The Factor Content of Trade When Countries Have Different Technologies

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Abstract

We develop two simple modifications of Heckscher-Ohlin-Vanek theory for countries with heterogeneous technologies: virtual endowments and modified Rybczynski effects. Virtual endowments predict factor trade using a reference country's technology. Modified Rybczynski effects show the domestic factor content of changes in foreign endowments. The empirical implications are striking. There is no missing trade, and we predict the direction of trade with significance levels exceeding 99%. We make no assumptions about home bias in consumption, not traded goods, trade costs, or trade in intermediate inputs. We make no corrections to measured endowments and estimate nothing; the data speak for themselves.

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I. Introduction

By now it is well known that simple tests of the Heckscher-Ohlin-Vanek paradigm fail primarily because countries have different technologies. Where do we international economists go from here? This paper argues that there has been a fundamental mismatch between the theory and the data. Factor endowments really do predict the volume and direction of trade remarkably well, once one makes full use of national accounts. In essence, we turn Prescott's (1986) philosophy of science on its head. For the Heckscher-Ohlin-Vanek paradigm, the data have been ahead of the theory. But either of two small theoretical advances that deal properly with factor productivity differences in multi-sector economies will reconcile data and theory without much fuss.

One pole of the literature bends the theory tortuously enough to fit the data exactly. Trefler (1993) used the technology matrix for the United States to measure the factor content of trade for thirty-three countries. His insight was that an American worker was not a Bangladeshi laborer and that a marginal piece of American capital was not its Swiss analog. Normalizing by American productivities, he calculated productivity parameters exactly to fit the data. Real wages showed that the labor parameters were reasonable, and real investment prices corroborated those for capital.

Its antipodes massages the data thoroughly enough to fit the theory. Using data from ten OECD countries in the 1980's, Davis and Weinstein (2001) explain why the paradigm fails and show step-by-step, with seven different models, how to improve its fit. They move the model's R^2 from 0.01 to 0.77 by estimating ten technology matrices.

We stand on middle ground. We do not force the theory to fit the data but ask instead, "What is the simplest modification of the Heckscher-Ohlin-Vanek paradigm that makes sense when technologies differ?" Also, we refrain from tweaking the data to fit the theory; *we estimate nothing and leave the data alone*. Our measures of technology, endowments, trade, and absorption are consistent, and the raw numbers already contain local factor prices. Then it is easy to show that Trefler's (1993) approach is not warranted. Forcing a model to fit the data doesn't make it true.

Davis and Weinstein's work (2001) is valuable, but it lacks elegance. Their preferred specification estimates 144 parameters to fit 20 data points.[1] They show how predictions and measurements depend upon the theory tested and offer explanations for why technology matrices differ. Tweaking the data to fit the theory may be the norm in our discipline, but should one stop searching for a simple model that fits the facts well?

We reconcile theory and data in two ways.

Our first approach uses a country's *virtual endowment*, the factor services needed to produce a country's output using a reference country's technology. The United States has been the usual reference; then the French virtual endowment is the vector of factors France would need to produce its output using American techniques. Our predictions use these endowments, and we measure factor content in the usual way. This simple modification works brilliantly, and it solves the mystery of missing trade.[2] Since output vectors are observable, it is child's play to construct a virtual endowment. It is a surprise

[1] Their model (T6) estimates 144 coefficients: 68 parameters that constitute a world technology matrix, 10 country-specific measures of technology, and 66 measures of factor uses in each sector. Harrigan (2003) also emphasized that technologies are adapted to local endowments. Davis and Weinstein assume that many goods are not traded, when in fact their data show they are. Also, their predictions depend upon a problematic specification of demand for intermediate inputs. In fairness, we should emphasize that they are not using least squares to fit the data; they are trying to come up with plausible estimates of technology for ten countries. But it is not clear to us why this approach is better than using the actual matrices themselves.

[2] Trefler's (1995) "mystery of missing trade" refers to the fact that the simplest tests predict a factor content of trade two orders of magnitude larger than what is measured in his data. Using Trefler's own data, Conway (2002) suggests that sluggish movement of factors across industries may account for the low volume of trade observed in the data. Estevadeordal and Taylor (2002) show that there was too little trade even a century ago. Again using Trefler's data, Debaere (2003) confirms that the model predicts the direction of trade well for country pairs whose factor endowments are quite different.

that almost no one has exploited these data before.[3] Using a virtual endowment means imposing full employment everywhere at the reference country's factor prices and technology. This is precisely one of the central assumptions of Heckscher-Ohlin theory.

Our second tack translates factor services between countries. We call this technique a *modified Rybczynski effect*. It shows how a marginal change in the exporting country's endowment maps into changes in the importing county's endowment. We use the Leontief measure of factor trade, but we do not impose identical technologies. The theoretical predictions are subtle: each country views the world through the prism of its local technology. Thus the predicted factor content differs country by country. This test does not perform as well as the first, but it still predicts the direction and volume of trade with uncanny accuracy. Again, it solves the mystery of missing trade.

A simple verification of the Heckscher-Ohlin-Vanek paradigm has been the Holy Grail for international economists since Leontief (1953). Leamer (1984) began the quest in earnest, and his work has had great influence on a subsequent generation of scholars. Important milestones were reached by Rosefielde (1974), Harkness (1978), Maskus (1985), and Bowen, Leamer, and Sveikauskas (1987).[4] We are proud to deliver the Chalice. Since our tests are simple, our confirmation of the theory is quite strong.

Hakura (2001) is our closest antecedent because she sticks with actual technology matrices. Using data from four European countries in 1970 and in 1980, she shows that allowing for technology differences improves the model's fit for tests of *bilateral* trade. Our work differs from hers in five respects: (1) we use a much wider sample of countries

[3] Davis, Weinstein, Bradford, and Shimpo (1997) construct imputed world endowments for regional trade within Japan. These endowments are akin to our virtual endowments.

[4] Reimer (2006) develops a method for measuring the factor content of traded intermediate inputs; he concludes that they may make it more difficult to explain missing trade. We are sympathetic with this new strand of the literature, but our tests show that his conclusion may be misplaced.

and more recent data; (2) our data on endowments are consistent whereas hers are put together from sources other than the input-output accounts themselves; (3) we conduct multilateral tests of factor content theory; (4) we develop two new techniques for assessing technology differences across countries; and (5) we show that missing trade is explained entirely by the failure to correct adequately for technology differences.

Section II presents the theory. We develop new techniques for comparing factor endowments when countries' technologies differ; these will be of considerable interest in their own right because they are theoretically elegant and easy to implement. Section III describes the data; here we emphasize how we use data values to get consistent measures of endowments, technology, net trade vectors, and absorption. Section IV presents our results, and we underscore that our support for the Heckscher-Ohlin-Vanek paradigm is quite robust. Section V shows that the mystery of missing trade is an artifact of predicting factor content incorrectly when countries have heterogeneous technologies. Section VI presents our brief conclusions and gives suggestions for future research.

II. Theory

Each country has f factors and ℓ goods. Then v^c is the $f \times 1$ endowment vector of country c measured in units of factor service per year. Let B^c be the $f \times \ell$ matrix of direct factor requirements, A^c be the $\ell \times \ell$ matrix of intermediate inputs, and y^c be the $\ell \times 1$ vector of final demand. The full employment condition is:

$$v^c = B^c (I - A^c)^{-1} y^c$$

The world endowment is:

$$v = \sum_c v^c + v^r,$$

where v^r is the factor content of net exports from the rest of the world.[5]

We construct our endowments from local technology matrices and local output vectors, not by gathering data on factor services from disparate sources. Our method simply assumes that the income and product approaches to national accounts are consistent. The custom has been to assemble data on factor uses and endowments from different sources than the input-output accounts. This convention is in part a historical artifact, dating from a time when input-output tables for a wide sample of countries were not readily available and computers were scarce. But this practice has real theoretical and empirical bite. We show elsewhere (2008) that the zero-profit conditions hold only when direct factor requirements are consistent with data on intermediate inputs. Also, the fact that almost everyone adjusts endowment data for "heteroskedasticity" shows that significant measurement error is endemic. Finally, our consistent measures of factor services allow us to compare different factors appropriately.[6]

Let x^c be the $\ell \times 1$ vector of country $c's$ exports and let m^c be the analogous vector of imports. The traditional *Leontief measured factor content* of trade is:

$$B^c(I - A^c)^{-1}(x^c - m^c). \qquad (1)$$

Using the local technology matrix to measure factor content is not without controversy. Deardorff (1982) gives the first and still best theoretical exploration of this issue, and he describe three approaches: (1) the traditional Leontief measure as above; (2) imputing factor content wherever value added takes place in the world; and (3) an analog that

[5] In this summation and all that follow, we are adding across all the thirty-three countries in our sample. We treat net trade with the rest of the world carefully. We follow Kemp and Wan (1976) and define equilibrium conditional on its factor content. Although this net trade vector is observed without error in our data, the definition of v^r depends upon the details of the theory being tested.

[6] Trefler (1995) graphed all nine factors in the same diagram in his famous picture of missing trade. He is literally comparing hectares of pasture land, real dollars of capital, and person-years of clerical workers. Estevadeordal and Taylor (2002) were more circumspect, making different graphs for different factors.

captures the global factor content of consumption. Deardorff shows that the Leontief measure may not have theoretically cogent properties. He prefers the second measure, but it is empirically intractable. In practice, the literature imputes it by assuming that each country's demand for any good is distributed equally across all exporters. We show below that this assumption is grossly violated in the data. The upshot is that we use the traditional Leontief measure and make sure our predictions are logically consistent.

