THE VOLUME OF TRADE IN DIFFERENTIATED INTERMEDIATE GOODS: THEORY AND EVIDENCE

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Abstract—The paper develops a model of trade in differentiated intermediate goods, and shows how the structure of the importing country's production will influence gross bilateral import volumes. A regression equation directly implied by the model is estimated using disaggregated bilateral trade data for the OECD countries in 1985. The data reject the model. A more general model suggested by the theory establishes strong links between a country's factor endowments and its gross trade volume. This model is dominated statistically by a fixed effects model, and does not substantially alter the conclusions of earlier empirical studies about openness to trade in manufactured goods.

Introduction

It is widely accepted among international trade observers that there is more trade in manufactured goods among the developed economies than can be explained by differences in factor endowments. A popular model that has been developed to explain this large volume of trade while leaving undisturbed the factor proportions explanation of net trade is the monopolistic competition trade model, summarized in Helpman and Krugman (1985). In its simplest form, the monopolistic competition model with consumption demand for differentiated final goods gives a very simple prediction for gross imports: imports in an industry are proportional to the exporter's total industry output, where the factor of proportionality is the importer's share in world spending. This can be expressed as

\[ m_{ijk} = s_j y_{ik} \] (1)

where

- \( m_{ijk} \) = imports of product \( i \) by country \( j \) from exporting country \( k \),
- \( s_j \) = country \( j \)'s share of total world expenditure, and
- \( y_{ik} \) = country \( k \)'s output of industry \( i \).

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Variants of this model have been used by many researchers to study the volume of trade, including Helpman (1987), Lawrence (1987), Saxonhouse (1989), Saxonhouse and Stern (1989), and Harrigan (1993).

An important implication of the model is that gross import volumes do not depend on the importing country's relative factor endowments, although net industry trade balances are influenced by factor endowments. This conclusion comes from the fact that demand for differentiated manufactured goods comes from variety-loving consumers. However, much of trade in manufacturers seems to be intermediate goods, which are transformed into final consumption by the production sector in the importing country. If the demand for imports of manufactured goods comes from the demand by domestic final goods producers for differentiated intermediates, then the volume of gross imports will depend on the industrial structure of the importing country, and equation (1) will not be an adequate model of the volume of trade. A model of demand for differentiated intermediate goods by final goods producers was developed by Ethier (1979, 1982) and studied further by Helpman and Krugman (1985, chapter 11). This paper develops the model further, and derives testable empirical implications for disaggregated trade flows in the form of linear regression equations linking gross bilateral imports by industry with the structure of production of the importing country. Using disaggregated data on trade and production within the OECD in 1985, I conclude that the model is not consistent with the data. A more general but less rigorously derived empirical model demonstrates that gross imports depend systematically on the importing country's factor endowments, which suggests that the importer's structure of production does influence the volume of trade.

I. A Model of Trade in Differentiated Intermediate Goods

The model of this section is a multidimensional generalization of Helpman and Krugman's (1985)
chapter 11 model. I will follow the procedure of describing an integrated world economy, and then investigate conditions in which the integrated equilibrium can be reproduced through free trade in goods between countries with immobile factors.

Final goods manufacturers produce subject to constant returns in inputs of primary factors and an index of intermediate goods. For a fixed physical quantity of intermediates, the value of the index increases with greater variety. For a fixed number of varieties, the index is homogeneous of degree one in the physical quantity of intermediates. Final goods industry $i$’s production function is given by

$$x_i = f_i(v_i, \Phi_i(z_{1i}), \Phi_{2i}(z_{2i}), \ldots, \Phi_{Mi}(z_{Mi}))$$

$$= f_i(v_i, \Phi_i)$$

where

$$x_i = \text{output of final goods industry } i, \ i = 1, \ldots, N$$

$$v_i = (u_{i1}, u_{i2}, \ldots, u_{iL})$$

$$z_{kiw} = \text{input of variety } o \text{ of intermediate good } k \text{ in final goods industry } i$$

$$z_{ki} = (z_{ki1}, z_{ki2}, \ldots)$$

$$\Phi_i = [\Phi_{i1}(z_{1i}), \Phi_{2i}(z_{2i}), \ldots, \Phi_{Mi}(z_{Mi})].$$

The aggregator $\Phi_k(\cdot)$ of different varieties of intermediate goods of type $k$ used in industry $i$ is given by the familiar CES form adapted by Ethier (1982):

$$\Phi_k(z_{ki}) = \left[ \sum_{o \in \Omega_k} (z_{kiw})^{\beta_{ki}} \right]^{1/\beta_{ki}}$$

where $\beta_{ki} = 1 - 1/\sigma_{ki}$ and $\Omega_k$ is the set of available varieties of type $k$ intermediate goods.

