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ABSTRACT

The dominant paradigm of world trade patterns posits two principal features. Trade between North and South arises due to traditional comparative advantage, largely determined by differences in endowment patterns. Trade within the North, much of it intra-industry trade, is based on economies of scale and product differentiation. The paradigm specifically denies an important role for endowment differences in determining North-North trade. This paper provides the first sound *empirical* examination of this question. We demonstrate that trade in factor services *among* countries of the North is systematically related to endowment differences and large in economic magnitude. Intra-industry trade, rather than being a puzzle for a factor endowments theory, is instead the conduit for a great deal of this factor service trade.

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Do Factor Endowments Matter for North-North Trade?

The new trade theory of the 1980's is primarily recognized for its novel contributions regarding increasing returns, product differentiation and imperfect competition.[1] Yet the influence of this literature goes beyond simply adding a few new models to the canon. In a pair of influential papers, Krugman (1981) and Helpman (1981) articulated a vision of world trade patterns that integrated the new trade theory with the traditional factor endowments theory of Heckscher-Ohlin. In this formulation, each theory plays a role, but the roles differ. Trade among rich countries of the North is intra-industry and takes advantage of gains from specialization in a world of scale economies. Trade between North and South is inter-industry based on differences in factor endowments. This hybrid paradigm is now the profession's dominant vision of the determinants of world trade patterns.

In arguing for the empirical relevance of the scale economies element of this paradigm, Krugman (1981) cited two seeming-paradoxes in world trade patterns when viewed through a factor endowments lens: "First, much of world trade is between countries with similar factor endowments. Second, a large part of trade is intra-industry in character – that is, it consists of two-way trade in similar products."[2] In effect, this paradigm specifically denied that factor endowment differences are important for understanding trade *among* the rich countries of the North, for which instead it turns to the new trade theory. And the predominance of intra-industry

[1] See the seminal papers of Krugman (1979) and Lancaster (1980).

[2] These observations about trade patterns were offered specifically to motivate a move to the new trade theory view which could account for these facts even among countries with identical endowments. Krugman (1980) also appealed to one element apart from trade patterns: an apparent absence of substantial distributional impact of trade reform.

trade is also viewed as a puzzle, because this is viewed as trade in goods of similar factor intensity.[3]

The present paper provides the first sound empirical scrutiny of the role of factor endowments in determining North-North trade. It has not been possible to examine this empirical issue previously because the literature on trade in factor services was dominated by anomalies and conundrums, such as Trefler's (1995) "mystery of the missing trade" and Gabaix's (1997) "rejection of the Heckscher-Ohlin-Leontief hypothesis," rather than models that match well with the data.[4] Recently, Davis and Weinstein (2001) have provided a simple theoretical framework that provides a surprisingly strong match between prediction and data for trade in factor services. This is the starting point for the present paper.

We will say that endowment differences are important for North-North trade if two criteria are met: (1) Factor service trade among countries of the North is *systematically* related to endowment differences; and (2) The magnitude of factor service trade is economically large. Our results show that both criteria are met.

This implies that the core vision of the determinants of world trade patterns needs to be amended, particularly as it pertains to trade among the rich countries of the North. As the current paradigm suggests, scale economies and product differentiation may well be important for trade

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[3] Helpman and Krugman (1985, p. 2) discuss the issue of intra-industry trade as follows: "In particular, countries should export goods whose factor content reflects their underlying resources. This is in fact by and large true of countries' *net* exports. But to casual observation, and on more careful examination, actual trade patterns seem to include substantial two-way trade in goods of similar factor intensity. This 'intraindustry' trade seems both pointless and hard to explain from the point of view of a conventional trade analysis." This perspective is evident as well in virtually all recent editions of trade textbooks. See also Davis (1997) for a discussion.

[4] Cf. Bowen, Leamer, and Sveikauskas (1987), Trefler (1995), and Gabaix (1997).

within the North – nothing that we do contests this. What we show is that endowments matter not only for North-South trade, but for trade *within* the North as well. Factor service trade for countries of the North is systematic, economically large, and frequently more intensively directed toward other countries of the North than toward the South.

Moreover, our work forces a reconsideration of the role of intra-industry trade. Conventionally its importance for bilateral trade among countries of the North is taken as evidence that endowments do not matter for this trade. What we show instead is that, when properly conceived and measured, intra-industry trade is instead one of the principal conduits of factor service trade for countries of the North. Indeed, recent work by Schott (2000) supports our interpretation. Schott examines highly disaggregated (10 digit harmonized trade system) US import data and finds evidence of great variation in unit values, which is consistent with intra-industry exchange being distinct goods with distinct input ratios.

We develop this paper in three additional sections. Section II articulates our basic theoretical framework, develops some new results regarding factor service trade with well-defined classes of countries, and provides a theoretical decomposition relating our measures to those employed in previous empirical work. Section III derives the principal empirical results. Section IV concludes.

II. Theory

The starting point for an investigation of the role of trade in factor services must be measurement. The classic framework for measuring trade in factor services is due to Vanek (1968). Trefler (1993, 1995) amends this in an adjusted factor price equalization framework to allow either for factor-augmenting or for Hicks-neutral technical differences. Deardorff (1982) and Helpman (1984) develop versions that are highly relevant for our work here, which allow for differences in relative factor prices across countries that cannot be handled as simple factor-augmenting differences. Davis and Weinstein (2001) develop a variant of the Deardorff-Helpman model with explicit consideration of the nature of technical differences, as well as the presence of non-traded goods, and show that such a model has substantial empirical support.

Here our concern is to move beyond a test of the theory to understand some key questions for which magnitudes matter. Is factor service trade important for countries of the North? If so, what is the relative importance in this trade of trade with other countries of the North? Is this factor service trade systematic, even among countries of the North? How does the fact that much trade within the North is intra-industry affect our view of factor service trade among these countries? Is intra-industry trade truly trade in goods of similar factor intensity? Over all, how important is intra-industry trade in the net exchange of factor services among countries of the North? To answer these questions, we specify a model that builds on Davis and Weinstein (2001).

The theoretical framework that we employ is exceedingly simple. We assume that we are in a Heckscher-Ohlin world with many goods, factors, and countries. Technologies are constant returns to scale. Preferences are identical and homothetic. Any technological differences are assumed to be of the factor-augmenting variety, so can be subsumed by converting factors to efficiency units. Factor price equalization is assumed not to hold for any pair of countries in our sample. The number of goods produced is assumed to be sufficiently large that we can safely ignore "boundary" goods produced by more than one country. In short, this is a standard multicone Heckscher-Ohlin model with specialization in traded goods. When considered in a two-factor framework, this model receives strong empirical support in Davis and Weinstein (2001).

In this paper, a prime concern will be tracking the factor content of trade. A standard way for measuring this in the case of No FPE is developed in Deardorff (1982) and Helpman (1984).[5] The key insight is that when techniques of production vary across countries, as is the case when FPE fails, factor contents should be measured using the producer's technology. Allowing $\boldsymbol{c}$ and $\boldsymbol{c'}$ to index countries, $\boldsymbol{B_{fc}}$ to be the $\boldsymbol{f}$'th row of the total factor input matrix of country $\boldsymbol{c}$, $\boldsymbol{E_c}$ to be gross exports from $\boldsymbol{c}$, and $\boldsymbol{M_{cc'}}$ to be gross imports by $\boldsymbol{c}$ from $\boldsymbol{c'}$, the Deardorff-Helpman measure of the factor content of trade for country c in this case with No FPE is:

$$F_{fc} \equiv \mathbf{B}_{fc}\mathbf{E}_{\mathbf{c}} - \sum_{c'} \mathbf{B}_{fc'}\mathbf{M}_{cc'} \qquad (1)$$

Note that for the case with FPE, $\boldsymbol{B_{fc}} = \boldsymbol{B_{fc'}}$, so this reduces to the standard Heckscher-Ohlin-Vanek measure.

An extremely important question is how the analytically correct Deardorff-Helpman measure of the net factor content of trade compares to the conventional measures of net factor trade that have been employed in the empirical literature. The conventional approach has been to

[5] This is very close to what Deardorff (1982) termed the "actual factor content of trade," which allowed him his most general results. To make our measure and his coincide exactly would have required an iteration procedure that traces back factor contents of intermediates used in exports, the factor content of imported intermediates used in the production of those intermediates, etc. Because a great deal of the factor content comes from use of non-tradables and because imports are typically a small portion of usage even in tradable sectors, we judged these issues to be of second order for our purposes. Note that Deardorff and Helpman used these measures to derive restrictions on comparative costs, whereas we will be concerned more directly with the measures of factor content themselves.

assume that the appropriate measure of a country's net factor trade is the product of a common technology matrix, typically that of the United States, and the country's net trade vector. This is easily accomplished via a decomposition of the appropriate measure into two components, one reflecting the conventional measure, and the second reflecting various types of measurement errors inherent in the conventional measure.

To do the decomposition, it is useful to start with a few key concepts. First, let $\boldsymbol{T}_{cc'}$ be the vector of net exports by industry between countries $\boldsymbol{c}$ and $\boldsymbol{c'}$. Positive elements correspond to industries in which $\boldsymbol{c}$ is a net exporter to $\boldsymbol{c'}$ and negative elements indicate those industries in which it is a net importer. It is convenient to divide up the net export vector into these two components. Define a variable $\boldsymbol{T}^{+}_{cc'}$ to be the level of net *exports* where this is positive, and to be zero elsewhere. Correspondingly, define $\boldsymbol{T}^{-}_{cc'}$ to be the level of net *imports* where c is a net importer (hence a negative number) and to be zero elsewhere. Then, it follows that:

$$\mathbf{T}_{cc'} \equiv \mathbf{T}^{+}_{cc'} + \mathbf{T}^{-}_{cc'}$$

It is also convenient to define a variable we can call "matched intra-industry trade." In bilateral trade, it is the positive quantity of imports within an industry that can be exactly matched with the bilateral exports within the same industry. Using the mnemonic of Grubel-Lloyd, matched intra-industry trade is defined for industry $\boldsymbol{i}$ as:[6]

$$G^{i}_{cc'} \equiv \min\left\{E^{i}_{cc'}, M^{i}_{cc'}\right\}$$

[6] Grubel and Lloyd (1975) provided an influential early documentation of the predominance of intra-industry trade, particularly among countries of the North.