Let $a^c = y^c - x^c + m^c$ be the $\ell \times 1$ vector denoting each country's absorption. This vector is observable, and we use it to define each country's consumption share:

$$s^c = \sum_{i=1}^{\ell} a_i^c \,/\, \sum_c \sum_{i=1}^{\ell} a_i^c.$$

We are taking advantage of the fact that our data are measured in values. Thus $\sum_{i=1}^{\ell} a_i^c$ does not is add apples and oranges; it adds dollars of apples and dollars of oranges.

We assume that countries have identical homothetic preferences, face the same goods prices, and that all goods are traded. Then the predicted factor content of trade is:

$$v^c - s^c v. \tag{2}$$

We make (2) operational in three different ways.

Our benchmark assumes that every technology matrix satisfies $B^c(I - A^c)^{-1} = B^0(I - A^0)^{-1}$ for some reference country 0. The *traditional factor content* of trade is:

$$B^0(I - A^0)^{-1}(x^c - m^c) \tag{3}$$

The benchmark test compares (2) and (3).[7] It fares poorly and suffers from missing trade, no matter which reference country is used. Much of the literature uses this traditional

[7] Let $x^r - m^r = -\sum_c (x^c - m^c)$ denote the *observable* net exports from the rest of the world; its factor content $v^r = B^0(I - A^0)^{-1}(x^r - m^r)$ is measured using the reference country's technology matrix. This vector is used to define the world endowment in (2).

measure with the United States as reference since its input-output matrix has been readily available. Indeed, Trefler (1993 and 1995) and all the work based on his data use it.

Trefler (1993) computes productivity parameters π_f^c for each factor in each country. If his specification is correct, then our benchmark tests are exact. When data are in values, each row of $B^c(I - A^c)^{-1}$ increases by π_f^c/π_f^0 when compared with the corresponding row of $B^0(I - A^0)^{-1}$, and our data make the proper factor price corrections. Since the benchmark does poorly, his sanguine conclusion was premature.

Our first real test is novel and simple. The *virtual endowment* for country c is:

$$\tilde{v}^c = B^0(I - A^0)^{-1}y^c. \tag{4}$$

This vector shows the resources that would be needed to produce the local output using the reference country's technology. Now $\tilde{v} = \sum_c \tilde{v}^c + v^r$ is our measure of the world endowment.[8] Our test compares the traditional factor content (3) with $\tilde{v}^c - s^c\tilde{v}$. It performs brilliantly, no matter which reference country is chosen.

We have made the minimal change to Heckscher-Ohlin-Vanek theory that makes the traditional measure of factor content (3) consistent with the model's predictions. We are simply assuming that every country has the same technology and factor prices as the reference country. In essence, we are forcing each country into the same prism as the one that measures factor content. We use every possible reference—and look at the world from 33 different but consistent angles--as a robustness check.

Tests using virtual endowments are not tautological. Think of a world identical to the one we observe but for one difference: a war that shuts down all international trade. Then we would still predict lots of factor trade, but the measured factor content would be

[8] The factor content of net exports from the rest of the world is still $v^r = B^0(I - A^0)^{-1}(x^r - m^r)$.

zero, no matter which reference country were chosen. Think of an alternative world where each country produces an identical output vector. Then, no matter which country is the reference, every country has the same virtual endowment, and there is no predicted factor trade. If commodity trade occurred because of differences in preferences or tariffs, there would be plenty of measured factor trade. These thought experiments show it is easy to reject a test based on virtual endowments. Not to reject is to find plausible the hypothesis that *factor endowments explain trade, even when technological differences across countries are as important as factor intensity differences across industries.*

An empiricist is more interested in data than thought experiments. A tautology is a relationship that is true in every state of the world. For example, running a regression of output on absorption and net exports always gives a perfect fit. On the other hand, our virtual endowments tests give outstanding but not perfect results. Their predictions depend upon the reference country, and the worst of them (with Poland as reference) predicts the direction of trade correctly for "only" 73 of 99 country-specific factors.

Our second substantive test uses factor conversion matrices. These matrices show the local factor content of the Rybczynski effects in a foreign economy.[9] They allow for arbitrary differences in technology and can be computed—not estimated--from the data.

Country $c's$ supply correspondence is:

[9] We give a very cursory discussion of these ideas here because we develop the theory in a companion paper (2008). There we show that the generalized inverse of a country' technology matrix is its Rybczynski matrix. Here is the intuition. Input-output accounting is concerned with this question, "How many extra resources are needed to make a marginal piece of output?" But classical trade theory asks, "How many extra pieces of output can be made from a marginal change in endowments?" So the two approaches deal with the same issue from opposite ends. We also explain why it is imperative to use a matrix of direct factor requirements that is consistent with the input-output table if one takes the zero-profit conditions seriously. This concern motivates our use of factor share matrices in this paper.

$$y^c = [B^c(I - A^c)^{-1}]^+ v^c + H^c q \tag{5}$$

where the $\ell \times f$ matrix $[B^c(I - A^c)^{-1}]^+$ is the Moore Penrose pseudo-inverse of the technology matrix, $H^c = I - [B^c(I - A^c)^{-1}]^+ B^c(I - A^c)^{-1}$ is an $\ell \times \ell$ matrix, and q is an arbitrary $\ell \times 1$ vector. The particular solution $B^c[(I - A^c)^{-1}]^+ v^c$ is the output vector of minimum norm that satisfies full employment. The homogeneous solution $H^c q$ consists of all vectors in the null space of the local technology matrix. These outputs have identical local factor content because they maintain full employment. There are $\ell - f$ degrees of freedom in defining outputs that use all local resources.

Let p be an $\ell \times 1$ vector of international prices for goods. National revenue is:

$$p^T y^c = p^T [B^c(I - A^c)^{-1}]^+ v^c + p^T H^c q \tag{6}$$

Since this equation is true for any choice of the slack variable q, we may conclude that $p^T H^C = 0$. Hence, even when there are more goods than factors, national revenue is uniquely determined. The intuition is that national revenue must equal total factor payments, and only the particular solution in (5) depends upon endowments.

The generalized inverse $[B^c(I - A^c)^{-1}]^+$ is $c's$ Rybczynski matrix because its $(i,j) - th$ element describes how the output of good i changes when the supply of factor j increases. Since the value of output equals national income, (6) implies that $(w^c)^T = p^T [B^c(I - A^c)^{-1}]^+$. Hence the particular solution in (5) preserves the duality between the Rybczynski and Stolper-Samuelson matrices at the heart of trade theory.

We define an $f \times f$ factor conversion matrix

$$F(c, c') = B^c(I - A^c)^{-1} [B^{c'}(I - A^{c'})^{-1}]^+. \tag{7}$$

The matrix in (7) describes the local factor content in the importing country of the Rybczynski effects in the exporting country. In other words, its columns show how local factors would change to accommodate the marginal output effect of a change in the foreign endowment. In particular, an extra unit of capital in the foreign country might correspond to marginal changes in *all the factors* in the home country. If technological differences were specific to each factor, then $F(c, c')$ would be a diagonal matrix. In empirical applications, these matrices are far from diagonal.

Trefler (1993) calculated "international efficiency units" for each factor. If countries had aggregate production functions, then this exercise would be cogent. Trefler (1993, p. 979) himself recognizes, "The interpretation that properly attaches to the π_f^c is not crystal clear." Perhaps he senses the difficulty inherent in defining efficiency units for an economy with many sectors. Each $F(c, c')$ has $f^2 = 9$ elements, but Trefler would restrict himself to identifying its three diagonal elements only. Thus we ought to be able to make better corrections for technology differences. The big surprise is that our productivity parameters are grounded in theory, work well empirically, and come directly from the technology matrices. We do not force them to fit measured factor content.

There is another interesting interpretation of these factor conversion matrices. If all goods are produced locally, we may write $p = [B^c(I - A^c)^{-1}]^T w^c$. Then (6) implies:

$$(w^{c'})^T = (w^c)^T B^c (I - A^c)^{-1} [B^{c'} (I - A^{c'})^{-1}]^+ = (w^c)^T F(c, c'). \tag{8}$$

Hence the rows of the factor conversion matrices translate factor prices in the home country into those in the foreign country. Country c' would recognize that the wage rate in c actually corresponds to a vector of factor payments in c'.

How do we implement tests using these matrices? We measure the Leontief factor content $B^c(I - A^c)^{-1}(x^c - m^c)$, and we predict:

$$v^c - s^c \bar{v}^c, \tag{9}$$

where $\bar{v}^c = \sum_{c'} F(c,c')v^{c'} + v^r(c)$ is the aggregate endowment from the perspective of country c. Here $F(c,c) = I$, and $v^r(c) = B^c(I - A^c)^{-1}(x^r - m^r)$ is the factor content of net exports from the rest of the world, measured according to the technology of country c. The main advantage of (9) is that one does not need data on the actual outputs, a restriction in keeping with the historical literature. Also, it does not impose the Procrustean assumption of identical technologies. Finally, it performs well empirically, and it shows again that the data do not suffer from missing trade.

III. Data

The technology matrices are from the OECD's most recent version of STAN. They span thirty-three countries, forty-eight sectors, and three factors.[10] All data on factor uses, endowments, absorption, exports, and imports are from the same source, assuring consistency. We convert all values to 2000 dollars using the purchasing power parity exchange rates in the Penn World Table Version 6.2.[11] Our sample represents 75 percent of world GDP and 67 percent of world trade. Although the majority of these countries have high gross domestic product per capita, the sample includes China, Brazil, and Indonesia. This broad range of economies has very disparate factor supplies.

