V_{fG} + V_{fG'}} - \frac{F_{f'G} - F_{f'G'}}{V_{f'G} + V_{f'G'}} = \frac{V_{fG} - V_{fG'}}{V_{fG} + V_{fG'}} - \frac{V_{f'G} - V_{f'G'}}{V_{f'G} + V_{f'G'}}. \tag{7}$$

If one now splits the world into two groups, the North (G) and the South (G'), one can directly compare the factor content of North-South trade. In that case the North's factor content of net trade should be the exact mirror image of that of the South. In the next section I shall discuss the sign test results based on the relative abundance equations for country and group pairs.

III. Empirical Results

Trefler (1995) studies HOV with six categories of labor, two types of land, and capital. For the implementation he bases the **A** technology matrix on the U.S. input-output total requirement table, and he also takes data on factor usage by industry from various U.S. industry censuses and the 1983 Annual Survey of Manufactures. I use his data to test the relative abundance equation (5). I distinguish four factors of

[4] The reason why a summation of factor contents for a set of countries yields the appropriate factor content for that group is as follows. Consider group G, which consists of countries c and c'. Define for country c $F^*_{cc'}$ as the factor content of its net bilateral trade and $F^*_{c(c')}$ as the factor content of net trade of country c with the rest of the world, excluding country c'. Define similarly for country c' $F^*_{c'c}$ and $F^*_{c'(c)}$. The sum of the factor content of countries c and c' can be rewritten as $F^*_G = F^*_{c(c')} + F^*_{cc'} + F^*_{c'(c)} + F^*_{c'c}$. As $F^*_{c'c}$ and $F^*_{cc'}$ refer to the same bilateral trade, they should have opposite signs (i.e., country c's exports are country c''s imports), $F^*_G = F^*_{c(c')} + F^*_{c(c)}$. This expression represents the factor content of net trade of group G with the rest of the world. Note that this logic applies also when there are technological differences between countries, as long as the factor content of trade can be defined as $A_{US}T_c$. For a discussion of alternative definitions of the factor content of trade, see Antweiler and Trefler (2002). See also Trefler and Zhu (2000), who use a factor content of trade definition similar to mine.

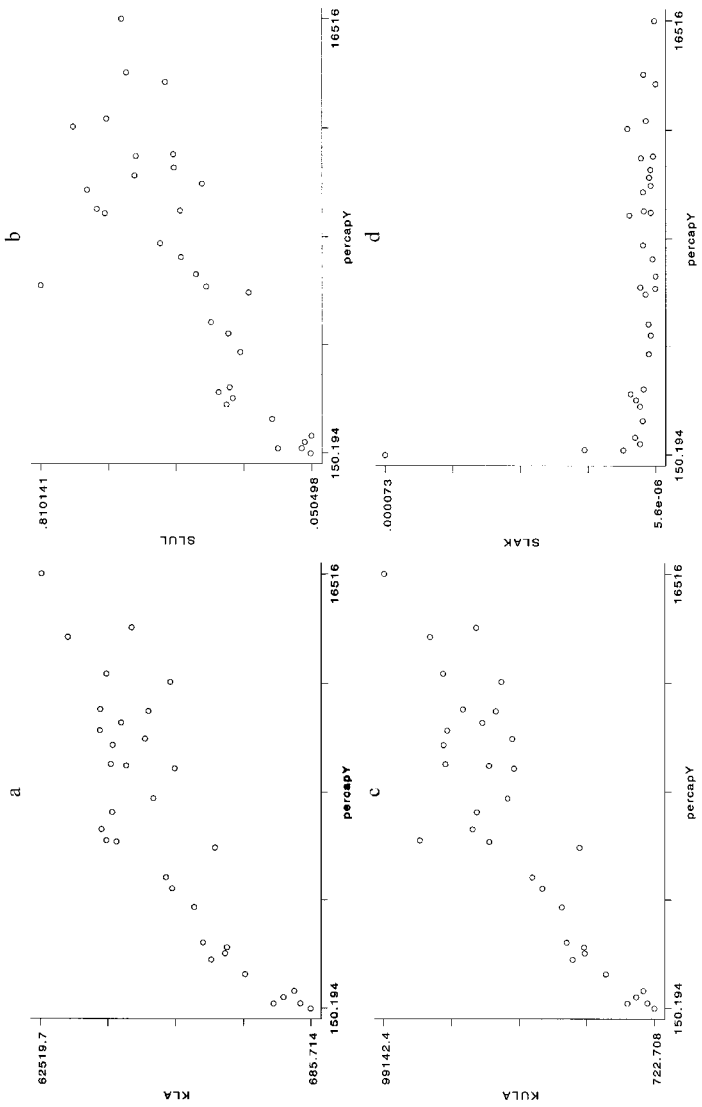
production: capital, land, skilled labor, and unskilled labor.[5] These four factors generate six different ratios: skilled–unskilled labor, skilled labor–land, skilled labor–capital, unskilled labor–land, unskilled labor–capital, and capital-land. To these six ratios I add the capital–total labor ratio since this ratio is of particular significance for North-South trade. For each ratio I generate for Trefler's 33 countries all possible 528 country pairs. See figure 1. The first row of table 1 provides the basic statistics of the sign tests based on equation (5). It provides the percentage of corresponding signs in comparisons of the right- and the left-hand sides of the equation. Across all factors one obtains, on average, a sign correspondence of a little more than 71 percent. With such high percentages one can easily reject the hypothesis that the factor contents (the left-hand side) and the endowments (the right-hand side) are independent.