Using this concept of matched intra-industry trade, it is possible to decompose the gross export vector into two components. Some goods we import on net, so that our gross exports equal precisely the level of matched intra-industry trade, $\boldsymbol{G}^{i}_{cc'}$. Others we export on net, so our gross exports are the sum of matched intra-industry trade plus the net exports. Our gross exports can then be written as:

$$\begin{aligned}\mathbf{E}_{cc'} &\equiv \mathbf{G}_{cc'} + \mathbf{T}^{+}_{cc'} \\ &\equiv \text{Matched Intra-Industry Trade + (Positive) Net Exports}\end{aligned}$$

We can do a similar decomposition for our net imports:

$$\begin{aligned}\mathbf{M}_{cc'} &\equiv \mathbf{G}_{cc'} - \mathbf{T}^{-}_{cc'} \\ &\equiv \text{Matched Intra-Industry Trade} - \text{(Negative) Net Imports}\end{aligned}$$

Just to tie this down, note that the net trade vector between c and c' is then:

$$\mathbf{T}_{cc'} \equiv \mathbf{E}_{cc'} - \mathbf{M}_{cc'} \equiv \left(\mathbf{G}_{cc'} + \mathbf{T}^{+}_{cc'}\right) - \left(\mathbf{G}_{cc'} - \mathbf{T}^{-}_{cc'}\right) \equiv \mathbf{T}^{+}_{cc'} + \mathbf{T}^{-}_{cc'}$$

Now we can turn to the decomposition of our appropriate measure of net factor trade. Since most previous studies employed the US technology matrix, we will use it for the decomposition. Recall that the conventional measure of country ***c***'s factor content of trade has been:

$$\mathbf{F}^{Conv}_{fc} \equiv \mathbf{B}_{f\,US}\mathbf{T}_{c}$$

If we add and subtract this from our appropriate measure from equation (1) above, we obtain the desired decomposition:

$$
\begin{aligned}
\mathbf{F}_{fc} &\equiv \mathbf{F}_{fc}^{Conv} - \left[\sum_{c'} \left(\mathbf{B}_{f\,US} - \mathbf{B}_{fc}\right)\mathbf{T}_{cc'}^{+}\right] - \left[\sum_{c'} \left(\mathbf{B}_{f\,US} - \mathbf{B}_{fc'}\right)\mathbf{T}_{cc'}^{-}\right] + \left[\sum_{c'} \left(\mathbf{B}_{fc} - \mathbf{B}_{fc'}\right)\mathbf{G}_{cc'}\right] \\
&\equiv \mathbf{F}_{fc}^{Conv} + \boldsymbol{\varepsilon}_{NE} + \boldsymbol{\varepsilon}_{NI} + \boldsymbol{\varepsilon}_{MIT}
\end{aligned}
$$

The first term is the conventional measure of the factor content of trade employed in previous studies, based on all countries using US technology. The remaining three terms identify systematic errors associated with the conventional measure, and are straightforward to interpret. The first error arises when the factor content of country ***c***'s net exports (NE) is incorrectly measured with the US technology matrix rather than the appropriate matrix from country ***c***. The second source of error comes similarly from the fact that the factor content of net imports (NI) is incorrectly measured with the US technology matrix rather than that of the producer, country c'. The final error arises because the use of any common technology matrix defines matched intra-industry trade (MIT) to have zero factor content, whereas the true factor content of trade must take account of the fact that even matched intra-industry trade will contribute to the net factor content, the magnitude of this error depends on the volume of matched intra-industry trade and the difference in production techniques employed by ***c*** and c'.

So far we have been working with a country's trade with the rest of the world. The standard theory typically makes no prediction about *bilateral* factor contents because the bilateral pattern of goods trade may not be uniquely defined. Here, however, the assumptions of specialization and identical homothetic preferences allow us to make bilateral factor content predictions. Because of specialization, there is little harm in thinking of each country producing a single composite good using all of its factors, which it both consumes and exports. Thus the net factor content of trade in factor f between country c and c', denoted $F_{fcc'}$, will be the difference between the exports of f from c and the imports of f by c:

$$F_{fcc'} = s_{c'}V_{fc} - s_cV_{fc'}$$

Simple manipulation of this implies that country c will be a net exporter of factor f bilaterally to any country such that:

$$\frac{V_{fc}}{s_c} > \frac{V_{fc'}}{s_{c'}}$$

In the reverse case it will be a bilateral net importer.

This last point is worth emphasizing. The typical country, one not at the extremes of abundance for a particular factor, will find that it is a net exporter of a factor to those less abundant than it as measured by V_{fc} / s_c and a net importer of those factor services in the reverse case. The measure of the net factor content of trade with the world as a whole tends to obscure this systematic feature of the model because the positive and negative bilateral net factor trades may be canceling out. Moreover, it is important to stress that even if the total net factor trade is driven toward zero, this does not mean that the gains from being able to engage in these trades are likewise heading toward zero. Rather, there are gains from trading both with those more and less well endowed with the factor.

This motivates separating out for each factor and country the set of countries that are more or less well endowed with a factor. Let $S(f,c)$ be defined as the set of countries c' more abundant in factor f than country c, i.e. in which $V_{fc} / s_c < V_{fc'} / s_{c'}$. Similarly, we can define $T(f,c)$ as the set of countries for which c is more abundant in f, i.e. $V_{fc} / s_c < V_{fc'} / s_{c'}$. This allows us to calculate the factor content of trade separately for each country and factor with respect to those with which that country is a net exporter vs. importer of the factor services. Hence define:

$$F_{fc}^{+} \equiv \sum_{c' \in \Omega(f,c)} \mathbf{B}_{fc} \mathbf{E}_{cc'} - \sum_{c' \in \Omega(f,c)} \mathbf{B}_{fc'} \mathbf{M}_{cc'} \quad \text{and}$$

$$F_{fc}^{-} \equiv \sum_{c' \in \omega(f,c)} \mathbf{B}_{fc} \mathbf{E}_{cc'} - \sum_{c' \in \omega(f,c)} \mathbf{B}_{fc'} \mathbf{M}_{cc'}$$

Finally, having spent so much time developing measures of the factor content of trade, we should say a few words about what we hope to learn from these measures. Deardorff and Staiger (1988) develop conditions under which it is possible to convert from factor content measures to welfare measures. The required restrictions are strong and do not hold in the present context. This makes it difficult to make strong normative statements based on the findings. Nonetheless, we do feel that the measures can be informative. First, the theory that we have developed actually places much stronger restrictions on the data than the traditional HOV theory, including predictions bilaterally and to theoretically-identified subsets of countries. Hence it will be informative to see if the measures conform to these predictions. Second, the predictions and measures of net factor trade with the distinct groups of countries provide at least some coarse insight about the likely magnitude of impact on local factor markets of trade with the distinct groups of countries. Lastly, they will also provide again at least a coarse guide to how important trade in factor services is within the OECD as opposed to with the remainder of the world.

III. Measuring Net Factor Trade

A. *Data*

All of our direct and indirect technology matrices for our OECD countries are constructed using information available in the STAN, ISDB, and OECD input-output databases. Each country's economy is divided into 34 sectors which yields industry definitions that are equivalent to ISIC three- or four-digit data. Endowment data are taken from these sources for our sample of ten OECD countries and from the Penn World Tables version 5.6. Trade data are taken from the OECD and from Feenstra, Lipsey, and Bowen (1997). The exact methods used to construct our technology matrices are often complex and details are described in detail in the data appendix. An important difference between the data used in that paper and the data in this paper, is that all trade tests in the former work are conducted using estimated technology matrices. In this paper, we only work with the actual technology matrices.[7] All other data are identical in the two papers.

All technology matrices and endowments were adjusted so that factor service flows are in efficiency units. This entails deflating each element of $\mathbf{B_c}$ and $\mathbf{V_c}$ by a Hicks-neutral parameter, λ_c, corresponding to the productivity of factors in that country. The parameter λ_{US} is normalized to unity. Each of these λ_c's is calculated according to specification P5 in Davis and Weinstein (2001). Since $\mathbf{B_c}\,\mathbf{Y_c} = \mathbf{V_c}$, it must also be the case that we have full employment in efficiency units, i.e. $\mathbf{B_c^E}\,\mathbf{Y_c} \equiv (1/\lambda_c)\,\mathbf{B_c}\,\mathbf{Y_c} = (1/\lambda_c)\,\mathbf{V}_c \equiv \mathbf{V_c^E}$. To keep the notation simple, however, we have suppressed the efficiency unit superscript (E) in subsequent sections.

[7] The technology matrix for the composite rest of the world corresponds to the one used in specification T6 in Davis and Weinstein (2001). This matrix satisfies the full employment condition for the rest of the world.

B. *True and Conventional Measures of Net Factor Trade*

In the theoretical section, we note that the starting point for our analysis is the Deardorff-Helpman measure of the factor content of trade in a No-FPE world. We also noted that this measure of the true factor content of trade can be decomposed into the conventional measure plus three sources of error. To place this in context, it is useful to think about what role might have been played by this measurement issue in the phenomenon that Trefler (1995) memorably termed the "mystery of the missing trade." The mystery concerns a feature of the data under the conventional empirical implementation of HOV:

$$F_{fc}^{Conv} \equiv \mathbf{B}_{f\,US}\mathbf{T}_c = \mathbf{V}_{fc} - s_c\mathbf{V}_{fW}$$

In simple terms, the mystery in the data is that the measured net factor trade on the LHS is an order of magnitude smaller than the predicted factor trade based on endowments on the RHS.

The major thrust of Trefler's effort to solve this anomaly was to take the LHS as given and ask what amendments on the RHS would help. His preferred specification featured Hicks-neutral efficiency differences across countries and a home bias in demand. The assumption of a home bias directly scales down the RHS, but the efficiency difference will affect both sides of the equation.

Davis and Weinstein (2001) and Helpman (1998) argue that the conventional measure of net factor trade, F_{fc}^{Conv}, is likely to be biased toward zero. The reasoning is quite straightforward. In a no-FPE world, factor prices vary inversely with factor abundance. This leads countries to specialize in the production of goods that use their abundant factors intensively and not to produce goods that use their scarce factors intensively. Since a country's technology matrix is based on what is actually produced in that country, countries that are abundant in a factor will use techniques that use more of their abundant factors. Applying this matrix to imports from less endowed countries will overstate the measured factor content of imports for abundant factors and understate it for less abundant factors. This will cause F_{fc}^{Conv} to be biased toward zero because we erroneously think that our imports are produced using the same technologies employed at home.