In the analysis below, we will use data on bilateral trade to confirm that the Leontief measure of factor content is the lesser of two evils. These data are from the 2005 edition of OCED STAN and are denominated in current dollars.[12] Data for Israel is missing, and only 27 of the other 32 countries report both imports and exports. For Brazil, China, Indonesia, Russia, and Taiwan, we construct bilateral imports from exports

[10] The URL is: http://www.oecd.org/document/3/0,3343,en_2649_34263_38071427_1_1_1_1,00.html

[11] It can be found at: http://pwt.econ.upenn.edu/php_site/pwt_index.php. We perform an important robustness check by using market exchange rates from the same source. The exchange rate does not matter.

[12] The URL is: http://www.oecd.org/document/55/0,3343,en_2649_201185_34718967_1_1_1_1,00.html

reported by the 27 countries with complete data. These data include only 25 sectors, excluding construction and most service sectors.[13]

A. Consistent Definitions of Factor Services and Factor Uses

Every study of the Heckscher-Ohlin-Vanek paradigm draws upon data describing the use of commodities and factors in the many sectors of an economy. Input-output accounts describe commodity flows, but data on factor requirements and endowments usually come from other sources. Many studies have used industry-level surveys on machines, land, and workers per unit of output. Could it be that confounding sources of data have caused some of the difficulty reconciling theory and data?

Concern with proper measurement of factors compels us to take a novel approach in this paper: We let the data speak for themselves. For us, the value of capital used in production is what actually appears in the input-output account. Since we follow the input output accounts as closely as possible, we must pay a cost. The data allow us to identify only three factors of production: labor, private capital, and social capital. The input-output tables report three measures of value added: compensation to employees, gross operating surplus, and indirect taxes. Thus those three categories are our factors of production. The first category corresponds to the flow of services of undifferentiated labor, the second to the rent on private capital, and the third to the rent on social capital.

It is not as unusual as one might think to consider a sector's indirect taxes as payments for the rents on social capital. Consider two countries with identical physical technological possibilities but different sector-specific patterns of indirect taxation. Even if world trade equalized commodity prices, these countries would have different factor

[13] We also aggregated several elements of the absorption vectors to make them consistent with the bilateral trade data. We combined "mining and quarrying, energy" with "mining and quarrying, non-energy", and we aggregated sectors 26 through 29, which cover various public utilities, into one rubric.

prices and disparate factor uses. There is an important qualification: a sector may be subsidized. Although factor shares always sum to unity, social capital's share in one sector might be negative and thus the sum of labor and private capital's share might be greater than one. Still, indirect taxes are treated identically with the payments to capital and labor in input-output accounts, and logic and empirical consistency compel us to define an aggregate factor called social capital for each country.

B. Input Output Accounting in Quantities and in Values.

There are only two consistent ways to do input-output accounting: the quantity approach and the value approach. In the former, all measures are in physical units. In the latter--the one used in the OECD STAN database and most national accounts—everything is denominated in units of local currency.

Let $B^c(I-A^c)^{-1}$ be the direct and indirect factor requirements in country c in *quantities.* The analog in the *value approach* is:

$$\Theta^c = W^c B^c (I-A^c)^{-1} P^{-1},$$

where W^c is the diagonal matrix of local factor prices, and P is the diagonal matrix of world commodity prices. In our empirical work, we use the observable factor shares Θ^c, not the unobservable physical quantities $B^c(I-A^c)^{-1}$. In the data, neither local factor prices nor goods prices can be measured, but the factor shares can.

Given world goods prices, the full employment condition in value terms is:

$$W^c v^c = \Theta^c P y^c$$

Consider a reference country with factor prices W^0. Then the virtual endowment of country c satisfies $W^0 \tilde{v}^c = \Theta^0 P y^c$. Since

$$W^0 \tilde{v}^c = \Theta^0 P y^c = W^0 B^0 (I-A^0)^{-1} y^c,$$

virtual endowments computed from data in values correspond to pre-multiplying their physical analogs in Section II by the reference country's unobservable factor prices. The Leontief *value* measure of the factor content of trade is:

$$\Theta^c(Px^c - Pm^c) = W^c B^c (I - A^c)^{-1}(x^c - m^c). \tag{1'}$$

This expression gives the physical factor content evaluated at local factor prices. Our predictions based upon virtual endowments use:

$$W^0 \tilde{v}^c - W^0 s^c \tilde{v}. \tag{2'}$$

The simple test compares (1') with (2') for fixed factor prices W^0. Our more sophisticated version compares (1') with (2'), evaluating each prediction at local factor prices W^c. Thus all the virtual endowments tests are consistent with the underlying theory based upon real quantities.

The benchmark test measures the physical factor content of trade at the reference country's factor prices, but its predictions are all wrong. (That's why the traditional tests always fail!) The value of the world endowment $\sum_c W^c v^c$ depends upon factor prices everywhere. Hence its prediction $W^c v^c - s^c \sum_c W^c v^c$ is inconsistent with its measure $W^0 B^0 (I - A^0)^{-1}(x^c - m^c)$ unless factor prices are equalized. It fails miserably because the unobserved variability in factor prices makes for a lot of predicted factor trade whereas the value of factor content is measured only at the reference country's factor prices. In a nutshell, this mismatch explains the mystery of missing trade.

Consider the factor conversion matrices that are the basis for our second test. We impose that unobserved good prices satisfy $P = I$ and define units of output as Leontief did. The only substantive restriction is that each good is produced in every country.

Now our factor conversion matrix in *values* satisfies

$$F(c,c') = \Theta^c(\Theta^{c'})^+ = W^c B^c (I - A^c)^{-1}[W^{c'} B^{c'}(I - A^{c'})^{-1}]^+$$

Cline (1964) gives a formula for the generalized inverse of a product. If all factor prices are positive, $W^{c\prime}$ is diagonal, and $B^{c'}(I - A^{c'})^{-1}$ has full rank, then we can show $(\Theta^{c'})^+ = [B^{c'}(I - A^{c'})^{-1}]^+(W^{c'})^{-1}$.[14] Thus the conversion matrix in values satisfies:

$$F(c,c') = W^c B^c (I - A^c)^{-1}[B^{c'}(I - A^{c'})^{-1}]^+(W^{c'})^{-1}. \tag{7'}$$

In our data, we compute

$$\Theta^c(\Theta^{c'})^+ W^{c\prime} v^{c\prime} = W^c B^c (I - A^c)^{-1}[B^{c'}(I - A^{c'})^{-1}]^+ v^{c'}$$

This expression measures the local factor content of the real Rybczynski effects (7) evaluated at the unobservable factor prices of the importing country c. Hence the Leontief value measure of factor content (1') is appropriate for this test.

We conclude this section by making an observation about an important shortcoming of the literature. The net trade vector is always measured in values, but almost every author uses physical units for some columns of the matrix of direct factor requirements. Hence the measured factor content confounds values and quantities. Some authors are careful to match endowments with the factor uses, but it is almost always true that the researcher is measuring physical units of one factor—such as hectares of pasture land—with dollar uses of capital, often computed using the perpetual inventory method. Most authors are careful to match units for the predicted factor content with the measured factor content, but almost everyone adjusts measured factors and endowments for "heteroskedasticity" using factor-specific and country-specific constants that make units comparable. Our consistent data obviate all these problems.

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[14] Cline's formula is $(XY)^+ = (X^+XY)^+[X(X^+XY)(X^+XY)^+]^+$. Write $X = W^{c\prime}$ and $Y = B^{c'}(I - A^{c'})^{-1}$. Since $W^{c\prime}$ is diagonal and no factor price is zero, its generalized inverse is just its regular inverse. Hence, $X^+X = I$, and $(XY)^+ = Y^+[XYY^+]^+$. Since $B^{c'}(I - A^{c'})^{-1}$ has full rank and there are more goods than factors, $YY^+ = I$. Hence, $(XY)^+ = Y^+X^+ = Y^+X^{-1}$.

IV. The Tests

This section presents three tests. The benchmark assumes that countries have identical technologies. Since endowments are measured at local factor prices, our first test encompasses Trefler's (1993) productivity corrections. The benchmark is a red herring; it just replicates the literature with our new and wider set of consistent data.

The first real test is based upon our notion of virtual endowments. Again, we can choose any reference country; we present the results for the United States and the reference that performs best. Its simple version measures factor content at the reference country's factor prices. Its sophisticated version allows factor prices to differ and uses the Leontief definition value definition (1') to measure factor content, but it adjusts the model's predictions according to the prism of the local technology.

The second real test uses factor conversion matrices. Again, we measure the factor content of trade using local technology and local factor prices. However, the predicted factor content converts foreign factor services into local ones using a bilateral matrix that depends upon the countries' technologies. This test can be implemented even when output vectors are not observable. We are again allowing factor prices to differ, so we consider this a test of the technology adjusted HOV *without* factor price equalization.