Intermediate goods producers incur a fixed cost for each variety produced, which induces returns to scale in the production of a single variety. Because of the structure of demand for intermediates, no firm will ever produce a variety produced by another firm, nor will any firm choose to produce more than one variety. Intermediate goods producers use primary factors and differentiated intermediates in production. By symmetry, each firm will be in equilibrium have the same scale and use the same level of inputs. Consequently, we can write a representative firm’s production function as

$$z_k = g_k[v_k, \Phi_k]$$

(3)

where $v_k$ and $\Phi_k$ are defined analogously to the definitions of $v_i$ and $\Phi_i$. Total output of industry $k$, $Z_k$, is just the number of firms in the industry, $n_k$, times the output of the representative firm:

$$Z_k = n_k z_k.$$ 

(4)

Free entry determines the number of firms in each intermediate goods industry. This is assumed to be a number which is “large,” so that monopolistic competition is a plausible market structure. Under monopolistic competition, each firm in an industry $k$ ignores the effect of its actions on other firms and faces a perceived fixed elasticity of demand by its customers in industry $i$ which is approximately equal to $-\sigma_{ki}$. With price discrimination, firms in different industries $i$ would be charged different prices which would depend in the usual way on their elasticity of demand $-\sigma_{ki}$. For generality, we can suppose in addition that the representative final goods consumer has a sub-utility function isomorphic to $\Phi(\cdot)$ which will generate a constant elasticity demand for differentiated products. I will assume that price discrimination is not feasible, so that consumers and all industries pay the same price $r_{kw}$ for variety $o$ of intermediate goods $k$.1

Since each intermediates producer in industry $k$ faces the same demand and cost conditions, each firm will charge the same price, $r_k = r_{kw}, o \in \Omega_k$. This price will be a markup $\mu_k > 1$ over marginal cost. Since the demand facing a firm is no longer a constant elasticity function, the optimal markup will not be a constant as it is in, for example, Helpman and Krugman (1985).

The production functions above give rise to the following unit cost functions for final goods producers:

$$c_i = c_i(w, r_1n_1^{-1/\sigma_{1i}}, r_2n_2^{-1/\sigma_{2i}}, \ldots, r_mn_m^{-1/\sigma_{Mi}})$$

which we can rewrite more compactly as

$$c_i = c_i(w, r, n)$$

(5)

1This simplification is not crucial. Relaxing it would increase the number of equations and unknowns in the model without altering any of the substantive conclusions.
where \( r = (r_1, r_2, \ldots, r_M) \), \( w = (w_1, \ldots, w_L) \) and \( n = (n_1, \ldots, n_M) \). The form of the cost function implies that the effective or productivity adjusted price of differentiated intermediates purchased from industry \( k \) decreases with \( n_k \).

For intermediate goods producers, the average cost function is decreasing in the scale of production. Making the substitution \( z_{k0} = z_k \) which will be true in equilibrium by symmetry, we have the representative firm’s unit cost function

\[
c_k = c_k(w, r, n, z_k).
\]

(6)

Denoting marginal cost as \( c'_k \), we can write the profit maximization conditions for the representative firm in each intermediate goods industry as

\[
r_k = \mu_k \cdot c'_k(w, r, n, z_k), \quad k = 1, \ldots, M.
\]

(7)

Consumption demand, for both homogeneous final goods and (possibly) differentiated goods, comes from a representative individual with homothetic preferences. The assumption of homotheticity implies that expenditure shares \( \alpha_i \) on the different goods depend only on relative final goods prices and the degree of variety available and not on income. The constraint that total expenditure equals total income can be written as

\[
\sum_{i=1}^{N+M} \alpha_i(p, r, n) = 1.
\]