While Davis and Weinstein (2001) demonstrate that F_{fc}^{Conv} is much smaller than predicted factor trade and that these predicted biases in the technology matrices exist, the paper did not directly examine whether these biases were critical to understanding the missing trade phenomenon. This is because in the Davis and Weinstein work, both the LHS and RHS change in the move across specifications. In this section, we show that measurement error alone suffices to generate the "mystery of the missing trade."

Rather than work with estimated technology matrices as in our earlier work, we compare F_{fc}^{Conv} with the correct Deardorff-Helpman measure of F_{fc}, calculated using the true technology matrices. A plot appears as Figure 1. If the conventional measure of net factor content is close to the true factor content, all of the data will lie on the 45 degree line, or more weakly, will lie in quadrants one and three. A quick scan of the plot reveals this is very much at odds with the data. The magnitude of the conventional measure of net factor trade is much smaller than true net factor trade. The variance of the former is only one-eighth as large as the latter. More surprising yet is that there is, if anything, a *negative* relation between conventional and true net factor trade. Less than one third of the points lie in quadrants one and three.

The fact that the conventional measure of net factor trade is much smaller than the true measure, and the fact that the relation is negative, carries an important message. Efforts to reconcile measured and predicted net factor trade by hypotheses that would alter predicted net factor trade were ultimately doomed. The attenuation bias is so severe that this sufficed to generate the mystery of the missing trade, quite apart from other problems in theory or measurement.

A natural question arises at this point. Nearly all of the studies have used only the US technology matrix. Yet from the theory, there are reasons to believe that the adoption of *any* common technology matrix will lead to attenuation, for example because it excludes the possibility that there is factor content in intra-industry trade. Hence it is reasonable to ask whether this crippling mis-measurement of net factor trade is a consequence of using the US technology matrix, or of using any common technology matrix. This is easy to resolve by simply substituting the technology matrices of other countries for that of the US and repeating the experiments. A plot using all available technology matrices appears as Figure 2. The results bear a striking resemblance to those based on the US technology matrix. The conventional measures understate the magnitude of true net factor trade, and indeed maintain the negative relation between the conventional and true measures. The severe mis-measurement of net factor trade is not simply a consequence of the choice of the US technology matrix.

A third issue arises regarding the conventional measure of net factor trade. Theory suggests that the mis-measurement of the factor content of imports is a critical element in generating the attenuation. Hence we should observe the bias even if we apply a country's technology matrix only to its own net trade vector. It is again simple to investigate this by restricting the sample from the last exercise to the cases in which there is a match between the country whose technology matrix is in use and the net trade vector we look at. The plot appears as Figure 3. From the standpoint of the previous literature, the result is very discouraging. The conventional measure and true net factor trade are no more strongly related even when we restrict the sample to the country whose technology matrix we employ.

C. *Decomposition of Net Factor Trade and the Role of Intra-Industry Trade*

So far we have been looking only at the relation between conventional and true measures of net factor trade. Our results suggest that insofar as there is a relation, it is negative. We now turn to a more formal decomposition in the data. We have noted there are three sources of error. For simplicity of reference, we repeat the decomposition here:

$$\begin{aligned} F_{fc} &\equiv F_{fc}^{Conv} - \left[\sum_{c'} \left(B_{f\,US} - B_{fc} \right) T_{cc'}^{+} \right] - \left[\sum_{c'} \left(B_{f\,US} - B_{fc'} \right) T_{cc'}^{-} \right] + \left[\sum_{c'} \left(B_{fc} - B_{fc'} \right) G_{cc'} \right] \\ &\equiv F_{fc}^{Conv} + \varepsilon_{fc}^{NE} + \varepsilon_{fc}^{NI} + \varepsilon_{fc}^{MIT} \end{aligned}$$

Our discussion will emphasize the last of these errors. It is a commonplace in the theory that the defining characteristic of intra-industry trade is that it is in goods of the same factor intensity because of the assumption that we are producing the same goods with the same technologies and factor prices.[8] Hence, matched intra-industry trade, where exports identically equal imports, should have zero factor content. In fact, this relation has been *imposed* in previous empirical tests of HOV, which look only at countries' *net* commodity trade vector. Yet by

[8] That is, we are in an "integrated equilibrium" in the sense of Helpman and Krugman (1985).

examining the equation above, and from the fact already observed that countries' technology matrices differ, we can see that this won't be precisely right.

This raises the question of how important a role intra-industry trade plays in carrying out net factor trade. Conventional wisdom based on integrated equilibrium models holds that this term should be small, for two reasons. First, where technologies differ greatly, as in North-South trade, we know there is little intra-industry trade. Second, where we know there is a great deal of intra-industry trade, as in North-North trade, the input coefficients should differ either trivially or randomly. Hence, for intra-industry trade to contribute importantly to true net factor trade, it must be the case that the technology differences are both large and systematic. The conventional wisdom, however, does not hold up if there is specialization of goods within industries and a failure of factor price equalization. In this case, intra-industry trade is likely to be an important conduit of factor service trade because even within industries goods are being produced with different factor proportions.

A simple approach to assessing the importance of intra-industry trade in the export of factor services is to plot the factor content of intra-industry trade, ε_{fc}^{MIT}, against the factor content of trade, F_{fc}. If intra-industry trade is unimportant as a communicator of net factor content, then the data should lie along the horizontal axis. In the unlikely case that all net factor content is carried out through intra-industry trade, the data will lie on the 45 degree line. The plot appears as Figure 4. It is striking that intra-industry trade has a much more systematic relation to true net factor content than our traditional measure does. Moreover, the slope of the line is 0.42, indicating that, on average, more than 40 percent of net factor trade is carried out through intra-industry exchange.

A more detailed view is revealed by examining the role of intra-industry trade in total net factor trade for individual countries. There is no *a priori* reason that these terms must have the same sign. But when they do, and when their ratio is less than unity, there is a natural interpretation of this ratio as the share of intra-industry trade in a country's total net trade in a factor. The results appear in Table 1. As it turns out, in 19 of 22 cases, the factor content of intra-industry trade is the same as the overall factor content of trade. By contrast, this was true for only 7 of 22 cases with the conventional measure of net factor trade. The median ratio of factor content of intra-industry trade relative to F_{fc} is 34 percent. This actually understates the importance of intra-industry trade for many countries. In half of the rich OECD countries in our sample, intra-industry trade is more important than inter-industry trade in the net export or import of factor services. Moreover, for France, the UK, and the US, the factor content of intra-industry trade is at least two-thirds as large as total net factor service trade.

This suggests that the profession has operated under a serious misconception. The prevalence of intra-industry trade has been taken as evidence that the factor content of North-North trade is minimal. An unexpected converse is closer to the truth: intra-industry trade is in fact one of the principal conduits of net factor trade. This is true even for the rich OECD countries.

D. *Are Factor Service Flows Important?*

The previous section shows that the conventional measure of factor service flows is quite small relative to actual flows. This still leaves open the question of how important actual factor service flows are. As we noted earlier, theory does not provide a uniquely appropriate measure. Here we will provide a variety of metrics that will throw light on various facets of the question.

We begin with a simple and intuitive measure. We just scale the absolute value of the net factor trade by the national endowment of a factor. This may roughly be interpreted as the share of the national endowment exported or imported on net. The results of this experiment appear in Table 2. The median in our sample of ten OECD countries is a net trader of approximately 5 percent of its total capital and 9 percent of its total labor. These shares are much higher for Netherlands and Denmark, which export capital services equal to over 10 percent of their capital and import labor services equal to over 15 percent of their labor.

In recent papers, Irwin (1996) and Feenstra (1999) have argued that scaling by a country's total resources (in their case, GDP) may be seriously misleading about the influence of trade within the tradable sectors. This point is underscored by the observation in Davis and Weinstein (2001) that the interaction between non-tradable sectors and the failure of FPE is very important in reconciling predicted and measured net factor trade. These considerations suggest the value of considering a scaling by national endowments net of resources devoted to non-traded production.[9] This is implemented easily. If we pre-multiply non-traded output by the relevant

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[9] Unfortunately, we do not have a perfect breakdown of tradable and non-tradable goods. If we define tradables to include all manufacturing, mining, and agricultural sectors, and define all other sectors as non-tradables, we obtain a rough division. The division is rough because many sectors that we label tradable contain goods traded only with great difficulty (e.g. concrete), and our non-tradable goods sectors contain some that are traded (e.g. Transport and

technical coefficients, we get the commitment of resources to non-traded sectors, which can be subtracted from national endowments to yield the desired endowments committed to traded sectors.

The results from scaling total net factor trade by endowments devoted to tradables are presented in Table 2. The median country is an absolute net trader of 18 percent of its capital endowment and 36 percent of its labor endowment devoted to tradables. This indicates that for the typical country, net factor trade looms quite large relative to total resources devoted to production of tradables.

E. *Special Properties of Net Factor Trade in a No-FPE World*

This paper has taken relatively little advantage thus far of the special structure of the underlying theoretical assumption of No-FPE. As it turns out, this assumption imposes a great deal more structure on our predictions than would the conventional HOV model. In the conventional HOV model, a country's net factor trade is well defined relative to all remaining countries taken together, but not typically to any subset of countries. We showed in the theoretical section that in the No-FPE world, there are very definite predictions of the model both bilaterally and relative to subsets of the remaining countries. In particular, it stresses that a Vanek-type chain can be formed, factor by factor, dividing the countries according to whether

Communication and Finance and Insurance). Even so, using this organization scheme, the median import to domestic-absorption ratio is 0.254 for the tradable sectors and 0.004 for the non-tradables sectors. Furthermore, when looking at the data on a sector-by-sector basis we find that the median import to domestic-absorption ratio is always above 0.12 for our tradables sectors and below 0.05 for non-tradables. This suggests that our classification scheme appropriately captures the differential tradability.

they are more or less well endowed with a factor than the country in question. The important fact for us here is that the typical country is predicted to be a net exporter of a factor's services to all countries, separately or together, who are less well endowed with this factor, and a net importer of services of this factor from any and all of the countries better endowed with this factor. This special structure allows us to further investigate the empirical robustness of our theoretical model.

The results of this exercise are presented in Table 3. With two factors and two groups for our sample of ten OECD countries and the composite Rest of the World, there are 40 observations.[10] In nearly 90 percent of the cases, the model correctly predicts the direction of net factor trade. This is significantly different from a random outcome at all conventional significance levels. This is particularly impressive given that we are predicting that each country will be a net exporter of a factor to one group of countries and a net importer of the same factor from a separate group of countries.