A. The Traditional Test

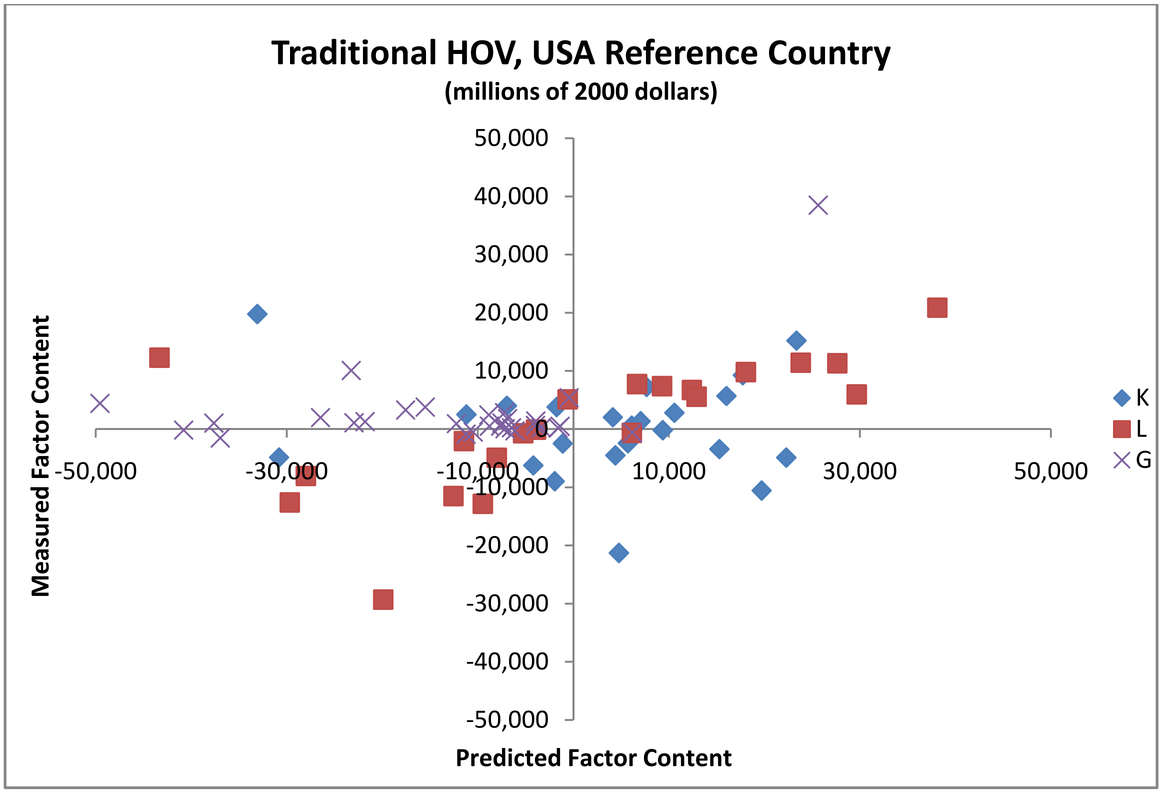
Table 1 presents our benchmark. It seems to corroborate that the theory is devoid of empirical content. What is new is that the paradigm performs poorly even with the productivity corrections implicit in local factor payments. In almost every case, there is significant missing trade, and the sign test is often no better than a coin toss. The average amount of trade explained is often dominated by a few outliers with large absolute values. The literature uses the average, but it is best to focus on the median. Among the 33 reference countries only 6 passed the sign test of size 5%, and there is a lot of missing trade. Nothing is special about the United States as a reference.

Table 1: The Traditional Test

Reference Country	Correct Signs	p-value	Average Share of Trade Explained	Median Share of Trade Explained
Australia	47	0.69	52%	17%
Austria	52	0.31	58%	21%
Belgium	51	0.38	67%	17%
Brazil	53	0.24	54%	26%
Canada	47	0.69	59%	19%
Switzerland	57	0.07	52%	14%
China	52	0.31	68%	29%
Czech Republic	57	0.07	63%	22%
Germany	52	0.31	97%	40%
Denmark	57	0.07	70%	19%
Spain	52	0.31	66%	15%
Finland	56	0.10	59%	22%
France	60	0.02	59%	18%
United Kingdom	50	0.46	66%	19%
Greece	54	0.18	148%	17%
Hungary	59	0.03	61%	14%
Indonesia	52	0.31	163%	39%
Ireland	45	0.82	73%	15%
Israel	49	0.54	52%	17%
Italy	66	0.00	86%	21%
Japan	56	0.10	59%	19%
Korea, Republic of	65	0.00	115%	26%
Netherlands	54	0.18	57%	21%
Norway	56	0.10	64%	20%
New Zealand	57	0.07	60%	21%
Poland	51	0.38	63%	17%
Portugal	57	0.07	79%	20%
Russia	54	0.18	379%	19%
Slovak Republic	52	0.31	67%	25%
Sweden	53	0.24	70%	18%
Turkey	60	0.02	293%	13%
Taiwan	63	0.00	102%	27%
United States	49	0.54	67%	23%

Note: There are 99 observations (country-specific factors) for each test. The p-values report the probability of observing a higher value of the test statistic under the null hypothesis that the model predicts the direction of trade no better than a coin flip.

Figure 1 shows the data and the predictions for the United States. It confirms the usual dismal performance of the theory with these new and consistent data. The main point is that the benchmark test is a dead end, even one when goes to extraordinary pains to make sure that all the data are consistent. There is a lot of missing trade too, but the picture is better than some in the literature.



B. The Tests with Virtual Endowments

So where does this leave us? What happens if we actually give the theory a chance and impose factor price equalization at the reference country's prices? In particular, we measure the traditional factor content of trade and predict using the virtual endowments. When we do this adjustment, the theory performs spectacularly.

Nothing in the literature approaches the successes in Table 2. The predictions for the direction of trade are striking, and there is hardly any missing trade. Again, the reference country does not matter. We illustrate the data for the historical norm that uses the United States in Figure 2 and for the best case with Korea in Figure 3.

Table 2: The Test Using Virtual Endowments

Reference Country	Correct Signs	p-value	Average Share of Trade Explained	Median Share of Trade Explained
Australia	81	0.00	692%	102%
Austria	79	0.00	120%	75%
Belgium	84	0.00	107%	74%
Brazil	82	0.00	147%	89%
Canada	80	0.00	165%	83%
Switzerland	83	0.00	163%	90%
China	85	0.00	414%	99%
Czech Republic	86	0.00	102%	96%
Germany	87	0.00	172%	101%
Denmark	85	0.00	136%	93%
Spain	83	0.00	126%	84%
Finland	79	0.00	287%	79%
France	83	0.00	285%	94%
United Kingdom	83	0.00	152%	102%
Greece	82	0.00	212%	76%
Hungary	89	0.00	152%	92%
Indonesia	87	0.00	172%	88%
Ireland	83	0.00	414%	77%
Israel	81	0.00	498%	90%
Italy	78	0.00	199%	89%
Japan	84	0.00	128%	93%
Korea, Republic of	**94**	**0.00**	**188%**	**100%**
Netherlands	82	0.00	338%	87%
Norway	81	0.00	101%	83%
New Zealand	87	0.00	118%	85%
Poland	73	0.00	135%	82%
Portugal	87	0.00	452%	102%
Russia	77	0.00	156%	64%
Slovak Republic	86	0.00	282%	97%
Sweden	89	0.00	109%	80%
Turkey	83	0.00	117%	81%
Taiwan	93	0.00	173%	101%
United States	**85**	**0.00**	**120%**	**90%**

Note: There are 99 observations (country-specific factors) for each test. The p-values report the probability of observing a higher value of the test statistic under the null hypothesis that the model predicts the direction of trade no better than a coin flip.

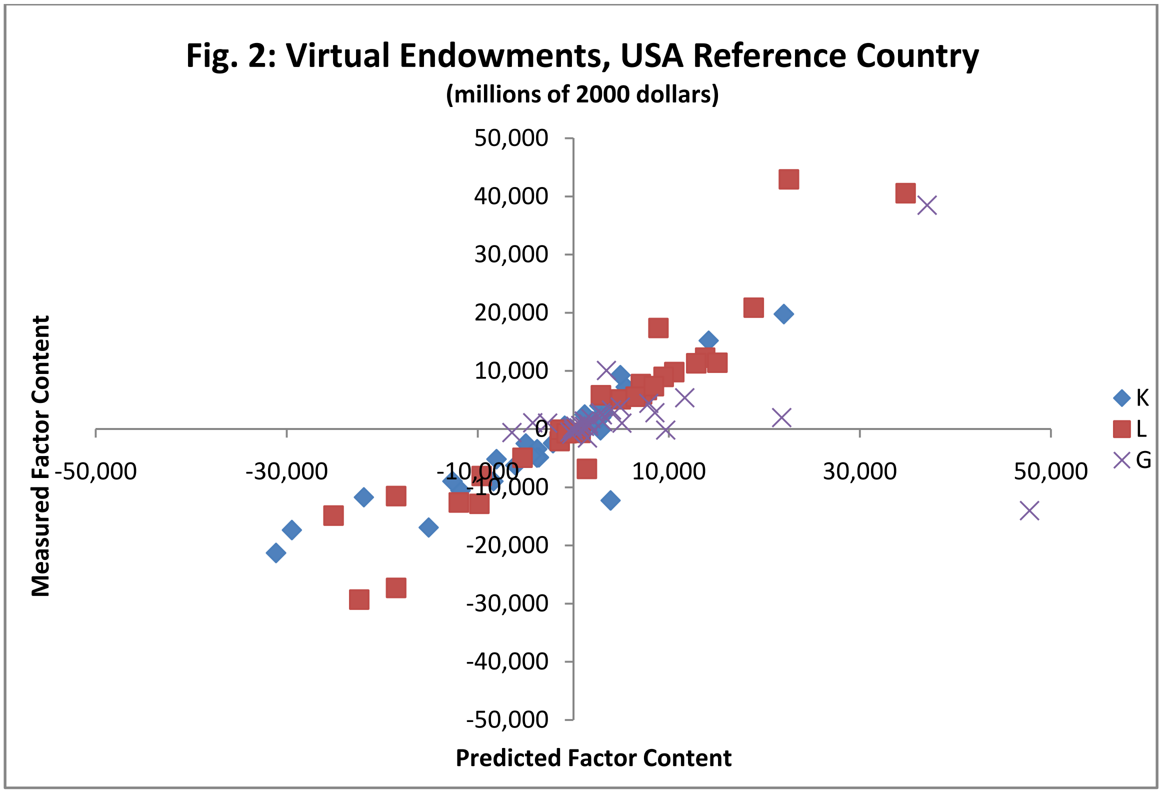


Fig. 2: Virtual Endowments, USA Reference Country
(millions of 2000 dollars)
50,000
40,000
30,000
20,000
10,000
0
-10,000
-20,000
-30,000
-40,000
-50,000
-50,000
-30,000
-10,000
10,000
30,000
50,000
Measured Factor Content
Predicted Factor Content
K
L
G