In the second, third, and fourth rows of table 1, I report a different set of statistics. I split the 33 countries into two groups. One group I call "the North"; it includes all the rich developed countries of the sample. The other group is "the South."[6] I give the percentage of sign correspondences for all 272 country pairs involving a country from the North and one from the South (North-South) and for all 136 country pairs of only rich developed countries (North-North) and finally the sign correspondences for the 120 pairs of only developing countries (South-South). There is an interesting pattern. I first discuss the number of times that two countries' relative abundance is revealed in their factor contents for the factors that are typically associated with Heckscher-Ohlin and North-South trade: capital and labor on the one hand and skilled and unskilled labor on the other hand. For both endowment ratios the percentage of matching signs is substantially higher for North-South than for North-North or South-South country pairs. Sign correspondences of up to 83.5 and 77 percent are found for the very different countries from the North and South, whereas among the more similar countries in the North and in the South, the HOV prediction barely does better than a toss-up.

I also report the results for the other five factor ratios. The previous North-South pattern is clearly repeated for the ratio unskilled labor versus capital. In the other cases, one does not obtain such a striking difference between the performance of the North-South group and the

[5] Skilled labor consists of professional and clerical workers. All other occupational categories are classified as unskilled labor. (Results are not sensitive to a slightly broader definition of skilled labor.)

[6] There is no standard definition of the South. In this paper, the South includes any country that does not belong to the following group of rich, developed countries: Austria, Italy, the United Kingdom, Japan, Belgium, the Netherlands, Finland, Denmark, West Germany, France, Sweden, Norway, Switzerland, Israel, Canada, and the United States.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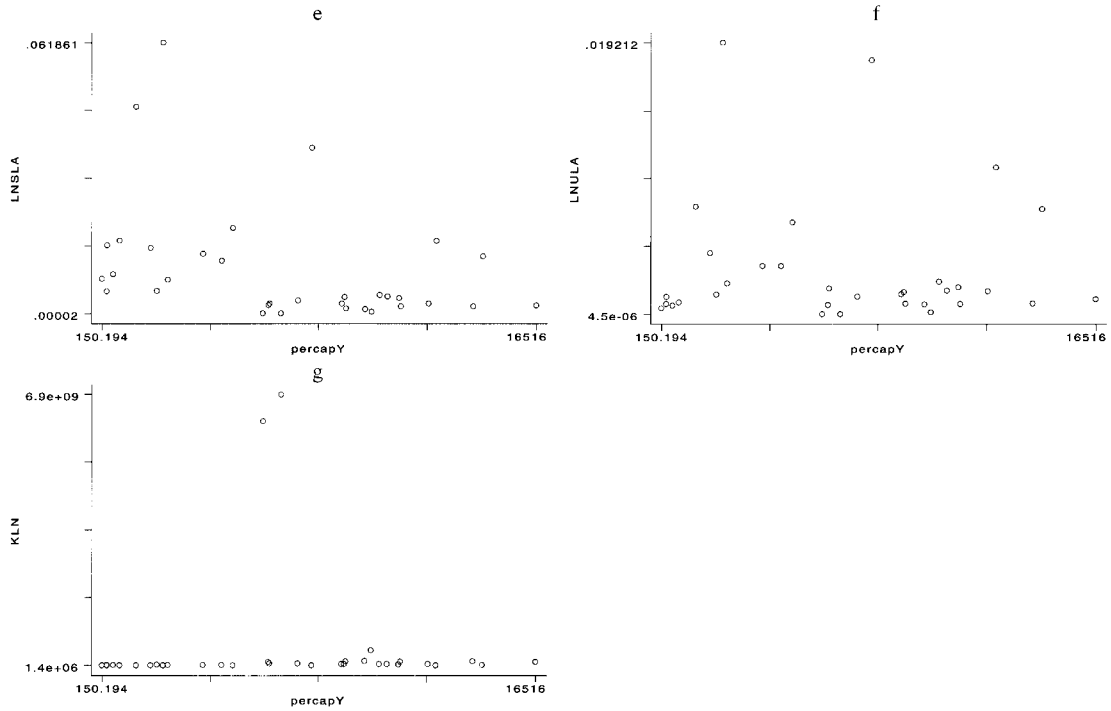