This also suggests one further amendment in our calculation of the role of net factor trade in a No-FPE world. A simple example will make the relevant analytic point. Consider the case of a country that happens to have endowments in nearly the same proportion as the world as a whole. The factor content of its production is nearly proportional to world endowments by market clearing. But identical and homothetic preferences insure that its absorption of factor services is exactly proportional to world endowments. With equal endowment mass both above and below the world diagonal, its net factor trade may be quite small. Yet this may mask the fact

[10]Countries at the extremes of the abundance distribution always have no trade with more extreme partners so we lose two observations per factor.

that it is engaging in a great deal of factor trade both with countries above the world diagonal as well as those below it.[11]

This example suggests breaking up the world into the same two groups, according to whether they are more or less abundant in a factor than a particular country. Absolute net factor contents would then be calculated for the two groups separately and added before scaling. The hope is that this will provide a more appropriate measure of the true role of net factor trade in a No-FPE world. The results of this exercise are presented in Table 2. The results show that this exercise raises measured net factor trade by approximately one-quarter, to a median of approximately 10 percent of total national endowments for capital and 12 percent for labor. If we were instead to scale by endowments in the tradable sectors, the corresponding figures would be 38 percent for capital and 49 percent for labor. These numbers indicate that OECD countries engage in large amounts of factor service trade.

F. *Net Factor Trade Within the North*

It is often suggested that factor service trade among wealthy countries is relatively unimportant. There is no question that a majority of factor service trade is North-South. However, this does not mean that North-North factor service trade is unimportant. First, when we exclude trade with the rest of the world from our sample, we find the same general pattern of

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[11] This example has one trick. Even if the country's endowment were exactly proportional to the world endowment, this would not drive its net factor trade to exactly zero. In fact, the country would be a net importer of both factors! The trick is that this country has a higher share of world income than it would in an integrated equilibrium. We know this by the fact that it has gains from trade although it could replicate (in miniature) the integrated equilibrium. Hence it will be a net importer of both factor services.

exporting factors to less abundant countries and importing factors from more abundant countries. Indeed in 85 percent of the cases we observe, these OECD countries are displaying this trade pattern. Hence we easily reject the notion that factor endowments are unimportant for understanding North-North trade.

More surprising is the importance of factor service trade within the North. In order to measure this, we calculate the following ratio:

$$\frac{\sum_{c' \in G10} \left| F_{fcc'} \right|}{\sum_{c'} \left| F_{fcc'} \right|}$$

where $F_{fcc'}$ is the net factor service exports of factor f from c to c'. Since the numerator is the sum of the absolute value of each country's net bilateral factor service trade in factor f with the nine other Northern countries (note $F_{fcc} = 0$) and the denominator indicates the absolute value of all of its net factor service trade, this ratio tells us what share of net factor service trade is with other Northern countries. The results in Table 4 indicate that, for the median country, between one-third and one-half of all of its factor trade is with other members of our ten-country OECD sample. For six of the ten countries, factor service trade, in volume terms, is actually more important within our set of nine other OECD countries than outside for at least one factor. This result is more surprising when we recall that all trade with the remaining thirteen OECD members not part of our ten countries is treated here as trade with the ROW.

G. *Bilateral Net Factor Trade Country-by-Country*

Thus far we have considered trade flows between any given country and the set of countries that are more or less abundant. Our theory, however, suggests that we should be able to cut the data even more finely. When examining bilateral trade between any two countries, the No-FPE model suggests that the net factor service flows should reflect the relative abundance of the two countries in question. If FPE obtains, then there would be no reason to think that relative abundances would be reflected in bilateral factor trade flows. In Table 3 we examine whether $\mathbf{Sign}\ (F_{fcc'}) = \mathbf{Sign}\ (V_{fc'}/s_c - V_{fc'}/s_{c'})$, where $F_{fcc'}$ is country c's net factor exports to country c'.

As one might expect, there is a slight deterioration in the percentage of sign matches.[12] Overall, we find that bilateral country factor trade is correctly predicted in 71 percent of the cases. This is significantly different from a coin flip at all conventional levels of significance, indicating that one can reject the hypothesis that endowments are not a factor in determining *bilateral* trade flows. This result by itself is perhaps not that surprising because few would argue that endowment differences are not important in explaining North-South trade. A stronger null hypothesis is to ask whether one should think of bilateral North-North trade as devoid of factor content. If bilateral North-North trade is devoid of factor content, then the factor content of bilateral North-North trade should be random. In Table 3 we repeat our experiment on bilateral

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[12] There are several reasons to believe that the results are likely to be weaker as we move to considering bilateral country data. The first is that we are likely to encounter more noise due to bilateral trade barriers, both political and geographic. Secondly, it is not clear how to handle trade surpluses and deficits. Large surpluses and deficits in countries like the Japan and the US that occurred at this time are likely to cause problems with factor content calculations among relatively similar countries. Third, the previous results implicitly weighted the results by the size of the factor content of trade. Small errors in bilateral factor content of trade would be offset as along as on average countries export their abundant factors to less abundant countries. This final specification treats small errors the same as large correct predictions.

factor content of trade by excluding all trade with the ROW. While this result is only significant at the 11 percent level for capital, it is highly significant for labor and for both factors considered jointly, with correct signs in two thirds of the cases overall. The results indicate that endowments help us to understand even bilateral trade in the North.

V. Conclusion

The central paradigm for explaining international trade flows relies on a dichotomy. Trade between North and South is explained by endowment differences. Trade within the North is explained by economies of scale and product differentiation. This paradigm specifically rejects an important role for endowment differences in explaining trade within the North.

We subject this paradigm to empirical scrutiny. We posit that endowments matter for North-North trade if two criteria are met. (1) Net factor service trade is systematically related to endowment differences; and (2) The economic magnitudes of this net factor service trade are large. Our empirical work shows that both criteria are met.

We would like to stress that nothing that we have done excludes the possibility that product-level Ricardian differences or scale economies will be important elements of a complete picture of world trade patterns. Indeed, our priors are that such a complete model will almost certainly draw on each of these elements, although identifying the contribution of each must await formal empirical work that places them in a common framework. Our aim here has been more modest: to show that the paradigm of world trade patterns needs to be broadened to acknowledge that differences in endowments do indeed matter for trade patterns even among countries of the North.

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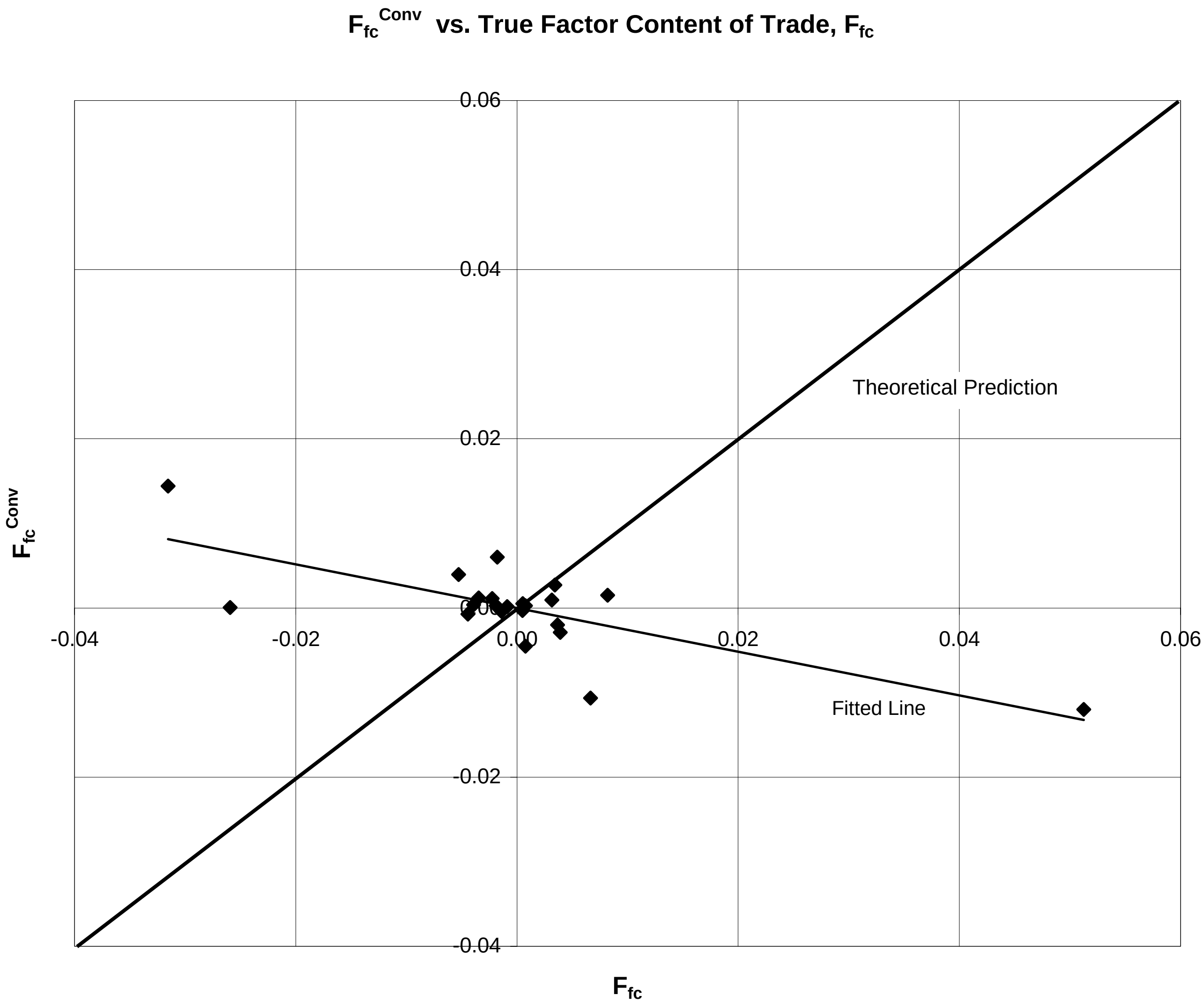
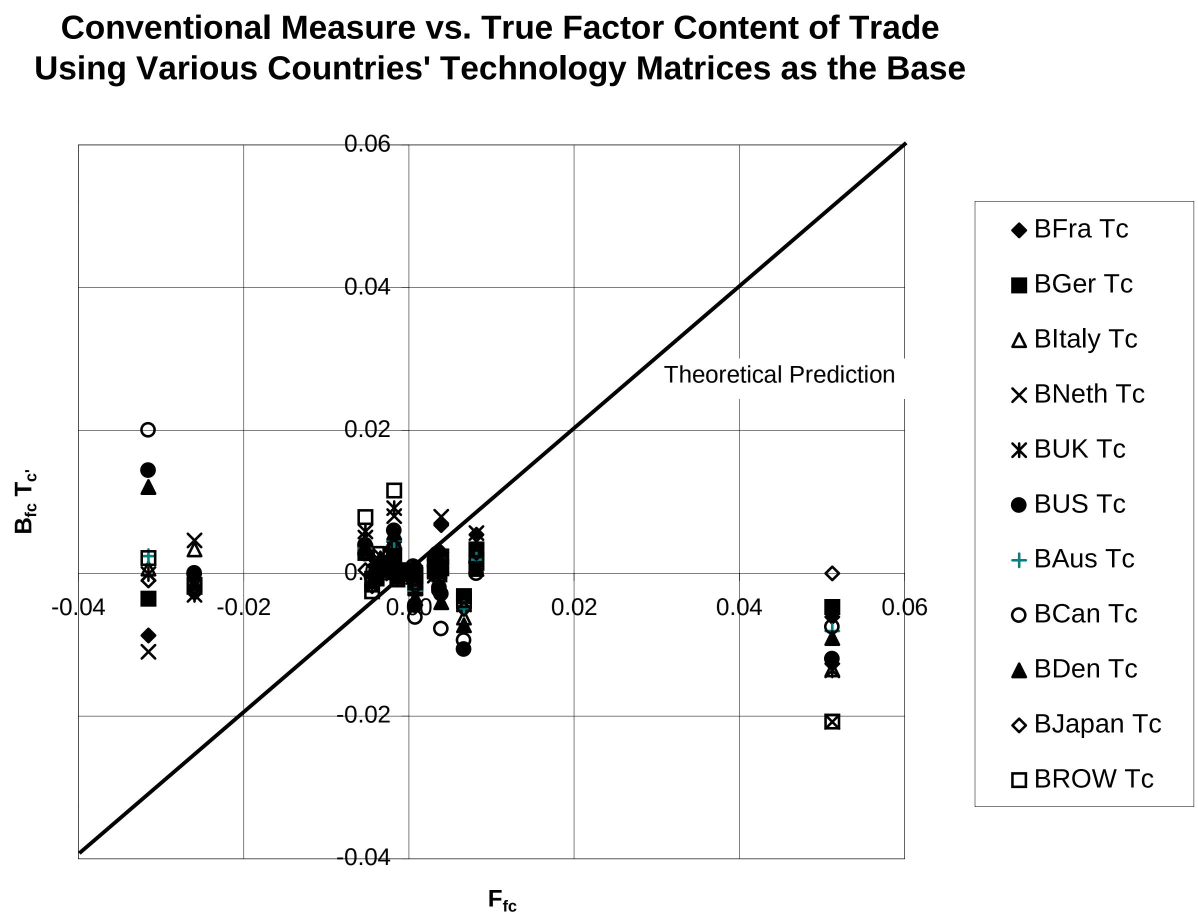
Figure 1