By Shepard’s lemma, we can get the demand for primary factors and intermediates by differentiation of the cost functions:

\[
a_{hl}(w, r, n) = \frac{\partial c_l(w, r, n)}{\partial w_l},
\]

\[
a_{ml}(w, r, n) = \frac{\partial c_l(w, r, n)}{\partial r_m},
\]

\[
a_{lk}(w, r, n, z_k) = \frac{\partial c_k(w, r, n, z_k)}{\partial w_l},
\]

\[
a_{mk}(w, r, n, z_k) = \frac{\partial c_k(w, r, n, z_k)}{\partial r_m}.
\]

The market clearing conditions for primary factors, intermediate goods, and final goods, respectively, are

\[
\sum_{i=1}^{N} a_{il} x_i + \sum_{k=1}^{M} a_{lk} z_k = v_l, \quad l = 1, \ldots, L
\]

(8)

\[
\alpha_m \cdot (w'v) + \sum_{i=1}^{N} a_{mi} x_i + \sum_{k=1}^{M} a_{mk} z_k = Z_m,
\]

\[
m = 1, \ldots, M
\]

(9)

\[
\alpha_i \cdot (w'v) = x_i, \quad i = 1, \ldots, N
\]

(10)

where \( v = (v_1, \ldots, v_L) \) is the vector of fixed factor supplies. Equations (9) and (10) make use of the fact that total income = \( w'v \), which follows since profits are zero in equilibrium.

The zero profit conditions for final goods and intermediate goods producers are given by

\[
p_i = c_i(w, r, n), \quad i = 1, \ldots, N
\]

(11)

\[
r_k = c_k(w, r, n, z_k), \quad k = 1, \ldots, M.
\]

(12)

The equations (4), (7), and (8)–(12) amount to \( 4M + 2N + L \) equations in the \( 4M + 2N + L \) unknowns \( p, r, w, n, z, Z, x \), where \( z, Z \), and \( x \) are the vectors of per-firm outputs in the intermediate goods industries and the industry outputs in all industries. The equilibrium of this system is referred to as the integrated equilibrium.

Factor price equalization occurs when it is possible to reproduce the integrated equilibrium through free trade in final and intermediate goods. This requires that there be at least as many goods as factors, and that each country can fully employ its fixed factor supplies using the input coefficients from the integrated equilibrium. The integrated equilibrium production techniques will define a region in factor supply space where such a condition can be met. For further analysis of factor price equalization in such models, see Helpman and Krugman (1985).

In what follows, I will assume that there is factor price equalization.

Now let superscripts denote countries. Then, from equation (9), country \( c \)'s usage of intermediate good \( m \) is given by

\[
\alpha_m \cdot (w'v^c) + \sum_{i=1}^{N} a_{mi} x_i^c + \sum_{k=1}^{M} a_{mk} z_k^c = Z_m^c,
\]

\[
m = 1, \ldots, M
\]

(13)
where \( Z^c \) is country \( c \)'s output of intermediate goods and \( \bar{Z}^c \) is country \( c \)'s usage of intermediate goods. Summing this equation over all countries in the world reproduces equation (9).

Now suppose that country \( d \) produces the proportion \( \gamma^d_m \) of the world's total output of \( Z_m \); that is,

\[
\gamma^d_m = \frac{Z^d_m}{\sum_{c=1}^{N} Z^c_m} = \frac{Z^d_m}{Z_m}.
\]

Because of the demand for variety, country \( c \) will consume differentiated intermediate goods from country \( d \) in proportion to country \( d \)'s output of them. We can therefore write country \( c \)'s consumption of country \( d \)'s output of intermediate good \( m \) as simply

\[
\gamma^d_m \cdot \bar{Z}_c^d = \frac{Z^d_m}{Z_m} \cdot \bar{Z}_c^d.
\]