FIG. 1.—Correlations between per capita GDP and the endowment ratios. *a*, Capital/labor vs. per capita GDP. *b*, Skilled labor/unskilled labor vs. per capita GDP. *c*, Capital/unskilled labor vs. per capita GDP. *d*, Skilled labor/capital vs. per capita GDP. *e*, Land/skilled labor vs. per capita GDP. *f*, Land/unskilled labor vs. per capita GDP. *g*, Capital/land vs. per capita GDP.

TABLE 1
SIGN CORRESPONDENCE FOR COUNTRY PAIRS (Percent Corresponding Signs, Eq. [5])

	Capital/Labor	Skilled Labor/ Unskilled Labor	Unskilled Labor/ Capital	Skilled Labor/ Capital	Unskilled Labor/ Land	Skilled Labor/ Land	Capital/Land
All country pairs	70	66	72.5	60	74.5	79	77.5
North-South pairs	83.5	77	86	65	72.5	78.5	81
North-North pairs	59.5	61	67	58	77	91	74
South-South pairs	48.5	48.5	49	51	76	66	73
Productivity adjustments:							
All	71.5	65	74	61	74.5	79	76
North-South pairs	88	82	86	63	69	75	88
	For Individual Countries						
South:							
Bangladesh	72	60	72	72	26	88	40
Pakistan	72	60	72	72	53	35	75
Indonesia	66	47	66	63	60	69	81
Sri Lanka	75	75	75	81	41	50	69
Thailand	72	66	72	72	41	91	88
Colombia	69	66	72	69	88	52	78
Panama	69	63	69	66	81	66	81
Yugoslavia	81	84	81	63	81	75	81
Portugal	69	78	75	69	56	94	50
Uruguay	38	91	44	22	97	25	91

Greece	75	75	75	56	78	78	78
Ireland	81	50	84	56	88	94	91
Spain	75	78	81	63	63	75	69
Hong Kong	75	78	75	44	100	94	97
Singapore	16	16	28	6	94	84	88
Trinidad	56	22	53	47	84	88	78
North:							
New Zealand	81	59	78	72	97	100	88
Austria	69	56	72	62	78	72	78
Italy	63	78	75	59	66	78	81
United Kingdom	66	66	66	53	81	84	81
Japan	69	63	71	69	75	75	78
Belgium	71	71	84	59	78	94	84
Netherlands	78	75	91	50	38	94	38
Israel	47	66	44	63	75	84	78
Denmark	75	75	75	75	72	97	63
West Germany	81	75	81	78	78	81	81
France	71	69	75	66	81	88	81
Sweden	53	59	69	19	78	84	81
Norway	97	66	97	94	66	72	66
Switzerland	66	78	75	44	75	75	84
Canada	87.5	69	94	59	81	97	84
United States	69	69	81	56	75	84	84
Finland	75	75	78	63	78	78	84

SOURCE.—Trefler (1995) and own calculations.

rest. (For skilled labor–capital and capital-land, the North-South group does only marginally better than the other groups, and for skilled labor–land and unskilled labor–land, either the North-North or the South-South group outperforms the North-South group.) In other words, it is not the case that comparing a country from the North and one from the South yields higher sign correspondences across all factor ratios. Figure 1 suggests why one should not be too surprised about this result. The figure plots per capita GDP versus the various factor endowment ratios. Only for capital-labor, skilled–unskilled labor, and capital–unskilled labor is there a clear association between per capita GDP and the factor endowment ratio. It is exactly for these factors that the North-South group has superior performance. The obtained results suggest that the sign tests perform better the more different the country endowments are. Before I more formally address this point with probability regressions, I briefly explain the rest of table 1.