$F_{fc}^{Conv} \equiv \mathbf{B}_{\mathbf{f},\mathbf{US}}\mathbf{T}^{\mathbf{c}}$ is the conventional measure of the factor content of trade.

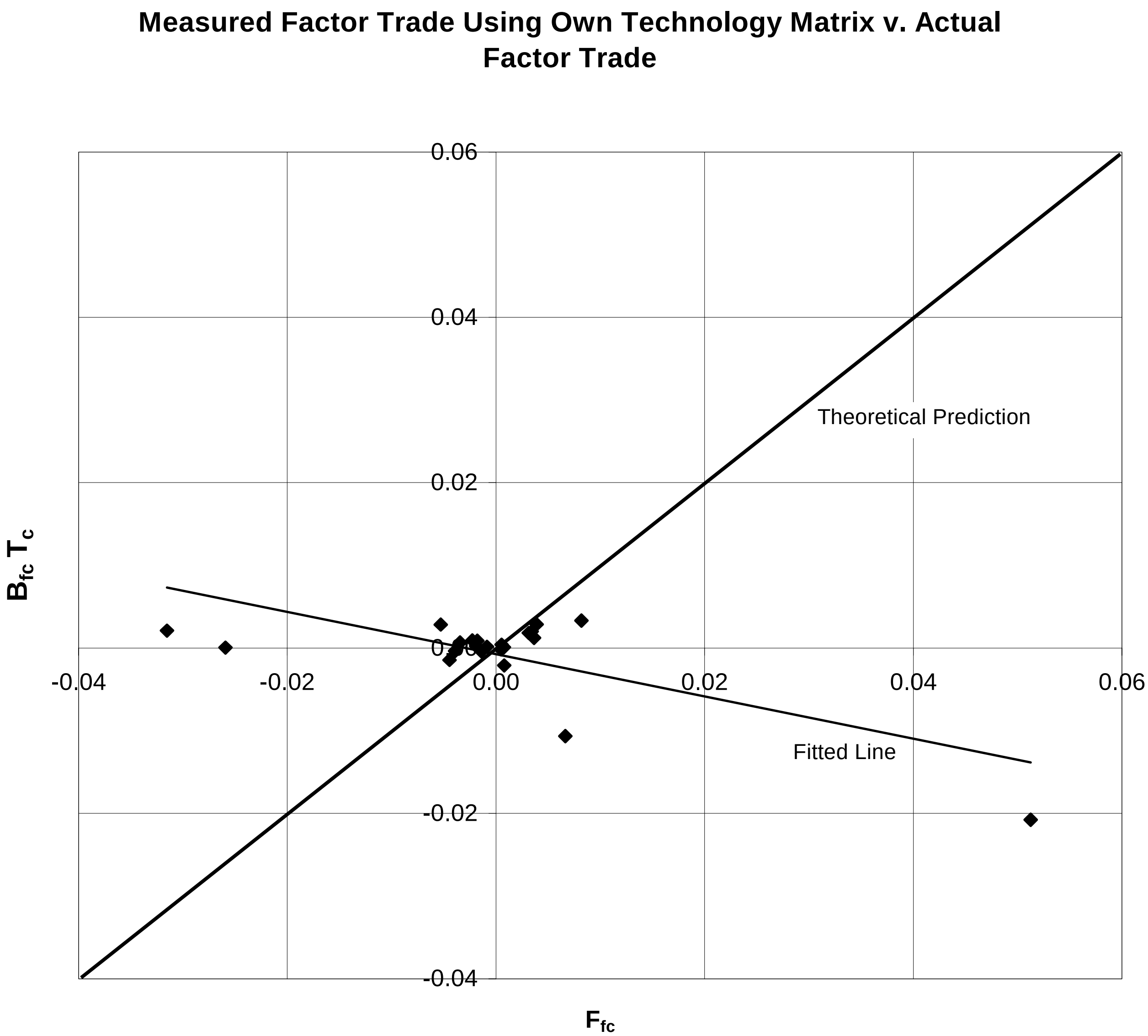
$F_{fc} \equiv \mathbf{B}_{\mathbf{fc}}\mathbf{E}_{\mathbf{c}} - \sum_{c' \neq c} \mathbf{B}_{\mathbf{fc'}}\mathbf{M}_{\mathbf{cc'}}$ is the Deardorff-Helpman measure of the factor content of trade. This figure shows that conventionally measured net factor service trade is negatively correlated with actual net factor service trade.

Figure 2



$\mathbf{B_{fc}T_{c'}}$ is a conventional measure of the factor content of country *c'* 's trade vector evaluated using country *c* 's technology matrix. The difference is that rather than assume everyone uses the US technology matrix, we calculate this respectively assuming all use the technology of France, then Germany, and so on. $F_{fc} \equiv \mathbf{B_{fc}E_c} - \sum_{c' \neq c} \mathbf{B_{fc'}M_{cc'}}$ is the Deardorff-Helpman measure of the actual factor content of trade. This figure shows that the negative correlation between conventionally measured net factor service trade and actual net factor service trade does not depend on the technology matrix used.