The term on the left hand side is simply imports in industry \( m \) by country \( c \) from country \( d \). Dividing both sides by country \( d \)'s output in industry \( m \) and substituting in for country \( c \)'s usage of intermediate goods from (13) gives

\[
\frac{M_{cdm}}{\text{GNP}^c} = \beta_{0m} + \sum_{i=1}^{N+M} \beta_{im} \frac{Y^c_i}{\text{GNP}^c} \tag{14}
\]

where

\[
M_{cdm} = \text{imports of good } m \text{ by country } c \text{ from country } d, \text{ as a proportion of country } d \text{'s output of good } m.
\]

\[
\text{GNP}^c = \text{country } c \text{'s GNP} = w^c v^c.
\]

\[
Y^c_i = \text{country } c \text{'s output of intermediate or final goods industry } i.
\]

Equation (14) is a linear relationship between observables, and the parameters are constant across countries (this is where factor price equalization comes in). As a result, given suitable data and statistical assumptions, (14) can be estimated by a cross-country regression of scaled bilateral gross import volumes on GNP and industry outputs. The constant term arises from demand for differentiated final goods in consumption, while the terms inside the summation sign arise from the demand for differentiated intermediate goods.

**II. The Econometric Model**

Equation (14) was estimated for 9 different industries corresponding to the 2-digit International Standard Industrial Classification (ISIC),\(^2\) for a sample of 21 OECD countries in 1985. With each of the 21 countries having 20 trading partners in the sample, each equation is estimated with a maximum of \(21 \cdot 20 = 420\) observations. Production and bilateral import data come from the OECD's COMTAP dataset (see Blades and Simpson (1985) for a description of the dataset). Macroeconomic data (GDP, current account, and exchange rates) come from the IMF's International Financial Statistics. To control for the large current account imbalances of the countries in the sample, absorption (defined as GDP minus the current account surplus) is used as a measure of aggregate expenditure in place of GDP. As documented by Blades and Simpson, the production data are measured with substantial error, which makes least squares an inconsistent estimation technique. Trade theory suggests that factor endowments are theoretically appropriate instrumental variables in such a case, since they can be treated as exogenous and since they will be correlated with output, and that is the approach used here.\(^3\) The factor endowments used are aggregate capital, land, and two types of labor, each scaled by absorption. The relevant features of the data are summarized in table 1, and regression results are reported in table 2.

The theory underlying equation (14) requires that the parameters \( \beta_{im} \) are non-negative, since they are input coefficients. As table 2 makes clear, the estimated parameters of (14) do not satisfy these theoretical restrictions: many of the point estimates are negative, while only 4 coefficients out of 81 are reliably positive. This conclusion can not be overturned by experimentation with different statistical models, sometimes called "data mining." This leads inevitably to the conclusion that the model is a poor description of reality. Accounting for the industrial structure of the importing country in the manner indicated by

\(^2\) The only exception is that Products of Petroleum Refineries (ISIC 353) was excluded from the Chemicals category, ISIC 35.

\(^3\) See Harrigan (1993) for a further discussion of the use of factor endowments as instruments for production.
the theoretical model does not improve the ability to predict gross bilateral imports.

Equation (14) embodies a number of special and counterfactual assumptions, including factor price equalization and complete symmetry in the demand for differentiated products. If these assumptions are violated, then (14) will not have constant coefficients across importing countries, and the estimated parameters of (14) need not satisfy non-negativity even if (14) holds for each importer individually.\footnote{This is because a matrix weighted average of two non-negative vectors need not be non-negative; cf. Leamer (1978).} Similar comments apply if
the ISIC categories used as empirical counterparts to industries aggregate sectors with different input mixes. Disaggregation into 3-digit ISIC categories, however, does not change the result that the estimated coefficients of (14) are often negative.

Despite the failure of (14), it does not seem warranted to conclude that a country's industrial structure does not influence its gross imports. It is well known that under certain assumptions, cross-country differences in industry outputs are a constant linear function of cross-country differences in factor endowments. These assumptions include equal numbers of goods and factors, as well as the assumptions necessary for factor price equalization. Under these assumptions, for each industry $i$ it is the case that

$$Y^*_i = \sum_{l=1}^{L} r_{il} v_{cl}$$

(15)

where $v_{cl}$ is country $c$'s endowment of factor $l$ and the $r_{il}$ are Rybczinski coefficients which can be positive or negative. Substituting (15) into (14) gives

$$\frac{M_{cdm}}{GNP_c} = \alpha_{0m} + \sum_{l=1}^{L} \alpha_{lm} \frac{v_{cl}}{GNP_c}.$$  