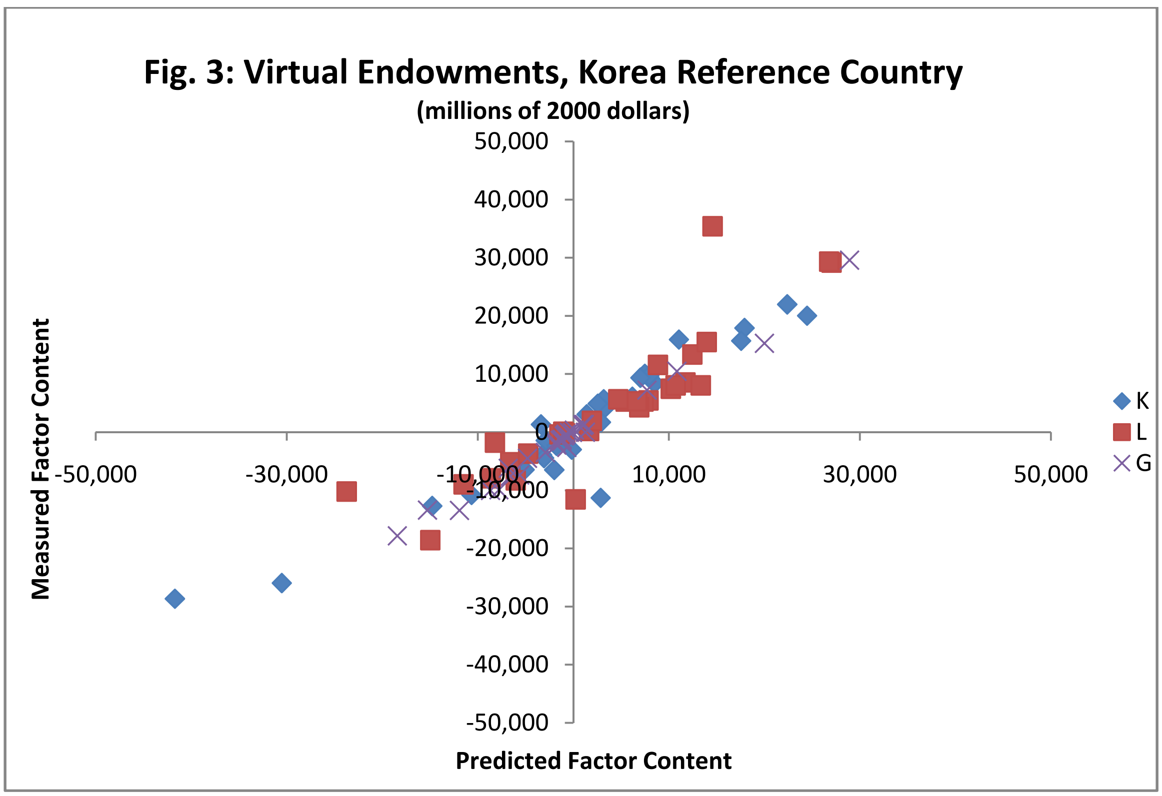
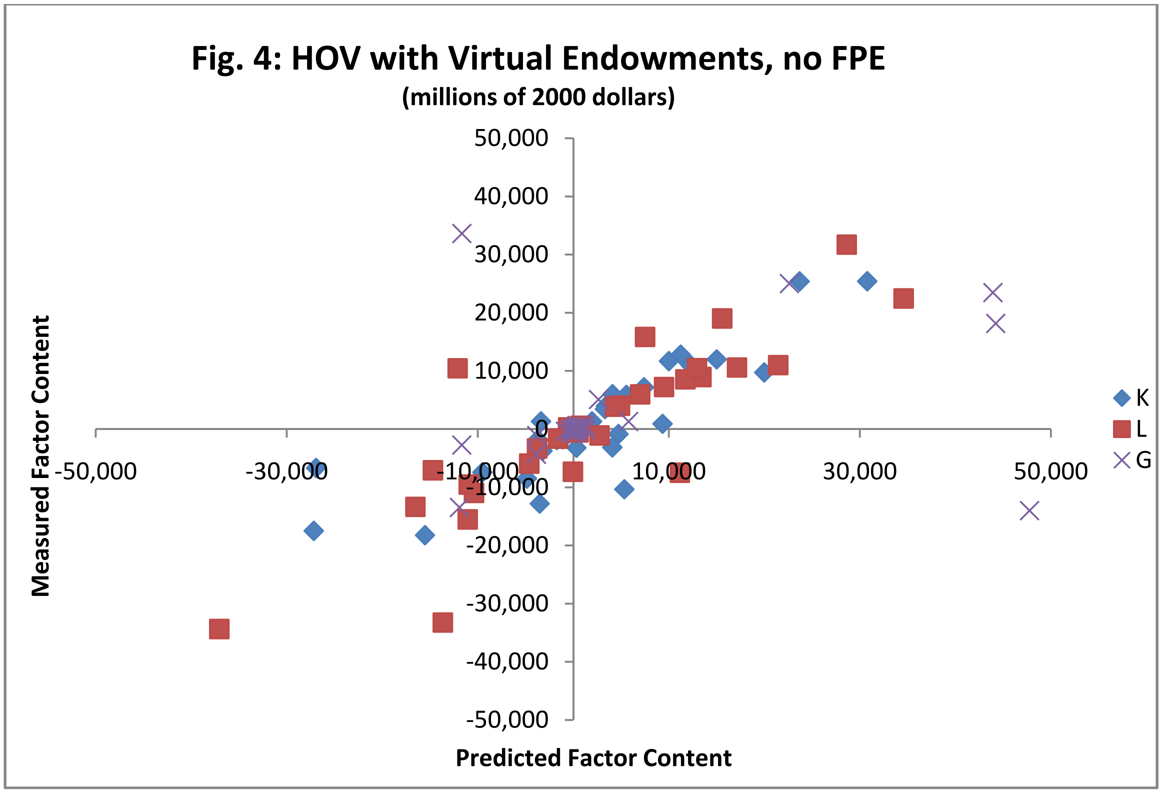


Fig. 3: Virtual Endowments, Korea Reference Country
(millions of 2000 dollars)
50,000
40,000
30,000
20,000
10,000
0
-10,000
-20,000
-30,000
-40,000
-50,000
-50,000
-30,000
-10,000
10,000
30,000
50,000
Measured Factor Content
Predicted Factor Content
K
L
G

There is one slightly unsatisfactory element of these simple tests with virtual endowments. Leontief would argue that factor content of trade should be measured by the local technology. Until now in this subsection, we have constructed virtual endowments and imposed factor price equalization at the reference country's factor prices. A French person is interested in the value of French factors saved if France imports apples instead of producing them locally.

But if we are going to measure the factor content of trade using the local technology, then the predicted factor content of trade will depend upon the prism of the local reporting country too. Hence, a slightly more sophisticated version of the test using virtual endowments relaxes the assumption of strict factor price equalization and reports the measured factor content of trade against the predicted factor content, when one allows measures and predictions to vary by reporting country. Figure 4 shows the results. The p-value for the sign test is again 0.00, the average share of trade explained is 265%, and the median share of trade explained is 86%. In a nutshell, the virtual endowments test that does not impose factor price equalization performs brilliantly too.



The main lesson from this analysis is what we do not need to make the theory conform to the data. First, we made no adjustment to endowments, technology matrices, or the measured factor content of trade using any econometrics at all. Second, identical homothetic preferences are indeed strongly corroborated.[15] Third, there is no home bias in consumption. Fourth, every good is traded; the model works even though we assume that the sector called hotels & restaurants is traded just like any manufactured commodity. Fifth, there are no trade costs or generalized notions of trade barriers. Sixth, no adjustment for traded intermediate goods is necessary.