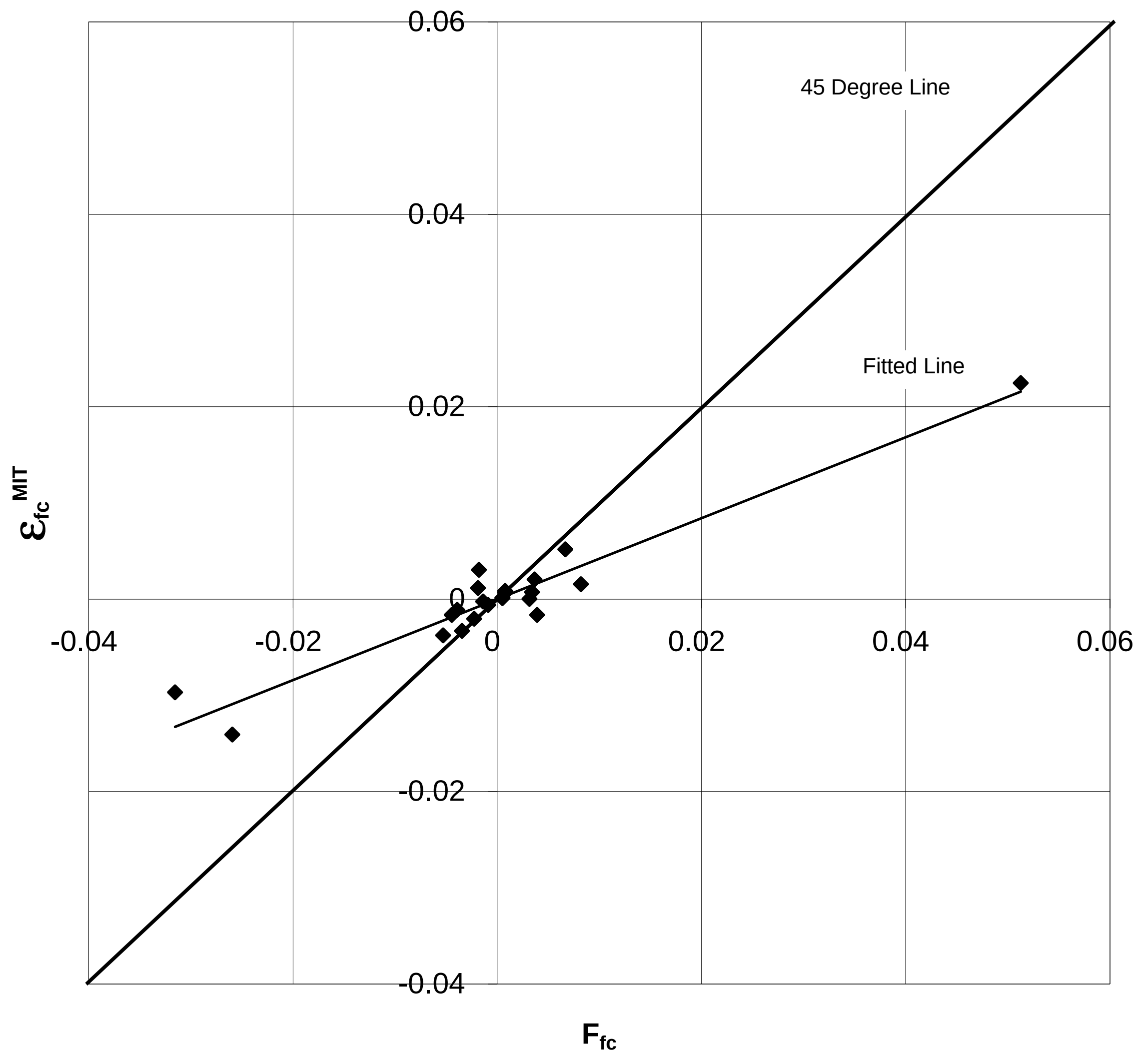
Figure 3



Here we apply each country's technology matrix only to its own net trade vector. That is, $\mathbf{B_{fc}T_c}$ is the factor content of country c 's trade vector evaluated using its own technology matrix. $F_{fc} \equiv \mathbf{B_{fc}E_c} - \sum_{c'\neq c} \mathbf{B_{fc'}M_{cc'}}$ is the Deardorff-Helpman measure of the factor content of trade. This figure shows that even if one applies each country's technology matrix to their own net trade vector, the measured net factor content of trade is still quite small compared with the (Deardorff-Helpman) measure of actual factor service flows.

Figure 4

Factor Content of Intraindustry Trade v. True F_{fc}



$\varepsilon_{fc}^{MIT} \equiv \sum_{c'} [\mathbf{B_{fc}} - \mathbf{B_{fc'}}]\mathbf{G_{cc'}}$ is the factor content of matched intra-industry trade.

$F_{fc} \equiv \mathbf{B_{fc}E_c} - \sum_{c' \neq c} \mathbf{B_{fc'}M_{cc'}}$ is the Deardorff-Helpman measure of the factor content of trade. This figure shows that the factor content of intra-industry trade is quite large as a share of, and highly correlated with, total factor service trade.

Table 1

The Factor Content of Matched Intra-Industry Trade as a Share of Total Factor Content Trade

	$\frac{\varepsilon_{fc}^{MIT}}{F_{fc}}$		
	Capital	Labor	Average
Australia	0.24	0.17	0.21
Canada	0.01	-0.61	-0.30
Denmark	0.23	0.68	0.45
France	0.56	0.96	0.76
Germany	0.19	0.71	0.45
Italy	0.84	0.28	0.56
Japan	-0.42	-1.70	-1.06
Netherlands	0.21	0.90	0.56
UK	1.11	0.36	0.74
USA	0.78	0.54	0.66
ROW	0.31	0.44	0.37
Median	0.24	0.44	0.34

$\varepsilon_{fc}^{\mathrm{MIT}} \equiv \sum_{c'} [\mathbf{B_{fc}} - \mathbf{B_{fc'}}] \mathbf{G_{cc'}}$ is the factor content of matched intra-industry trade.

$F_{fc} \equiv \mathbf{B_{fc}E_c} - \sum_{c' \neq c} \mathbf{B_{fc'}M_{cc'}}$ is the Deardorff-Helpman measure of the factor content of trade. This table shows that the factor content of intra-industry trade is large relative to total the total net factor content of trade for most countries and factors.

Table 2

Net Factor Service Flows as a Share of National Endowments

	Capital	Labor
Median Abs(F_{fc} / V_{fc})	0.077	0.102
Median Abs(F_{fc} / V_{fc}) G10 Only	0.048	0.089
Median Abs(F_{fc} / $V_{fc}^{tradable}$)	0.181	0.357
Median {Abs((F_{fc}^{+} / V_{fc})+Abs (F_{fc}^{-} / V_{fc})}	0.098	0.123

Note: G10 refers to the sample of 10 OECD countries for which we have technology matrices. $F_{fc} \equiv \mathbf{B_{fc}E_c} - \sum_{c' \neq c} \mathbf{B_{fc'}M_{cc'}}$ is the Deardorff-Helpman measure of the factor content of trade. F_{fc}^{+} is net factor trade with more abundant countries; F_{fc}^{-} is net factor trade with less abundant countries; and V_{fc} are endowments of factor *f* in country *c*. This table shows that net factor service flows are quite large relative to national endowments. This is especially true when considering the magnitudes of these flows relative to endowments used in the production of tradables or when correcting for the attenuation bias arising from the fact that countries systematically are net exporters of factor services to less abundant countries and net importers from more abundant countries.

Table 3

Sign Tests for Trade with More and Less Abundant Countries

	Proportion Correct in World		Proportion Correct in G10	
	Capital	Labor	Capital	Labor
Aggregate Data				
Imports Factors from More Abundant Countries	0.700	1.000	0.667	1.000
Exports Factors to Less Abundant Countries	1.000	0.800	1.000	0.700
Total	0.850	0.900	0.842	0.858
p-value	0.001	0.000	0.002	0.002
Bilateral Country Data				
Imports Factors from More Abundant Partners or Exports Factors to Less Abundant Partners	0.673	0.746	0.600	0.689
p-value	0.007	0.000	0.116	0.008
Overall	0.709		0.644	
p-value	0.000		0.000	

Note: G10 refers to the sample of 10 OECD countries for which we have technology matrices. The first panel of this table shows that countries systematically are net exporters of factors to the set of less abundant countries and net importers from the set of more abundant countries. The second panel shows that even bilateral trade reflects endowment differences.

Table 4

Bilateral Net Factor Service Trade among the G10
as a Share of Total Net Factor Service Trade

	Capital	Labor
Australia	0.40	0.62
Canada	0.67	0.37
Denmark	0.69	0.37
France	0.26	0.24
Germany	0.37	0.31
Italy	0.81	0.24
Japan	0.82	0.45
Netherlands	0.50	0.30
UK	0.47	0.40
USA	0.39	0.43
Median	0.48	0.37

G10 refers to the sample of 10 OECD countries for which we have technology matrices. This table shows that net factor service flows within the North constitute a large proportion of the net factor service flows of these countries.

Appendix I: Data Sources and Issues

A. *Data Overview*

This appendix, drawn from Davis and Weinstein (2001), explains how the data set was constructed. An important contribution of Davis and Weinstein (2001) is the development of a rich new data set for testing trade theories. We believe that the data set we develop is superior to that available in prior studies in numerous dimensions. The precise mechanics of the construction of the data set are detailed at the end of this appendix. Here we provide a brief description of the data and a discussion of the practical and conceptual advances.

The basis for our data set is the Organization for Economic Cooperation and Development's Input-Output Database [OECD (1995)]. This database provides input-output tables, gross output, net output, intermediate input usage, domestic absorption and trade data for thirty-four industries in ten OECD countries.[1] Significantly, all of the data are designed to be compatible across countries. We constructed the country endowment data and the matrices of direct factor input requirements using the OECD's International Sectoral Database and the OECD's STAN Database. Hence for all countries, we have data on technology, net output, endowments, absorption, and trade. By construction, these satisfy:

(1) $\boldsymbol{B}^c \boldsymbol{Y}^c \equiv \boldsymbol{V}^c$.

(2) $\boldsymbol{Y}^c - \boldsymbol{D}^c \equiv \boldsymbol{T}^c$

We also have data for 20 other countries that we aggregate and refer to as the "Rest of the World" or ROW.[2] Data on capital is derived from the Summers and Heston Database while that for labor is from the International Labor Organization. For countries that do not report labor force data for 1985 we took a labor force number corresponding to the closest year and assumed that the labor force grew at the same rate as the population. Gross output data are taken from the UN's Industrial Statistics Yearbook, as modified by DWBS (1997). Net output is calculated by multiplying gross output by the GDP weighted average input-output matrix for the OECD and subtracting this from the gross output vector.

Bilateral trade flows for manufacturing between each of our ten OECD countries as well as between each country and the ROW were drawn from Robert C. Feenstra, Robert E. Lipsey, and Harry P. Bowen (1997) and scaled so that bilateral industry import totals match country totals from the IO tables. Country c's bilateral imports from country c' in non-manufacturing sector i is set equal to the share of country c's total manufacturing imports that came from

[1] Australia, Canada, Denmark, France, Germany, Italy, Japan, Netherlands, United Kingdom, and the United States. These are the ten available in the IO database.

[2] Argentina, Austria, Belgium, Finland, India, Indonesia, Ireland, Israel, Korea, Mexico, New Zealand, Norway, Philippines, Portugal, Singapore, South Africa, Spain, Sweden, Thailand, and Turkey. These are the countries for which either gross output or value added is available for all sectors.

country c' times total non-manufacturing imports in sector i.[3] ROW absorption was then set to satisfy condition 2 above.[4] Bilateral distance data comes from Shang-Jin Wei (1996).

In sum, this data set provides us with 10 sets of compatible technology matrices, output vectors, trade vectors, absorption vectors, and endowment vectors. In addition we have a data set for the ROW that is comparable in quality to that used in earlier studies.

B. *Data Issues*

One point that we want to emphasize is the consistency with which the data are handled. In part this corresponds to the fact that we are able to rely to a great extent on data sources constructed by the OECD with the explicit aim to be as consistent as practicable across sources. In addition, the OECD has made great efforts to insure that the mapping between output data and trade categories is sound. Finally, the consistency extends also to conditions we impose on the data which should hold as simple identities, but which have failed to hold in previous studies because of the inconsistencies in disparate data sets. These restrictions include that each country actually uses its own raw technology matrix, reflected in $\boldsymbol{B}^c\boldsymbol{Y}^c \equiv \boldsymbol{V}^c$.[5]

We would also like to note, though, that the desire to bring new data sources to bear on the problem has carried a cost. Specifically, the factors available to us for this study are limited to capital and aggregate labor. We would very much have liked to be able to distinguish skilled and unskilled workers, but unfortunately the number of skilled and unskilled workers *by industry* is not available for most countries.