(16)

If the assumptions underlying (15) hold, then the parameters of (16) have the precise interpretation of linear combinations of the Rybczinski derivatives:

$$\alpha_{lm} = \sum_{i=1}^{N+M} r_{il} \beta_{im}.$$  

In this case, a positive estimated $\alpha$ on (say) capital can be interpreted as follows: capital accumulation increases the volume of trade in an industry by shifting the economy's production pattern in such a way that greater demand is generated for the differentiated goods of that industry. Although the assumptions required for equation (15) are no less problematic than the assumptions that underlie equation (14), they do suggest that bilateral gross imports might be influenced by the importing country's factor endowments, possibly in a non-linear fashion in the absence of evenness and factor price equalization. In this case, equation (16) can be interpreted as a more general relationship between scaled bilateral imports and the importer's factor endowments, keeping in mind that the simple monopolistic competition model of equation (1) says that the importer's factor endowments should play no role.

<table>
<thead>
<tr>
<th>RHS Variables: Dom. Output of ...</th>
<th>Dependent Variable: Scaled Bilateral Imports of ...</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Food</strong></td>
<td><strong>Apparel</strong></td>
</tr>
<tr>
<td>Coeff</td>
<td>-0.08</td>
</tr>
<tr>
<td>$t$</td>
<td>-0.02</td>
</tr>
<tr>
<td>$t$</td>
<td>-0.11</td>
</tr>
<tr>
<td>Wood Coeff</td>
<td>-3.14</td>
</tr>
<tr>
<td>$t$</td>
<td>-0.57</td>
</tr>
<tr>
<td>Paper Coeff</td>
<td>0.59</td>
</tr>
<tr>
<td>$t$</td>
<td>0.21</td>
</tr>
<tr>
<td>Chemicals Coeff</td>
<td>10.40</td>
</tr>
<tr>
<td>$t$</td>
<td>2.62</td>
</tr>
<tr>
<td>Glass Coeff</td>
<td>4.16</td>
</tr>
<tr>
<td>$t$</td>
<td>0.21</td>
</tr>
<tr>
<td>Metals Coeff</td>
<td>-9.03</td>
</tr>
<tr>
<td>$t$</td>
<td>-1.01</td>
</tr>
<tr>
<td>Machinery Coeff</td>
<td>-1.27</td>
</tr>
<tr>
<td>$t$</td>
<td>-0.57</td>
</tr>
<tr>
<td>Other Coeff</td>
<td>-38.2</td>
</tr>
<tr>
<td>$t$</td>
<td>-0.88</td>
</tr>
<tr>
<td>$N$</td>
<td>420</td>
</tr>
<tr>
<td>$R^2$</td>
<td>0.216</td>
</tr>
</tbody>
</table>

Notes: Dependent variables are bilateral imports divided by the product of importing country absorption and exporting country industry output. Explanatory variables are importing country industry output divided by importing country absorption. Each equation is estimated by instrumental variables with exporter fixed effects. Estimates of the exporter fixed effects are not shown. For readability, coefficient estimates in the table have been multiplied by 10^3.
The parameters of (16) are estimable by a linear regression of scaled bilateral imports on the importing country's factor supplies relative to GNP. An appropriate estimation technique is least squares with exporter fixed effects to control for exporter-specific average errors which might affect the volume of trade (for example, distance from the importing country, or "openness"). The purpose of this empirical exercise is to see if accounting for the factor endowments of the importing country helps explain the pattern of bilateral gross imports, but not necessarily in the specific way described in the model of the previous section. As such, this is an exercise in data description or reduced-form estimation, rather than in structural estimation. To allow for a possibly non-linear relationship between scaled bilateral imports and measured factor endowments, a log-linear version of (16) is also estimated. Because of the severe measurement error in the factor endowments and because of the restrictive assumptions required for (15) to hold, the estimated \( \alpha \)'s should be interpreted with caution. In particular, the estimated \( \alpha \)'s can answer such questions as "do countries with large measured capital stocks have larger import volumes?" This is a less ambitious question than "does capital accumulation increase the volume of trade?"