The Heckscher-Ohlin-Vanek paradigm gives an elegant identity relating the measured and predicted factor content of trade when technologies are uniform and

[15] Analyzing bilateral trade flows from two decades ago among a smaller subset of countries than ours, Choi and Krishna (2004) test a theoretical prediction that is robust with respect to the specification of preferences. Our works shows that the assumption of identical homothetic preferences is not rejected if one uses a consistent set of data and to define absorption shares carefully.

countries have identical and homothetic preferences. Only the first of these assumptions is restrictive. When complex differences in technology are accurately accounted for and factor inputs are appropriately measured, the identity is as solid as an empiricist could hope for. *Factor endowments predict the direction and volume of trade almost perfectly, once one makes the minimal change to the theory that allows for different technologies.*

C. The Tests with Modified Rybczynski Effects

Our second test uses a technique that does not rely upon having observable output vectors. It can be implemented if only endowments and technology matrices are measured. Our factor conversion matrices use a generalized inverse because there are more goods than factors in any sensible Heckscher-Ohlin-Vanek model.

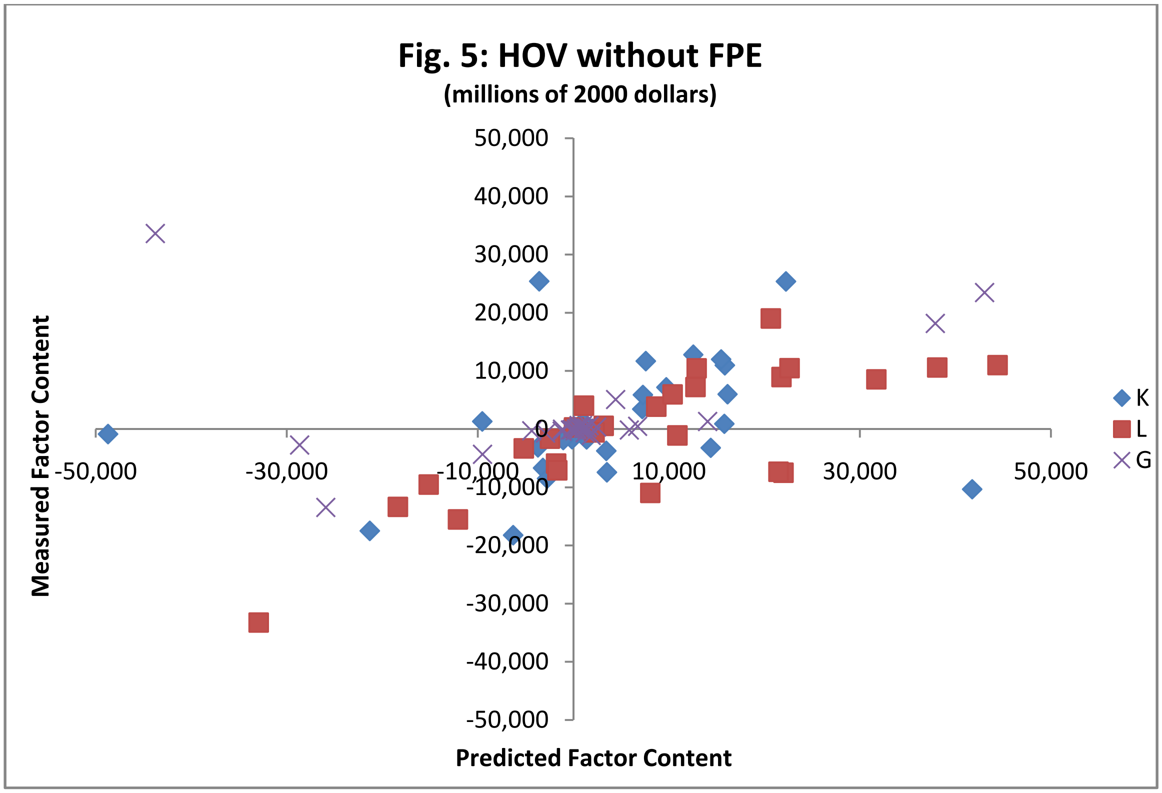
Here is the simplest possible example of a modified Rybczynski effect. Consider a Ricardian world with no intermediate goods and two final goods. The input requirements for the home country are $B^H(I-A^H)^{-1}=[b_1^H \quad b_2^H]$ and for the foreign country are $B^F(I-A^F)^{-1}=[b_1^F \quad b_2^F]$, row vectors of unit labor requirements. The 1×1 "matrix" converting foreign labor into domestic labor is:

$$[b_1^H \quad b_2^H][b_1^F \quad b_2^F]^+ = \frac{(b_1^H/b_1^F)(b_1^F)^2+(b_2^H/b_2^F)(b_2^F)^2}{(b_1^F)^2+(b_2^F)^2}$$

Assume that the home country has comparative advantage in the first good. Then this expression is a weighted average of the lowest $w^F/w^H=b_1^H/b_1^F$ and highest $w^F/w^H=b_2^H/b_2^F$ double factoral terms of trade. The weights are determined by the autarky prices in the exporting (foreign) country, with a higher weight accorded to the good with the higher foreign autarky price. In sum, one extra unit of foreign labor translates into $[b_1^H \quad b_2^H][b_1^F \quad b_2^F]^+$ units of home labor. This adjustment is between the lowest and highest relative factor prices consistent with equilibrium.

Our results demonstrate that the empirical success of our second test is not dependent on a specific vector of outputs observed in the data. In the spirit of previous tests, we begin with a description of a country's endowment and demonstrate that the Leontief factor content of trade can be predicted accurately, as long as one adjusts for differences in technology across countries. Thus this test is a general test of the HOV paradigm where we allow for different technologies and factor prices.

The results are presented in Figure 5. The sign test has 77 correct predictions (of a possible 99) and its p-value is 0.00. The average ratio of measure trade to predicted trade is 95%, and the corresponding median is 49%. These results are not as strong as those based upon virtual endowments, but they are better than anything that has been seen before in the literature. We remind the reader that there are no adjustments to the raw data here. We hope our use of these modified Rybczynki effects will have a broad appeal to empirical trade economists.



D. Robustness Checks

Since our theory is based upon values, it behooves us to make sure that we did not get lucky with our choice of exchange rates. Hence we redid all the calculations using the market exchange rates. Table A1 in the Appendix shows how different the PPP and market exchange rates are. Since the input-output data are sampled in slightly different years, we use the United States GDP deflator to adjust across time into 2000 dollars. These exchange rates affect the real values of net exports, factor services, and the absorption shares. How do they affect our tests?

The results for the benchmark were almost unchanged. The median number (across 33 reference countries) of correct signs with market exchange rates is 52 now, not the 54 in Table 1. The virtual endowments test that used market exchange rates has a median of 84 correct signs, instead of the 83 in Table 2. With market rates, the test based upon Rybczynski effects now has 78 correct signs, instead of the 77 in Figure 5.

Consider Japan as a large reference country. Its PPP rate indicates that the market overvalues the yen by around 50 percent. Look at Table 1 when Japan is the reference; the benchmark predicts 56 correct signs, and the median of the ratio of measured to predicted trade is 19 percent. When we use the market exchange rate, these figures are 54 correct signs and a median of 24 percent of predicted trade measured. Now consider Table 2 when Japan's technology is used to define virtual endowments; our test shows 84 correct signs and a median of 93 percent of predicted trade measured for the virtual endowments test. The same figures when we use the market exchange rate are 88 correct signs and a median of 92 percent of predicted trade measured.

These tests are so robust that even large differences in the exchange rate do not matter. *What matters is that the data and the theory are consistent*.

We have stated on several occasions that a simple model where countries import each good from every source according to the importer's absorption share is just not supported in the data. Davis and Weinstein[16] (2001) and others use this demand-side assumption to make operational Deardorff's (1982) second measure of factor content. We will run some regressions that refute this specification. This is not a nihilistic exercise because we have shown already that the traditional Leontief measure works well in practice. Occam's razor cuts very cleanly here: if the simple theory works, then extra assumptions are superfluous, especially when they are clearly violated empirically.

[16] They define factor content of trade in specifications (T4) and higher using this assumption.

Table A2 in the Appendix reports the results from 32 regressions that support our claim. Fix reporting country c, and stack up all imports by trading partner and sector.[17] We ran regressions based on:

$$m(c, c', i) = \beta_0 + \beta_1 s^c y(c', i) + u(c, c', i), \qquad c \neq c', i = 1, \dots, 25$$

where $m(c, c', i)$ is bilateral imports of good i from country c' and $y(c', i)$ is the net output of good i there, and $u(c, c', i)$ is an error that includes trade barriers, economic distance, real exchange rates, and other factors that affect disaggregated bilateral trade. In each case, we test the null hypothesis that $\beta_0 = 0$ and $\beta_1 = 1$. It is rejected resoundingly in 31 regressions, but we cannot reject in the case of Canada. With all due respect to our northern neighbors, we would not want to hang a theory of trade in intermediate inputs on data from their economy alone.

Here is the last nail in the coffin of that demand specification. We estimated:

$$a^c(i) = \beta_0 + \beta_1 s^c y(i) + u(c,, i), \;\; c = 1, \dots, 33 \;\; and \; i = 1, \dots, 48$$

This equation states that $a^c(i)$, absorption of good i in country c, from *all the sources in the world economy* $y(i) = \sum_c y(i, c)$, satisfies the simple restriction implied by homothetic preferences. Now the error term $u(c,, i)$ includes other factors like trade barriers that influence absorption of good i in country c. We are including sectors that are often called not traded goods here. It has $n = 1584 = 33 \times 48$ observations, and we used the Newey-West correction with $k = 60$. Our estimated equation is:

$$\widehat{a^c(i)} = \underset{(667)}{702} + \underset{(0.06)}{0.96} \; s^c y(i), \;\; R^2 = 0.81.$$

[17] Since trade data for 25 sectors are reported and bilateral trade with Israel is omitted, each regression typically has $775 = 25 \times 31$ observations. Each regression for Brazil, China, Indonesia, Russia, and Taiwan had only 675 observations.