So far, I have relied on HOV with its standard set of assumptions, including identical technology and factor price equalization. Trefler (1993, 1995) has introduced factor-augmenting productivity differences in this setting to relax factor price equalization and to account for technological differences between countries. If a country's factors are only half as productive as in the United States, he divides its endowments by two to express them in U.S. productivity equivalents. Note that with factor-augmenting productivity differences, factor price equalization holds only in productivity equivalents. I follow Trefler (1995) and use the difference in per capita GDP between a country and the United States to proxy for Hicks neutral productivity differences π_c ($\pi_{US} = 1$).[7] The productivity-adjusted version of the relative abundance equation (5) simply requires premultiplying a country's factors by its productivity measure π_c. (The factor contents do not have to be adjusted since the U.S. technology matrix was used to calculate them for all countries.) As one can see in row 5 of table 1, there is only a minor difference between the sign test results with or without productivity adjustments. Finally, in the rest of table 1, I also present the sign test results for all individual countries and all factor combinations. The table illustrates that it is not the case that the performance of one or another individual country drives the result.

I also propose a more formal procedure to show that the extent to which endowments differ determines the success of the HOV sign test, irrespective of country groups and factor pairs. I estimate a probability

[7] In a personal communication, Trefler justified this stylized treatment of technological differences by arguing that technological differences across countries are much more significant than differences in productivity between various factors within a country, especially when developed and developing countries are concerned. I follow Trefler in this argument.

model $F(Y_i = 1|X_i) = f(\beta X_i)$. The dependent variable Y_i equals one if there is a sign match for a country pair and zero otherwise. The independent variable X_i measures the extent to which the endowment ratios differ between two countries c and c'. Three different measures are used. The first measure, X_1, compares the absolute difference between endowment ratios:

$$X_1 = \left| \frac{V_{fc}}{V_{f'c}} - \frac{V_{fc'}}{V_{f'c'}} \right|.$$

The second measure, X_2, captures the relative magnitudes of endowment ratios:

$$X_2 = \begin{cases} \dfrac{V_{fc}/V_{f'c}}{V_{fc'}/V_{f'c'}} & \text{if} \geq 1 \\ \dfrac{V_{fc'}/V_{f'c'}}{V_{fc}/V_{f'c}} & \text{otherwise.} \end{cases}$$

And finally, the third measure, X_3, is closely related to X_2. For each country c, it gives the rank order of its endowment ratio with respect to all other 32 countries (1 is most similar to c, 32 most different). In the implementation I take the logarithm transformation of X_1 and X_2.

In table 2 the results are reported for probit, logit, and linear probability (ordinary least squares [OLS]) models. All measures of endowment differences are positive and significant at the 95 percent level in virtually all cases. The regression results indicate that the HOV sign prediction is more likely to hold as country endowments are more different.

Note that the skilled labor–capital ratio constitutes the only exception in table 2. The regressions fail to yield significant coefficients at the 95 percent level for this factor ratio. (Note that the sign test results for all country pairs were also the weakest for this factor pair.) This outcome is not too surprising since both factors are positively correlated; with per capita GDP, the share of skilled labor increases and so does the capital abundance. Consequently, there is less variation in the skilled labor–capital ratio than with other factors. The first row of table 3 shows the difference between the lowest and the highest ratio for all ratios of production factors. The second row provides the standard deviation for each ratio across country pairs. (I normalize by the value of the country pair with the lowest ratio.) In each case the skilled labor–capital ratio has the lowest value. Note that there is most variation when the factor land is involved, which explains the stronger sign test results. In other