We would like to note how the reader should think about this factor "aggregate labor," and why we do not believe this presents too great a problem for our study. There are at least a couple of interpretations that can be given. Note that labor is converted to efficiency units. A first fact about our labor variable is that in our specifications the OECD countries are judged scarce in labor while the ROW is abundant in it. This suggests that one appropriate interpretation is that our variable labor is a very rough proxy for unskilled or semi-skilled labor. We have little doubt that if it were possible to distinguish highly-skilled labor separately for our study, the US and some of the other OECD countries would be judged abundant in that factor.

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[3] This is not ideal, but given that the median ratio of imports to gross output in non-manufacturing/non-agriculture for our sample of countries is 1 percent, this is not likely to introduce large errors.

[4] It is reasonable to ask why we aggregated the ROW into one entity rather than working with each country separately. A major strength of this paper is that our data are compatible and of extremely high quality. Unfortunately, the output and endowment data for the ROW countries are extremely noisy (See Robert Summers and Alan W. Heston for a discussion of problems with the endowment data). It is quite difficult to match UN data with OECD IO data because of aggregation issues, varying country industry definitions, and various necessary imputations (see DWBS (1997) for details on what calculations were necessary). As a result, the output and absorption numbers of any individual country in the ROW are measured with far more error than OECD data. To the extent that these errors are unbiased, we mitigate these measurement errors when we aggregate the ROW. In view of all this, we decided that we did not want to pollute a high quality data set with a large number of poorly measured observations.

[5] See the discussion in BLS of related difficulties. The only exception to this is the ROW where we were forced to use an estimated $\boldsymbol{B}$. See section Davis and Weinstein (2001) for details.

These reservations notwithstanding, we believe that there are good reasons to believe that choice of factors does not confer an advantage to us over prior studies. Many of the factors we omit are land or mineral factors, which were the best performers for BLS and Trefler (1995). Hence their omission should only work against us. As we will see below, the factors that we do include exhibit precisely the pathologies (e.g. “mystery of the missing trade” and the Leontief paradox) that have characterized the data in prior studies. Finally, in our study of the net factor trade of Japanese regions, DWBS (1997), we were able both to include more factors and to distinguish between skilled and unskilled workers. The HOV theory performed admirably in these circumstances. These points suggest that, if anything, the unavailability of factor data for our study may make it more difficult to find positive results, not easier.

In sum, we have constructed a rich new data set with compatible data for 10 OECD countries across a wide range of relevant variables. Importantly, we introduce to this literature direct testing on technology and absorption data of the central economic hypotheses in contest. Finally, although in some respects the available data fall short of our ideal, we do not believe that this introduces any bias toward favorable results.

C. Detailed Description of Methodology Employed to Build The Data Set

Data Sources:

For capital and labor:

Data for manufacturing sectors were taken from the 1997 OECD Structural Analysis (STAN) Industrial Database for years 1970-1995.

Data for other sectors were taken from the 1996 International Sectoral Database (ISDB) for years 1960-1995.

For production, demand and trade:

Data were taken from the 1995 OECD Input-Output Database.

Countries:

We used the 10 countries included in the OECD IO Database:

Australia, Canada, Denmark, France, Germany, Italy, Japan, Netherlands, UK, and US

Some countries did not have an IO table for 1985. We chose the closest year to 1985 for which an IO table existed. These countries and their related years are:

Australia (1986), Canada (1986), Germany (1986), Netherlands (1986), UK (1984)

Sectors:

Data for each of the 10 countries is organized into 34 sectors. All sectors were defined as in the IO tables except for sectors 29 and 30 (ISIC 7100 and 7200) which were aggregated due to the inability to disaggregate ISDB data for these two sectors. The individual sectors and their ISIC Revision 2 codes are given below:

IO Sector	ISIC Rev. 2 codes	Description
1	1	Agriculture, forestry, and fishery
2	2	Mining and quarrying
3	31	Food, beverages, and tobacco
4	32	Textiles, apparel, and leather
5	33	Wood products and furniture
6	34	Paper, paper products, and printing
7	351+352-3522	Industrial chemicals
8	3522	Drugs and medicines
9	353+354	Petroleum and coal products
10	355+356	Rubber and plastic products
11	36	Non-metallic mineral products
12	371	Iron and steel
13	372	Non-ferrous metals
14	381	Metal products
15	382-3825	Non-electrical machinery
16	3825	Office and computing machinery
17	383-3832	Electric apparatus, nec
18	3832	Radio, TV, and communication equipment
19	3841	Shipbuilding and repairing
20	3842+3844+3849	Other transport
21	3843	Motor vehicles
22	3845	Aircraft
23	385	Professional goods
24	39	Other manufacturing
25	4	Electricity, gas, and water
26	5	Construction
27	61+62	Wholesale and retail trade
28	63	Restaurants and hotels
29/30	71+72	Transport and storage, and Communication
31	81+82	Finance and insurance
32	83	Real estate and business services
33	9	Community, social, and personal services
34		Producers of government services
35		Other producers

Capital Stock Data:

Capital stock was calculated using the perpetual inventory method. For non-manufacturing sectors, data were taken from ISDB ITD, which contains information on gross fixed capital formation in 1990 PPP prices in US dollars. All values were then converted to 1985 prices. One compatibility problem that arises in these data is that sometimes the value added in a sector in ISDB is different from that the IO tables. To prevent variation in classification to produce variations in factor intensities we scaled up all investment series by the ratio of value added in the IO tables relative to value added in the same sector as reported in the ISDB.

Formally, for each non-manufacturing sector (j), GFCF was calculated as:

$$GFCF_j = ITD_j^{ISDB} * \frac{P^{US,1985}}{P^{US,1990}} * \frac{VA_j^{IO}}{VA_j^{ISDB}}$$

For manufacturing sectors, the ISDB data was at a higher level of aggregation than we liked. Therefore, data were taken from the STAN database. The investment series we used was Gross Fixed Capital Formation (GFCF), in current prices and national currencies. To convert all data to 1985 PPP prices, the STAN data were multiplied by a capital stock price deflator, derived from the ISDB. Where ISDB sectors contained several STAN sectors, we used the same capital stock price information for each sector. Our price deflator consisted of ISDB ITD/IT, where ISDB IT is investment in current prices and national currencies. We then converted these numbers into 1985 dollars. Manufacturing data were also scaled by the ratio of ISDB to STAN GFCF in total manufacturing. This was done so that the size of manufacturing sectors relative to non-manufacturing sectors would be consistent if ISDB or STAN consistently under- or over-report the size of manufacturing sectors. Finally, all sectors were scaled by the sector ratio of IO to STAN or ISDB Value Added (VA). This was done so that sectors would be weighted more heavily if the sector was larger in the IO table than in STAN or ISDB. Ideally, we would have used ISDB data instead of STAN data for this last adjustment but we could not because the matching between the IO tables and the STAN data was much better for manufacturing.

Hence, for each manufacturing sector (I), for each country, and for each year, GFCF was calculated as:

$$GFCF_i = GFCF_i^{STAN} * \frac{ITD_i^{ISDB}}{IT_i^{ISDB}} * \frac{P^{US,1985}}{P^{US,1990}} * \frac{GFCF^{ISDB,TotalManuf.}}{GFCF^{STAN,TotalManuf.}} * \frac{VA_i^{IO}}{VA_i^{STAN}}$$

Note: Japanese ISDB IT data were missing in manufacturing, so a slightly different method was used for each Japanese manufacturing sector (I). An overall capital goods price deflator (CGPD) for each year (from Economic Statistics Annual, Bank of Japan, 1994) was used to first convert all investment levels into 1990 yen prices. We then used the overall capital price deflator from ISDB (ITV/ITD) to convert these prices into 1990 US PPP dollars and then followed our standard procedure.

Japanese capital formation was therefore calculated as follows

$$GFCF_{i,Japan} = GFCF_i^{STAN} * \frac{1}{CGPD} * \frac{ITD^{ISDB}}{ITV^{ISDB}} * \frac{P^{US,1985}}{P^{US,1990}} * \frac{GFCF^{ISDB,TotalManuf.}}{GFCF^{STAN,TotalManuf.}} * \frac{VA_i^{IO}}{VA_i^{STAN}}$$

After the gross fixed capital formation was calculated for each year and each sector, a permanent inventory method was used to determine capital stocks. Capital formation for each year from 1975 to

1985, inclusive, was used with a depreciation rate of 0.133. Capital formation from 1976-1986 (1974-1984), was used for those countries which have IO tables for 1986 (1984). These capital totals were also converted to 1985 US dollars.

Labor Data:

For manufacturing sectors, data were taken from STAN Number Engaged (NE). For non-manufacturing sectors, the ISDB Total Employment (ET) was used. These labor data include self-employed, owner proprietors, and unpaid family workers. Labor data were taken from the same year as the IO table (1984, 1985, or 1986). Some scaling was also performed on the labor data. All sectors were scaled by the ratio of IO to STAN value added. In addition, manufacturing sectors were scaled by the ratio of ISDB to STAN total manufacturing employment.

For each manufacturing sector (I), in each country, for the year 1984, 1985, or 1986, labor was calculated as:

$$L_i = NE_i^{STAN} * \frac{ET^{ISDB,TotalManuf}}{NE^{STAN,TotalManuf}} * \frac{VA_i^{IO}}{VA_i^{STAN}}$$

For each non-manufacturing sector (j), labor was calculated as:

$$L_j = ET_j^{ISDB} * \frac{VA_j^{IO}}{VA_j^{ISDB}}$$

Production Data:

Data were taken from Gross Output column of the OECD Input-Output table and converted to 1985 US$.

Data Problems

Not all data were available in each database or consistent between databases. The following sectors have data problems of one sort or another. (Superscripts refer to the type of problem, discussed below.)