The asymptotic standard errors are in parenthesis. The p-value of the F-statistic based upon the hypothesis that $\beta_0 = 0$ and $\beta_1 = 1$ is 0.57. Numbers speak louder than assumptions. International economists should use the Leontief measure of factor content, or be ready to justify exactly how they back out the stages of value added when intermediate inputs are traded around the globe.

V. Heterogeneous Technologies and Missing Trade

Our measure of a country's technology is its matrix of factor shares across 48 industries. In a world with identical technologies, these matrices would all be the same. Table A3 in the Appendix shows the coefficients of variation of these shares (across 33 countries) for each industry in our data. Table A4 reports the same statistics across industries within a country for each country in our sample. Factor shares are as variable within the same industry across countries as they are within the same country across many industries. This is perhaps the most salient feature of the data, and it implies that a serious test of the theory must address disparate technologies in a fundamental manner.

What accounts for this substantial variation of these cost shares? Investigating in why countries have different technologies is beyond the purview of this paper. For example, if we followed Davis and Weinstein's (2001) lead, we would estimate 317 coefficients: 144 parameters for a world technology matrix; 32 normalized country-specific measures of technology, and 141 measures of factor uses in each sector. We leave this exercise to those with a taste for it, but we emphasize that our model's fit, for five times as much data from a much wider sample of countries, is as good as anything achieved by Davis and Weinstein. *And we have estimated nothing!*

Schott (2003) gives our favorite explanation for technology differences. He analyzes three-digit International Standard Industrial Classification data on manufacturing only. He notes that electrical machinery “includes both low-end portable radios and high-tech communications satellites.” Since these goods are probably not produced using the same technology, the taxonomic aggregation will not match the predictions of Heckscher-Ohlin theory. The typical data used for tests of factor content theory are at the two-digit level, a taxonomy that exacerbates the problem. Aggregation bias creates measured differences in technology that cannot be easily corrected. One cannot determine if these matrices reflect factor price differences, true differences in techniques, or bias from combining disparate goods within the same rubric.[18]

The puzzle of missing trade itself is a result of the heterogeneity of local technologies. In our data, the endowment vector is the flow of factor services needed to produce the local output vector using the *local technology.* In the traditional tests, the measured factor content of trade is based on the reference country technology, usually the United States or occasionally some world average technology matrix. Since the reference country does not change, the variation in measured factor content is determined by the variance in net export vectors across countries. However, the local output vector consists of net exports plus domestic absorption, so it must be more variable than net exports alone, as long as absorption and net exports are not negatively correlated.

This problem is exacerbated by measuring endowments in physical quantities, not in the values of factor services. For example, a country that is abundantly endowed with pasture land will be predicted to have large net exports of that factor. But its local technology will surely have adapted to inexpensive pasture land. Hence the value of the

[18] Feenstra and Hanson (2000) make this point in a slightly different context.

flows of factor services will naturally be less variable across countries than the variance of physical endowments because factor prices are negatively correlated with endowments.[19] The simplest tests of the paradigm make this point moot, since they impose factor price equalization. This assumption has been their weakest point. *Our virtual endowments test shows that there is no mystery of missing trade once one makes the minimal theoretical change that allows for different technologies*.

VI. Conclusions

We showed strong empirical support for the most elegant paradigm in applied general equilibrium, the Heckscher-Ohlin-Vanek model. We have delivered where the literature has failed for two reasons. First, we took great care to use consistent data. Second, we gave the theory a chance in a world where countries' technologies differ.

Since our data were accurate, we could focus our attention onto how to make the theory work when countries have heterogeneous technologies. Our biggest theoretical contribution was to construct virtual endowments and apply them to a wide set of international data. Once we had seen the results behind Figures 2, 3, and 4, we knew that the theory was correct. Our careful treatment of technology differences also explains the mystery of missing trade. While our benchmark exhibits missing trade, our virtual endowments predict roughly 80 to 100 percent of observed trade.

Constructing a virtual endowment depends upon a specific output vector, and in a world of many goods and few factors, there are many vectors that satisfy full employment. We extended our results with a technique that works even if we observe only endowments. This modified Rybczynski effect is based on some innovative ideas

[19] This is why our benchmarks using value data predict less missing trade than the norm in the literature.

that will have wider application in empirical trade in the future. It shows again that the theory works remarkably well if one adjusts for technology differences appropriately.

There is a lot of room for future research. We conjecture that the poor performance of the past studies will be overturned if one constructs virtual endowments wherever local output vectors are observable. Much more finely aggregated technology matrices are available than the consistent OECD data we have used here. Constructing virtual endowments with many factors will give richer predictions of the factor content of trade. Also, it will be fruitful to study factor conversion matrices in detail.

In the end, we hope that we have restored the profession's confidence in one of our most important paradigms that has ready applications in international economics, public finance, and development economics. The Heckscher-Ohlin-Vanek paradigm is too elegant in theory not to be true in fact.

Appendix

This appendix serves four functions. First, it shows the exchange rates that we used in our analysis and in our robustness checks. Second, it supports our contention that countries do not trade sector by sector according to a simple gravity specification. Hence, the demand-side assumptions that the literature uses to calculate the factor content of traded intermediate inputs are wrong. Third, it lists of our sample of countries, and it shows the level of aggregation of our consistent technology matrices. Fourth, it supports the statements in the text that differences in technologies across each industry in the world are as important as differences across industries within each country.

Table A1:
PPP and Market Exchange Rates

Country	Year	PPP	Market
Australia	1998/99	1.38	1.57
Austria	2000	0.96	1.09
Belgium	2000	0.99	1.09
Brazil	2000	0.87	1.83
Canada	2000	1.29	1.49
China	2000	1.96	8.28
Czech Republic	2000	15.38	38.60
Denmark	2000	8.71	8.08
Finland	2000	1.11	1.09
France	2000	0.97	1.09
Germany	2000	1.00	1.09
Greece	1999	265.06	305.65
Hungary	2000	114.31	282.18
Indonesia	2000	1,496.20	8,421.77
Ireland	1998	0.81	0.70
Israel	1995	3.01	3.01
Italy	2000	0.90	1.09
Japan	2000	167.96	107.77
Korea, Republic of	2000	789.67	1,130.96
Netherlands	2000	1.00	1.09
New Zealand	1995/96	1.47	1.49
Norway	2001	9.86	8.80
Poland	2000	2.18	4.35
Portugal	1999	0.64	0.94
Russia	2000	5.40	28.13
Slovak Republic	2000	17.84	46.04
Spain	2000	0.79	1.09
Sweden	2000	9.90	9.16
Switzerland	2001	1.98	1.69
Taiwan	2001	21.97	33.81
Turkey	1998	145,757.59	260,724.25
United Kingdom	2000	0.66	0.66
United States	2000	1.00	1.00

Note: The exchange rates are in units of local currency per dollar. The year refers to the time at which the OECD sampled the input-output data. We adjust across countries into dollars using these exchange rates and across time using the US GDP deflator.

Table A2: Demand Tests

	$\hat{\beta}_0$	$\hat{\beta}_1$	se($\hat{\beta}_0$)	se($\hat{\beta}_1$)	R^2	F-Statistic	p-value
AUS	41.89	0.16	11.55	0.07	0.15	146.72	0.00
AUT	64.21	0.23	22.60	0.17	0.04	45.24	0.00
BEL	164.55	0.40	43.94	0.25	0.04	19.84	0.00
BRA	25.22	0.09	11.31	0.02	0.19	1844.80	0.00
CAN	99.57	0.65	78.38	0.54	0.12	1.82	0.40
CHE	85.95	0.22	23.78	0.15	0.03	60.95	0.00
CHN	82.91	0.05	35.35	0.02	0.13	2711.42	0.00
CZE	33.30	0.11	8.94	0.08	0.02	207.39	0.00
DEU	453.85	0.11	69.34	0.05	0.06	324.96	0.00
DNK	44.44	0.16	10.10	0.09	0.05	139.59	0.00
ESP	129.25	0.12	31.87	0.07	0.05	175.40	0.00
FIN	32.89	0.18	6.41	0.10	0.04	98.28	0.00
FRA	279.19	0.12	54.28	0.07	0.07	192.75	0.00
GBR	291.48	0.14	53.36	0.08	0.08	126.89	0.00
GRC	25.92	0.10	5.00	0.06	0.05	291.97	0.00
HUN	29.64	0.16	6.73	0.12	0.04	89.53	0.00
IDN	15.24	0.07	6.68	0.04	0.14	700.92	0.00
IRL	38.65	0.31	15.81	0.19	0.03	19.69	0.00
ISR	N.A	N.A	N.A	N.A	N.A	N.A	N.A
ITA	200.76	0.10	41.65	0.06	0.06	307.06	0.00
JPN	154.61	0.20	53.57	0.03	0.34	640.73	0.00
KOR	90.05	0.22	33.89	0.08	0.11	113.82	0.00
NLD	148.85	0.27	31.72	0.14	0.07	45.32	0.00
NOR	32.73	0.15	6.72	0.07	0.06	167.47	0.00
NZL	11.98	0.19	4.25	0.10	0.07	71.73	0.00
POL	49.47	0.07	11.09	0.05	0.02	523.72	0.00
PRT	40.60	0.10	11.91	0.07	0.03	170.58	0.00
RUS	20.88	0.06	4.29	0.02	0.27	2169.41	0.00
SVK	13.42	0.11	3.98	0.10	0.01	106.55	0.00
SWE	70.96	0.15	15.84	0.10	0.03	107.26	0.00
TUR	37.95	0.07	7.62	0.04	0.07	446.10	0.00
TWN	43.67	0.51	21.86	0.16	0.16	15.96	0.00
USA	772.90	0.10	250.05	0.05	0.09	353.77	0.00

Note: Each regression is estimated individually. We report Newey-West standard errors with $k = 30$. Each regression has 775 observations, except for those involving Brazil, China, Indonesia, Russia and Taiwan which have 675. The p-value is asymptotic probability of computing a larger F-statistic under the null hypothesis that $\beta_0 = 0$ and $\beta_1 = 1$. This statistic uses the variance covariance matrix that incorporates the Newey-West corrections.