TABLE 2
PROBABILITY REGRESSIONS

	Capital/Labor	Skilled Labor/ Unskilled Labor	Unskilled Labor/ Capital	Skilled Labor/ Capital	Unskilled Labor/ Land	Skilled Labor/ Land	Capital/ Land
	A. $X_1 = \lvert V_{fc}/V_{f'c} - V_{fc'}/V_{f'c'} \rvert$: Absolute Differences in Factor Endowments						
Probit:							
$\ln(X_1)$	.178	.224	.14	.178	.409	.131	.288
t-statistic	2.96	2.653	2.537	1.61	6.499	4.71	6.024
Pseudo R^2	.014	.011	.01	.004	.109	.043	.08
Log likelihood	−320	−334	−307	−353	−267	−262	−259
Logit:							
$\ln(X_1)$	.311	.376	.247	.29	.733	.216	.552
t-statistic	2.898	2.628	2.497	1.586	6.235	4.574	5.763
Pseudo R^2	.014	.011	.01	.004	.109	−2.62	.085
Log likelihood	−320	−334	−307	−353	−267	.041	−253
OLS:							
$\ln(X_1)$	.098	.079	.044	.066	.075	.034	.062
t-statistic	2.964	2.662	2.539	1.599	7.129	4.774	6.31
R^2	.017	.011	.01	.005	.086	.039	.07
	B. $X_2 = (V_{fc}/V_{f'c})/(V_{fc'}/V_{f'c'})$ if >1; otherwise $X_2 = (V_{fc'}/V_{f'c'})/(V_{fc}/V_{f'c})$: Relative Differences in Factor Endowments						
Probit:							
$\ln(X_2)$	.101	.212	.067	.039	.153	.056	.152
t-statistic	3.52	3.901	2.34	1.062	4.583	1.96	4.91
Pseudo R^2	.019	.022	.01	.002	.042	.007	.47
Log likelihood	−319	−331	−307	−354	−287	−270	−268

Logit:							
$\ln(X_2)$	.173	.332	.115	.0635	.153	.095	.264
t-statistic	3.522	3.799	2.338	1.055	4.683	1.96	4.743
Pseudo R^2	.02	.022	.01	.002	.042	.007	−268
Log likelihood	−319	−331	−307	−354	−287	−270	.047
OLS:							
$\ln(X_2)$	.035	.079	.22	.015	.039	.039	.039
t-statistic	3.608	3.855	2.359	1.056	4.72	1.96	4.995
R^2	.022	.027	.01	.002	.041	.007	.045
	C. X_3 Ranks X_2 for Each Country: Ranking the Factor Endowment Differences						
Probit:							
X_3	.002	.001	.001	.0003	.003	.002	.003
t-statistic	4.3	3.33	3.763	.966	7.211	4.86	6.678
Pseudo R^2	.029	.016	.0232	.0013	.094	.045	.086
Log likelihood	−315	−332	−303	−354	−272	−260	−257
Logit:							
X_3	.003	.002	.002	.0005	.0052	.0035	.005
t-statistic	4.288	3.318	3.761	.964	6.922	4.75	6.452
Pseudo R^2	.029	.017	.0232	.001	−272	.044	.085
Log likelihood	−315	−332	−303	−354	.09	−260	−258
OLS:							
X_3	.0006	.0004	.0005	.000135	.0009	.0006	.008
t-statistic	4.41	3.373	3.255	.964	7.633	4.973	7.05
R^2	.034	.019	.025	.0018	.099	.044	.086

SOURCE.—Trefler (1995) and own calculations.

NOTE.—Dependent variable equals one if there is a sign match and zero otherwise. Each cell represents a separate regression. X_1, X_2, and X_3 measure the extent to which the endowment ratios of two countries differ.

TABLE 3
VARIATION IN THE ENDOWMENTS
A. IN RATIOS

	Capital/ Labor	Skilled Labor/ Unskilled Labor	Unskilled Labor/ Capital	Skilled Labor/ Capital	Unskilled Labor/ Land	Skilled Labor/ Land	Capital/ Land
Max/min	91	16	137	13	3,156	4,316	5,098
Standard deviation	28	5	22	2	624	751	1,079

B. IN SHARES

	Capital	Skilled Labor	Unskilled Labor	Land
Max/min	4.3	8	42	420
Standard deviation	.7	1.6	12	142

SOURCE.—Trefler (1995) and own calculations.

words, the more variation across countries there is for a factor, the higher the sign correspondence for that ratio.