Estimates of equation (16) are reported in table 3. Focusing on the log-linear estimates for ease of interpretation, it can be seen that an abundance of skilled labor and of land is associated with lower imports in each industry, while abundant unskilled labor and capital are associated with higher imports in each industry. The labor elasticities are large and precisely estimated, while the land and capital effects are somewhat smaller and less precisely estimated. The signs of the effects are constant across the two specifications reported, with the exception of the capital coefficient in four industries (wood, metals, machines, and other). The sturdiest conclusion from table 3 seems to be the large and opposite-signed effects of skilled and unskilled labor on gross bilateral imports. As noted above, it is not possible to give these coefficients a structural interpretation because of measurement error and because of the stringent assumptions necessary to move from (14) to (16).

Despite the statistical significance of the estimates reported in table 3, the adequacy of the empirical model can not be assessed in the absence of a competing explanation. A very simple alternative model is to treat scaled bilateral imports as random, except for fixed importer and exporter effects. This is the model that results from appending an error term to the model of equation (1). Since the factor endowment measures vary across importers, they are perfectly collinear with importer dummy variables, so the two effects can not be jointly estimated. Because of the perfect collinearity, however, the model of equation (16) can be seen as a restricted version of the fixed effects model, where the linear restrictions are given by the linear projection of the factor endowment measures on the dummy variables.

To clarify, let \( N \) be the number of countries, so that there are \( M = N \cdot (N - 1) \) bilateral trade flows in each industry. Rewrite (16) in the following form:

\[
y = X\gamma_1 + V\beta + \epsilon \tag{17}
\]

where \( y \) is an \( M \times 1 \) vector of scaled gross imports, \( X \) is an \( M \times (N - 1) \) matrix of exporter dummy variables, \( V \) is an \( M \times k \) matrix of scaled importer factor endowments, \( \epsilon \) is the error vector, and \( \gamma_1 \) and \( \beta \) are conformable vectors of coefficients. This is the model estimated and reported in table 3. The alternative model is

\[
y = X\gamma_1 + Z\gamma_2 + \epsilon \tag{18}
\]

where \( Z \) is an \( M \times (N - 1) \) matrix of importer dummy variables and \( \gamma_2 \) is a conformable vector of coefficients. Because the columns of \( V \) vary only over importers, \( V \) can be written as a linear combination of the columns of \( Z \):

\[
V \cdot R = Z
\]

where the \( k \times (N - 1) \) matrix of constants \( R \) is given by

\[
R = (V'V)^{-1}V'Z.
\]

Substituting \( V \cdot R = Z \) into (18) gives

\[
y = X\gamma_1 + V \cdot R\gamma_2 + \epsilon.
\]

Therefore, if

\[
R\gamma_2 = \beta \tag{19}
\]

the two models (17) and (18) are identical. Testing this equality amounts to testing the validity of the \( k \) linear restrictions on \( \gamma_2 \) embodied in \( R \). The test can easily be implemented by comparing
# Table 3: Regression Results, Equation (16)