Table A3:
Coefficients of Variation of Cost Shares by Industry

Industry	Capital	Labor	Social Capital
Agriculture, hunting, forestry and fishing	0.26	0.37	-3.13
Mining and quarrying (energy)	0.53	0.67	11.43
Mining and quarrying (non-energy)	0.25	0.22	1.33
Food products, beverages and tobacco	0.25	0.24	3.31
Textiles, textile products, leather and footwear	0.26	0.19	1.64
Wood and products of wood and cork	0.27	0.24	2.63
Pulp, paper, paper products, printing and publishing	0.26	0.22	1.89
Coke, refined petroleum products and nuclear fuel	0.46	0.62	7.66
Chemicals excluding pharmaceuticals	0.22	0.23	1.68
Pharmaceuticals	0.23	0.21	1.35
Rubber & plastics products	0.25	0.20	1.67
Other non-metallic mineral products	0.23	0.21	1.41
Iron & steel	0.28	0.24	1.77
Non-ferrous metals	0.26	0.26	1.10
Fabricated metal products, except machinery & equipment	0.29	0.20	1.73
Machinery & equipment, nec	0.27	0.19	1.74
Office, accounting & computing machinery	0.36	0.27	2.20
Electrical machinery & apparatus, nec	0.28	0.20	1.69
Radio, television & communication equipment	0.30	0.26	1.96
Medical, precision & optical instruments	0.27	0.22	3.07
Motor vehicles, trailers & semi-trailers	0.56	0.21	-14.62
Building & repairing of ships & boats	0.36	0.21	2.54
Aircraft & spacecraft	0.30	0.20	2.06
Railroad equipment & transport equip nec.	0.24	0.18	1.10
Manufacturing nec; recycling (include Furniture)	0.30	0.24	5.10
Production, collection and distribution of electricity	0.19	0.29	1.64
Manufacture of gas; distribution of gaseous fuels through mains	0.30	0.39	1.42
Steam and hot water supply	0.33	0.31	1.71
Collection, purification and distribution of water	0.28	0.30	1.62
Construction	0.30	0.24	1.48
Wholesale & retail trade; repairs	0.36	0.30	1.64
Hotels & restaurants	0.30	0.25	1.56
Land transport; transport via pipelines	0.32	0.23	4.66
Water transport	0.27	0.24	2.58
Air transport	0.30	0.22	1.95
Supporting and auxiliary transport activities	0.29	0.24	2.24
Post & telecommunications	0.22	0.23	1.52
Finance & insurance	0.30	0.23	1.73
Real estate activities	0.13	0.44	1.32
Renting of machinery & equipment	0.25	0.38	1.37
Computer & related activities	0.39	0.25	1.95
Research & development	0.38	0.24	-20.82
Other Business Activities	0.31	0.24	1.49
Public admin. & defence; compulsory social security	0.35	0.12	1.88
Education	0.64	0.15	2.01
Health & social work	0.35	0.16	2.41
Other community, social & personal services	0.25	0.20	1.82
Private households with employed persons	0.71	0.39	2.76
Median	**0.29**	**0.24**	**1.73**

Table A4:
Coefficients of Variation of Cost Shares by Country

Country	Capital	Labor	Social Capital
Australia	0.31	0.25	0.29
Austria	0.30	0.24	2.35
Belgium	0.29	0.26	1.19
Brazil	0.29	0.39	0.33
Canada	0.34	0.25	0.71
Switzerland	0.33	0.15	1.66
China	0.21	0.20	0.22
Czech Republic	0.17	0.23	-1.76
Germany	0.35	0.28	-3.75
Denmark	0.43	0.34	-3.94
Spain	0.28	0.24	-10.52
Finland	0.33	0.27	-2.47
France	0.38	0.23	0.35
United Kingdom	0.41	0.22	0.54
Greece	0.36	0.38	0.79
Hungary	0.21	0.18	4.34
Indonesia	0.27	0.43	-9.27
Ireland	0.37	0.29	2.11
Israel	0.40	0.22	0.94
Italy	0.23	0.36	1.86
Japan	0.35	0.24	1.58
Korea, Republic of	0.22	0.29	1.57
Netherlands	0.38	0.34	-10.55
Norway	0.36	0.27	-2.35
New Zealand	0.21	0.23	0.71
Poland	0.25	0.26	0.84
Portugal	0.59	0.39	-0.96
Russia	0.25	0.37	0.51
Slovak Republic	0.20	0.20	-1.64
Sweden	0.31	0.18	1.08
Turkey	0.19	0.57	4.05
Taiwan	0.31	0.26	1.87
United States	0.32	0.24	0.94
Median	**0.31**	**0.26**	**0.71**

REFERENCES

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

Choi, Yoong-Seok, and Pravin Krishna. "The Factor Content of Bilateral Trade: An Empirical Test." *Journal of Political Economy* August 2004, *112*(4), pp. 887-914.

Cline, R. E. "Note on the Generalized Inverse of the Product of Matrices." *SIAM Re*view *6*, 1964, pp. 57-58.

Conway, Patrick J. "The Case of Missing Trade and other Mysteries: Comment**."** *American Economic Review,* March 2002, *92*(1), pp. 394-404.

Davis, Donald R. and David E. Weinstein. "An Account of Global Factor Trade." *American Economic Review,* December 2001, *91*(5), pp.1423-53.

Davis, Donald R., David E. Weinstein, Scott C. Bradford, and Kazushige Shimpo. "Using International and Japanese regional Data to Determine when the Factor Abundance Theory of Trade Works." *American Economic Review*, June 1997, *87*(3), pp.421-46.

Deardorff, Alan V. "The General Validity of the Heckscher-Ohlin Theorem." *American Economic Review,* September 1982, 72*(4)*, 683-694.

Debaere, Peter. "Relative Factor Abundance and Trade." *Journal of Political Economy*, June 2003, *111*(3), pp. 589-612.

Estevadeordal, Antoni and Alan M. Taylor. "A Century of Missing Trade?" *American Economic Review*, March 2002, *92*(1), pp.383-93.

Feenstra, Robert C. and Gordon H. Hanson. "Aggregation Bias in the Factor Content of Trade: Evidence from U.S. Manufacturing." *American Economic Review Papers and Proceedings*, May 2000, *90*(2), pp.155-60.

Fisher, Eric O'N. and Kathryn G. Marshall. "The Structure of the American Economy." http://www.calpoly.edu/~efisher/The%20Structure%20of%20the%20American%20Economy.pdf

Harrigan, James. "Specialization and the Volume of Production: Do the Data Obey the Laws?" in E. Kwan Choi and James Harrigan, *Handbook of International Trade*, Oxford: Blackwell, 2003.

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.

Harkness, Jon. "Factor Abundance and Comparative Advantage." *American Economic Review*, December 1978, *68*(5), pp. 784-800.

Heston, Alan, Robert Summers, and Bettina Aten. "Penn World Table Version 6.2" Center for International Comparisons, University of Pennsylvania (CICUP), September 2006.

Kemp, Murray C. and Henry Y. Wan, Jr. "An Elementary Proposition Concerning the Formation of Customs Unions." *Journal of International Economics*, February 1976, *6(1)*, pp. 95-97.

Leamer, Edward E. *Sources of International Comparative Advantage: Theory and Evidence.* MIT Press: Cambridge, 1984.

Leontief, Wassily. "Domestic Production and Foreign Trade: The American Capital Position Re-examined." *Proceedings of the American Philosophical Society,* September 1953, *97(4),* pp. 332-49.

Maskus, Keith E. **"**A Test of the Heckscher-Ohlin-Vanek Theorem: The Leontief Commonplace." *Journal of International Economics,* November 1985 *19(3-4),* pp. 201-212**.**

Prescott, Edward C. "Theory Ahead of Business Cycle Measurement." *Federal Reserve Bank of Minneapolis Quarterly Review,* Fall 1986 10(4), pp. 9-22.

Reimer, Jeffrey J. "Global Production Sharing and Trade in the Services of Factors." *Journal of International Economics,* March 2006, *68(2),* pp. 384-408.

Rosefielde, Steven. **"**Factor Proportions and Economic Rationality in Soviet International Trade 1955-1968." *American Economic Review*, September 1974, *64(4)*, pp. 670-681.

Schott, Peter K. "One Size Fits All? Heckscher-Ohlin Specification in Global Production." *American Economic Review*, June 2003, *93(3*), pp.686-708.

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

_____. "The Case of Missing Trade and Other Mysteries." *American Economic Review,* December 1995, *85*(5), pp. 1029-46.