Finally, I turn to the sign test results that are based on equation (7), with which I study North-South trade while aggregating country endowments and factor contents. I aggregate the northern countries into the North (G). The factor content of the northern countries reflects the factor content of its net trade with the South (G'). I then compare the North's endowments and factor contents each time with those of one country from the South. I prefer this asymmetric specification in which I do not also aggregate all southern countries into one group for a number of reasons. First, while I have data for almost all the developed countries, I do not have data for the majority of the developing countries. In other words, by adding up the net factor content of all the developed countries, I can obtain the net factor content of the North with the rest of the world, that is, the South. With an incomplete set of developing countries, the net factor content of trade that is obtained by summing up the factor content of the available developing countries can never be the negative of the net factor content of the North (which it should be, at least in theory). Second, by lumping countries together, one treats them as one country. For the developed countries that share more or less the same technology (and one could even claim that there is a fair amount of factor mobility among them), this may seem justified. For the very heterogeneous group of developing countries that are certainly less integrated among each other, this is probably more difficult

TABLE 4
SIGN CORRESPONDENCE NORTH-SOUTH TRADE, GROUPS (Percent Matching Signs, Eq. [7])

	Capital/ Labor	Skilled Labor/ Unskilled Labor	Unskilled Labor/ Capital	Skilled Labor/ Capital	Unskilled Labor/ Land	Skilled Labor/ Land	Capital/ Land
North-South	88	82	82	63	75	69	88
North-South 2*	93	86	86	64	79	65	79

SOURCE.—Trefler (1995) and own calculations.
NOTE.—Pairwise comparison of a country from the South with the group of rich, developed countries.
* Hong Kong and Singapore are part of the North in North-South 2.

to justify. Therefore, I prefer to compare the North-South net factor content with the trade of one developing country at a time.[8]

I report the obtained results in in table 4. (I provide results for two subdivisions of North and South to emphasize that these results do not critically depend on a narrower or broader definition of North and South. That is, I include or exclude Hong Kong and Singapore from the North.) Here again the results are very strong for the "typical" North-South factors capital-labor and skilled–unskilled labor. In up to 90 percent of the cases one obtains the sign that the theory predicts. Note also that introducing Hicks neutral differences does not significantly change the results.

IV. Assessment of the Empirical Results and Conclusion

Sign tests are an integral part of the empirical evaluation of the HOV model. Because they are relatively weak tests of the theory, their poor performance has often been interpreted as devastating evidence against the HOV theory. This paper presents qualitative results that are very different from the ones in the literature and that reveal a striking regularity.[9] In this section I explain what generates such different results.

As I showed in Section II, the relative abundance equation (5) that I use for the sign test can be derived from the standard HOV equation (2) on which Trefler bases his analysis. Both equations do not hold exactly in the data. Therefore, a sign test based on one or the other equation does not have to yield the same result even though one ex-

[8] Note that the major part of the trade of a developing country occurs with the North. In 1985 about 73 percent of the exports of the less developed countries went to the developed countries.

[9] Leontief's (1953) finding is perhaps the most prominent qualitative result in the literature that was revisited in an HOV framework by Leamer (1980). Davis and Weinstein (2001) survey the other main results in the existing literature. Davis et al. (1997) study especially the production side of HOV for Japanese regions.

pression follows from the other. (Kohler [1991] has made the point before that sign test results vary with test specification.) Nevertheless, one may wonder why the outcome is so different.

Technology is probably most different between developed and developing countries. In the previous section I discussed the sign test results when Hicks neutral differences, proxied for by a country's per capita GDP versus that of the United States, were introduced. My specification proves fairly robust to these technology corrections. As the empirical results in table 1 illustrate, introducing Hicks neutral differences hardly makes any difference for the actual success of the HOV sign prediction. (The results reported in table 1 also underscore that the Hicks neutral differences do not affect the North-South trade predictions of the relative abundance equation [7] for groups either.)

This observed insensitivity to technological differences is only in part the advantage of working with two factors at a time. Indeed, all factors of a country are affected by Hicks neutral differences in a similar way, and so wherever there are ratios, the technological differences will cancel. It is not difficult to show (see App. B) that if the term within parentheses on the right-hand side of equation (6) is positive (negative) without technological differences, it will also be positive (negative) with Hicks neutral differences. Note, however, that the technology corrections do not cancel on the left-hand side of equation (6). The data show, however, that the left-hand side hardly ever changes signs when Hicks neutral differences are introduced. Trefler's standard HOV equation (2), however, is very sensitive to technological differences. He reports how introducing Hicks neutral differences increases the sign correspondence from 49.5 percent to 62 percent. The fact that my specification is not so sensitive to technological differences is one important reason for the superior performance in the sign test. There is still another reason, however.