Australia	(3-15[1], 16[7,8], 17[1], 18[8], 19[1], 20[5,6,8], 21[8], 22[6], 23[1], 25[4], 28[1], 33[8], 35[1,5,8])
Canada	(20[5,6], 23[1], 24[2,4], 35[1,5])
Denmark	(14[1], 15[8], 16[8], 17[1], 18[1], 19[7], 20[2,5,8], 21[2,4,8], 22[5,6,8], 23[1], 28[1], 32[2], 33[2], 35[1,8])
France	(5[1,2], 10[2], 20[2,4], 23[2], 24[2], 32[2], 33[2], 34[2,4], 35[3,4])
Germany	(7[8], 8[8], 17[8], 18[8], 20[8], 32[2,4], 33[2,4])
Italy	(2[2,4], 5[1,6], 7[2], 8[2], 32[5], 33[2,3,4,8], 34[8], 35[8])
Japan	(5[1], 9[8], 20[7,8], 22[7], 24[8], 28[2,4], 29/30[2,4], 31[2,4], 32[2,5], 33[2,4], 35[1,8])
Netherlands	(12[8], 13[8], 14[1], 15[1], 16[1], 17[8], 18[8], 19[2,4], 20[2,4], 21[1], 22[1], 23[1], 31[2], 33[2], 35[2])
UK	(5[2], 14[2], 23[2], 27[3,5], 28[3,5], 31[3,5], 32[3,5], 35[1,5])
US	(20[2,4], 21[2,4], 27[2,4], 28[2,4], 35[1,3,5])

1. The following sectors have missing ISDB GFCF data or GFCF price data (IT and/or ITD files):

Australia (3-15, 17, 19, 23, 28, 35), Canada (23, 35), Denmark (14, 17, 18, 23, 28, 35), Italy (5), Japan (5, 35), Netherlands (14-16, 21-23), UK (35), US (35).

2. The following sectors have ISDB or STAN capital data which include or exclude sectors that differ from the IO tables:

Canada (24), Denmark (20, 21, 32, 33), France (5, 10, 20, 23, 24, 32, 33, 34), Germany (32, 33), Italy (2, 7, 8, 33), Japan (28-33), Netherlands (19, 20, 31, 33, 35), UK (5, 14, 23), US (20, 21, 27, 28).

3. The following sectors have missing ISDB Value Added (VA) data:

France (35), Italy (32), UK (27, 28, 31, 32), US (35).

4. The following sectors have ISDB or STAN employment data which include different sectors than the IO tables:

Australia (25), Canada (24), Denmark (21), France (20, 34, 35), Germany (32, 33), Italy (2, 33), Japan (28-31,33), Netherlands (19, 20), US (20, 21, 27, 28).

5. The following sectors have missing ISDB or STAN employment values:

Australia (20, 35), Canada (20, 35), Denmark (20, 22), Italy (32), Japan (32), UK (27, 28, 31, 32, 35), US (35).

6. The following sectors have completely missing ISDB or STAN GFCF values:

Australia (20, 22), Canada (20), Denmark (22), Italy (5)

7. The following sectors have ISDB or STAN GFCF values that are missing for some years:

Australia (16), Denmark (19), Japan (20, 22).

8. The following have unusual sectors included or excluded from the IO VA values:

Australia (16, 18, 20, 21, 33, 35), Denmark (15, 16, 20, 21, 22, 35), Germany (7, 8, 17, 18, 20), Italy (33, 34, 35), Japan (9, 20, 24, 35). Netherlands (12, 13, 17, 18).

These omissions and inconsistencies were dealt with in the following ways:

1. The following sectors had missing GFCF price deflators (ITD/IT), for which the average manufacturing price deflator for the particular country was used.
   Netherlands (14-16, 21-23), Australia (3-15, 17, 19, 23), Canada (23), Denmark (14, 17, 18, 23)

2. Otherwise, see the description below for corrections of other missing data.

Construction of missing data for production, capital, and labor:

In all but a few cases, missing data were replaced by a two-step process. First, we calculated average input coefficients for countries which had output data for the sector. Second, this average was weighted by the size of gross output in the country with the missing sector.

1. For a country (r) with a missing sector (i) in the three non-manufacturing sectors 33-35 (SOC, PGS, and OPR), the production data was calculated as follows:

$$\tilde{X}_i^r = \frac{\sum_c X_i^c}{\sum_c X^{c,\,total}} * X^{r,\,total}$$

   This was done in: Australia (33, 35), Italy (33, 34)

2. To calculate missing or aggregated production data for manufacturing sectors, where STAN data were available, the following formula was used:

$$\tilde{X}_i^r = \left(X_i^r\right)^{Stan} * \frac{\left(X^{r,\,total\ \ manuf}\right)^{IO}}{\left(X^{r,\,total\ \ manuf}\right)^{Stan}}$$

   This was done in: Australia (16, 18, 21), Denmark (15, 16), Germany (7, 8, 17, 18, 20), Netherlands (12, 13, 17, 18)

3. Occasionally, IO, STAN, and ISDB production data were all problematic. In this case, the value of production in these sectors was taken directly from the IO tables without correction. Denmark's sectors 21 and 22 were included in sector 20, and the IO values of zero were used for 21 and 22.

   This was done in: Australia (20), Denmark (20, 21, 22)

4. Some countries had data for OPR recorded as zeros, but this was believed to be the correct value.

These sectors were: Denmark (35), France (35), UK (35)

For all other sectors we set $\tilde{X}_i^c = X_i^c$.

5. For a country (r) with a missing sector (i), the capital stock in sector i was calculated by first finding the average input coefficient in other countries. This average was then multiplied by the total output of the country in the missing sector.

$$\tilde{K}_i^r = \frac{\sum_{c\neq r} K_i^c}{\sum_{c\neq r} \tilde{X}_i^c} * \tilde{X}_i^r$$

   This was done in: Australia (22, 28, 33, 35), Canada (20, 24, 35), Denmark (19, 28, 32, 33), France (5, 10, 20, 23, 24, 32, 33, 34), Germany (32, 33), Italy (2, 5, 7, 8, 32, 33, 34, 35) , Japan (5, 9, 20, 22, 24, 28-33, 35), Netherlands (19, 20, 31, 33, 35), UK (5,14,23, 27, 28, 31, 32), US (20, 21, 27, 28, 35)

6. Sectors with missing labor data were calculated in an identical way.

$$\tilde{L}_i^r = \frac{\sum_{c\neq r} L_i^c}{\sum_{c\neq r} \tilde{X}_i^c} * \tilde{X}_i^r$$

   This was done in: Australia (25, 33, 35), Canada (20, 24, 35), France (20, 34), Germany (32, 33), Italy (2, 32, 33, 34) , Japan (9, 20, 24, 28-33, 35), Netherlands (19, 20), UK (27, 28, 31, 32), US (20, 21, 27, 28, 35)

7. For sectors where production is zero, capital and labor are set equal to zero; K/X & L/X were set to average of other countries' values.

   This was done in: Denmark (21, 22, 35), France(35), UK(35)

8. After recalculating the data by the steps above, the total capital and labor for each country no longer summed to the total value given ISDB TET. Thus capital and labor for each sector were scaled as follows:

$$\tilde{\tilde{K}}_i^r = \frac{\tilde{K}_i^r}{\sum_i \tilde{K}_i^r} K^{r,\text{ISDB TET}}$$

$$\tilde{\tilde{L}}_i^r = \frac{\tilde{L}_i^r}{\sum_i \tilde{L}_i^r} L^{r,\text{ISDB TET}}$$

Production values were not rescaled. These were the final values (of capital, labor and production) used in this paper. Once we had these variables, we then constructed the matrix of direct factor input requirements by dividing the amount of a given factor employed in a sector by gross output in that sector.

Construction of the matrix of intermediate input usage, demand, and trade data:

1. The matrix of intermediate input usage, (henceforth the A matrix) was constructed by first taking input-output data from the IO tables and then dividing the input used in each sector by the corresponding sector's gross output. Any problematic elements of the A matrix were replaced by the average value of other countries whose corresponding elements have no problem. That is,

$$\tilde{a}_{ij}^{R} = (a_{ij}^{R})^{avg}$$

2. Since both the A matrix and production were constructed independently for problematic sectors, $\tilde{A}^R\tilde{X}$ did not correspond to the values for total use $A^R X_{IO}$ given in the IO table, where A^R is the Rth row of the A matrix. Therefore, the A matrix was further scaled by the following method:

Let $A^R X_{IOPL} = \begin{cases} A^R X_{IO} & \text{if X in this sector was not constructed.} \\ \tilde{A}^R \tilde{X} & \text{otherwise.} \end{cases}$

Let AX_{IOPL} be the matrix whose rows are composed of $A^R X_{IOPL}$

Find λ such that

$$\begin{pmatrix} \lambda_1 & & & 0 \\ & \lambda_2 & & \\ & & \ddots & \\ 0 & & & \lambda_n \end{pmatrix} \tilde{A}\tilde{X} = AX_{IOPL}$$

Then $\tilde{\tilde{A}} = \lambda\tilde{A}$ was used as the final A matrix. We then postmultiplied our matrix of direct factor input requirements by $(I - \tilde{\tilde{A}})^{-1}$ to obtain the matrix of direct and indirect factor input requirements

3. Demand data were taken from the IO table as the sum of Private Domestic Consumption, Government Consumption, GFCF and Changes in Stocks.

   For problematic sectors of SOC, PGS or OPR, the demand data were constructed as:

   $$\tilde{D} = (I - \tilde{\tilde{A}})\tilde{X}$$

   This was done in Australia (33,35), Italy (33,34) because we believed there to be very little trade in these sectors.

   For sectors where export data were missing from the IO table due to aggregation problems but present in STAN, the demand data were constructed as:

   $$\tilde{D} = (I - \tilde{\tilde{A}})\tilde{X} - (\tilde{E} - \tilde{M}) ,$$

   where

   $$\tilde{E}_i^R = \frac{\left(E_i^R\right)^{Stan}}{\left(E^{M. total\ manuf}\right)^{Stan}} * \left(E^{M, total\ manuf}\right)^{IO}$$

   $$\tilde{M}_i^R = \frac{(M_i^R)^{Stan}}{(M^{M, total\ manuf})^{Stan}} * (M^{M, total\ manuf})^{IO}$$

   This was done in Australia (16, 18, 21), Denmark (16, 17), Germany (7, 8, 17, 18, 20), Netherlands (13, 14, 17, 18).

4. Trade data were then constructed in the following way:

   $$\tilde{T} = (I - \tilde{\tilde{A}})\tilde{X} - \tilde{D}$$

Data Sources

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