In table 3, I report, on the one hand, the ratio of the maximum over the minimum factor endowment ratio that I referred to before and, on the other hand, the standard deviation across country pairs per factor ratio (lowest ratio set to one). The capital-labor ratio of the poorest country is 137 times lower than the one of the richest countries, and the skilled–unskilled labor ratio of the most skilled labor–abundant country is about 16 times as high as that of the least skill-abundant country. In other words, there is a significant amount of variation in the ratios: Note that the huge variation involving land is partially driven by a few outliers such as the city-states Singapore and Hong Kong. The table also provides separately for each factor a measure of the variation between a country's endowment V_{fc} and world endowments V^*_{fw}. Both terms are found on the right-hand side of the standard HOV equation that Trefler tests. I report the maximum ratio of V_{fc}/V^*_{fw} (or its inverse

if it is smaller than one) and the standard deviation. As one sees, especially for capital and skilled labor, there is much more variation for the specification in ratios.[10] A specification of HOV such as mine that more fully exploits the variation in the data should yield a more powerful test.[11] Finally, note another benefit from the specification in ratios. My HOV specification does not involve the world endowments. As such, errors due to the mismeasurement of the world endowments will be avoided. This reason has, however, less of an impact. The success of the sign test only marginally increases (from 49.5 to 52 percent matching signs) when one goes from the standard HOV equation to equation (4), which does not contain the world endowments.

Note that Trefler also reports a weighted sign test that yields the higher score of 71 percent corresponding signs. This result is sometimes referred to as an indication that the relation between endowments and factor contents is not completely random. To interpret Trefler's 71 percent sign matches, it is worthwhile to explicitly analyze the weights that Trefler proposes to improve the result from 50 percent to 71 percent.[12] Few have observed that the improvements are driven by six out of 33 nations (Italy, Canada, the United States, the United Kingdom, Japan, and Germany) that have above-average performance. Their weight is increased from 18 to 72 percent. This significant improvement implies that exactly the countries for which endowment-driven trade is thought to matter most perform worst. Indeed, the countries that do not belong to the rich OECD countries have a record of 45 percent sign matches. A justification for Trefler's weighting scheme may be the volume of trade. Indeed, these big developed countries are responsible for a major fraction of world trade. The HOV theory does not tell us, however, that the model should perform better for bigger countries than for others.

Now consider my analysis of North-South trade, on the one hand, and the analysis of the trade of developed and developing countries on the other hand. Breaking down the sample into a North-North, South-South, and North-South group unveils a striking pattern that is also supported by the probability regressions. The more different the endowments between country pairs are, the more different the differences in their factor contents of net trade are. One could rightly argue that

[10] I report the variation in ratios since this is most easily related to relative abundance. The variation between the terms within the brackets of the relative abundance equation (6) is comparable. Note that extensive variation on the right-hand side of the standard HOV equation (2) by itself does not guarantee a successful sign test, since there are still substantial technological differences unaccounted for.

[11] Note that there is also a theoretical rationale for considering my specification. The HOV theory characteristically includes multiple production factors since they constitute the basis for comparative advantage. By specifying the ratios, one makes explicit that link.

[12] With home bias and technological differences, one even obtains 91 percent right signs.

the focus on North-South (and North-North or South-South) is just another way of weighting the results—giving more weight to North-South trade (and North-North or South-South). The justification for doing so comes, however, from the essence of the Heckscher-Ohlin theory. There has always been a presumption that the factor content of trade between very different countries will be very different or that North-South trade is the primary case of trade that should be endowment driven.

My approach therefore judges HOV by studying those cases in which the differences in endowments are very pronounced indeed. This can be justified also in the following way. It is well known that it is hard to explain the deviations from the HOV predictions and to incorporate alternative hypotheses to account for them. The recent research on missing trade has emphasized especially this quantitative gap between predictions and actual factor contents of trade. Hence, it may prove worthwhile to pay particular attention to those cases in which the endowments are very different, which is my rationale for considering North-South trade and for comparing factor contents of trade between developed and developing countries. And indeed, my results show that the significant differences in capital-labor and unskilled–skilled labor ratios between countries from the North and the South help explain the success of the sign tests in the North-South group. Alternatively, for these two factor pairs, the relative similarity in endowment ratios among the similar countries from the North or among the countries from the South accounts for the low fraction of corresponding signs.

My findings do not resolve the mystery of missing trade, yet they support a basic idea of the Heckscher-Ohlin theory. Endowments do matter for trade. There is a systematic link between differences in endowments and differences in factor contents that is most pronounced when endowment ratios are very different, even when there are technological differences. In particular, the huge gap in the capital-labor ratio or in the unskilled–skilled labor ratio between developed and developing countries produces superior sign predictions for the HOV model.

Appendix A

Relating HOV to Relative Factor Abundance

I derive expression (6) from equation (5) and show that factor contents of trade are related to relative factor abundance:

$$\begin{aligned}
&\frac{V_{fc}-V_{fc'}}{V_{fc}+V_{fc'}}-\frac{V_{f'c}-V_{f'c'}}{V_{f'c}+V_{f'c'}}\\
&=\frac{2V_{fc'}}{V_{f'c}+V_{f'c'}}\left[\frac{V_{fc}V_{f'c}+V_{fc}V_{f'c'}-V_{fc'}V_{f'c}-V_{fc'}V_{f'c'}}{2V_{fc'}(V_{fc}+V_{fc'})}-\frac{V_{f'c}}{2V_{fc'}}+\frac{V_{f'c'}}{2V_{fc'}}\right]\\
&=\frac{2V_{fc'}}{V_{f'c}+V_{f'c'}}\left[\frac{V_{f'c'}}{V_{fc'}}-\frac{V_{f'c'}}{2V_{fc'}}-\frac{V_{f'c}}{2V_{fc'}}+\frac{V_{fc}V_{f'c}+V_{fc}V_{f'c'}-V_{fc'}V_{f'c}-V_{fc'}V_{f'c'}}{2V_{fc'}(V_{fc}+V_{fc'})}\right]\\
&=\frac{2V_{fc'}}{V_{f'c}+V_{f'c'}}\left[\frac{V_{f'c'}}{V_{fc'}}-\frac{V_{f'c'}V_{fc}+V_{f'c'}V_{fc'}}{2V_{fc'}(V_{fc}+V_{fc'})}-\frac{V_{f'c}V_{fc}+V_{f'c}V_{f'c}}{2V_{fc'}(V_{fc}+V_{fc'})}\right.\\
&\quad\left.+\frac{V_{fc}V_{f'c}+V_{fc}V_{f'c'}-V_{fc'}V_{f'c}-V_{fc'}V_{f'c'}}{2V_{fc'}(V_{fc}+V_{fc'})}\right]\\
&=\frac{2V_{fc'}}{V_{f'c}+V_{f'c'}}\left[\frac{V_{f'c'}}{V_{fc'}}-\frac{2V_{f'c'}V_{fc'}+2V_{fc'}V_{f'c}}{2V_{fc'}(V_{fc}+V_{fc'})}\right]\\
&=\frac{2V_{fc'}}{V_{f'c}+V_{f'c'}}\left(\frac{V_{f'c'}}{V_{fc'}}-\frac{V_{f'c}+V_{f'c'}}{V_{fc}+V_{fc'}}\right),
\end{aligned}$$

where V_{fc} is the endowment for country c of factor f, and F_{fc} is the net factor content of trade for country c of factor f.

Appendix B

Relative Abundance and Hicks Neutral Productivity Differences

I introduce Hicks neutral differences in the right-hand side of equation (6):

$$\begin{aligned}
&\frac{V_{f'c'}}{V_{fc'}}>\frac{V_{f'c}}{V_{fc}}\Leftrightarrow\frac{\pi_{c'}V_{f'c'}}{\pi_{c'}V_{fc'}}>\frac{\pi_{c}V_{f'c}}{\pi_{c}V_{fc}}\\
&\qquad\Leftrightarrow\pi_{c}\pi_{c'}V_{f'c'}V_{fc}>\pi_{c}\pi_{c'}V_{f'c}V_{fc'}\\
&\qquad\Leftrightarrow\pi_{c}\pi_{c'}V_{f'c'}V_{fc}+\pi_{c'}\pi_{c'}V_{f'c'}V_{fc'}>\pi_{c}\pi_{c'}V_{f'c}V_{fc'}+\pi_{c'}\pi_{c'}V_{f'c'}V_{fc'}\\
&\qquad\Leftrightarrow\frac{\pi_{c'}V_{f'c'}}{\pi_{c'}V_{fc'}}>\frac{\pi_{c}V_{f'c}+\pi_{c'}V_{f'c'}}{\pi_{c}V_{fc}+\pi_{c'}V_{fc'}},
\end{aligned}$$

where V_{fc} is the endowment for country c of factor f, and F_{fc} is the net factor content of trade for country c of factor f.

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