<table>
<thead>
<tr>
<th>Industry</th>
<th>Variables</th>
<th>Linear</th>
<th>Log-Linear</th>
</tr>
</thead>
<tbody>
<tr>
<td>Food</td>
<td>Skilled</td>
<td>-0.36</td>
<td>-1.17</td>
</tr>
<tr>
<td></td>
<td>Unskilled</td>
<td>7.45</td>
<td>1.95</td>
</tr>
<tr>
<td></td>
<td>Capital</td>
<td>0.76</td>
<td>0.92</td>
</tr>
<tr>
<td></td>
<td>Land</td>
<td>-0.73</td>
<td>-0.25</td>
</tr>
<tr>
<td>Apparel</td>
<td>Skilled</td>
<td>-1.65</td>
<td>-2.44</td>
</tr>
<tr>
<td></td>
<td>Unskilled</td>
<td>31.40</td>
<td>3.29</td>
</tr>
<tr>
<td></td>
<td>Capital</td>
<td>1.95</td>
<td>1.95</td>
</tr>
<tr>
<td></td>
<td>Land</td>
<td>-1.39</td>
<td>-0.20</td>
</tr>
<tr>
<td>Wood</td>
<td>Skilled</td>
<td>-0.47</td>
<td>-2.11</td>
</tr>
<tr>
<td></td>
<td>Unskilled</td>
<td>9.29</td>
<td>2.60</td>
</tr>
<tr>
<td></td>
<td>Capital</td>
<td>-1.03</td>
<td>0.79</td>
</tr>
<tr>
<td></td>
<td>Land</td>
<td>-0.69</td>
<td>-0.25</td>
</tr>
<tr>
<td>Paper</td>
<td>Skilled</td>
<td>-0.44</td>
<td>-1.45</td>
</tr>
<tr>
<td></td>
<td>Unskilled</td>
<td>8.15</td>
<td>2.47</td>
</tr>
<tr>
<td></td>
<td>Capital</td>
<td>0.53</td>
<td>1.00</td>
</tr>
<tr>
<td></td>
<td>Land</td>
<td>-0.40</td>
<td>-0.16</td>
</tr>
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<td>Chemicals</td>
<td>Skilled</td>
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<td>-1.30</td>
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<td></td>
<td>Unskilled</td>
<td>23.60</td>
<td>2.31</td>
</tr>
<tr>
<td></td>
<td>Capital</td>
<td>1.14</td>
<td>1.16</td>
</tr>
<tr>
<td></td>
<td>Land</td>
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<td>-0.15</td>
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<td>Glass</td>
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<td>-1.40</td>
</tr>
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<td></td>
<td>Unskilled</td>
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<td>2.17</td>
</tr>
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<td></td>
<td>Capital</td>
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<td>0.49</td>
</tr>
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<td></td>
<td>Land</td>
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<tr>
<td>Metals</td>
<td>Skilled</td>
<td>-0.68</td>
<td>-0.92</td>
</tr>
<tr>
<td></td>
<td>Unskilled</td>
<td>21.50</td>
<td>2.62</td>
</tr>
<tr>
<td></td>
<td>Capital</td>
<td>-1.82</td>
<td>0.41</td>
</tr>
<tr>
<td></td>
<td>Land</td>
<td>-1.80</td>
<td>-0.29</td>
</tr>
<tr>
<td>Machines</td>
<td>Skilled</td>
<td>-0.89</td>
<td>-1.66</td>
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<tr>
<td></td>
<td>Unskilled</td>
<td>21.40</td>
<td>2.80</td>
</tr>
<tr>
<td></td>
<td>Capital</td>
<td>-1.07</td>
<td>1.08</td>
</tr>
<tr>
<td></td>
<td>Land</td>
<td>-0.78</td>
<td>-0.07</td>
</tr>
<tr>
<td>Other</td>
<td>Skilled</td>
<td>-1.19</td>
<td>-1.66</td>
</tr>
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<td></td>
<td>Unskilled</td>
<td>18.20</td>
<td>1.76</td>
</tr>
<tr>
<td></td>
<td>Capital</td>
<td>-0.24</td>
<td>0.79</td>
</tr>
<tr>
<td></td>
<td>Land</td>
<td>-2.91</td>
<td>-0.12</td>
</tr>
</tbody>
</table>

Notes: Dependent variables are the same as in table 2. Independent variables are economy-wide factor endowments of the importing country, divided by importing country absorption. For each industry, linear and log-linear results are reported. Each equation is estimated by least squares with exporter fixed effects. Estimates of the exporter fixed effects are not shown. To improve readability, the coefficients in the linear model have been multiplied by the following factors: labor 10^0, capital 10^1, land 10^2.

the error sum of squares from the factor endowments model (17) and the fixed effects model (18). The question being addressed in such an exercise is “does a short list of factor endowment variables explain the volume of trade as well as a longer list of dummy variables?”

A classical $F$-test is one way of comparing the two models. However, this procedure treats the two models asymmetrically, and cannot address questions about the relative probabilities of the two models. A Bayesian approach computes the posterior probabilities of the two models, based on some prior views about their relative plausibility and about likely values for the parameters. If the models are considered equally likely a priori, and if prior views about the parameters are very vague, then Leamer (1978, p. 114) provides a method of computing the posterior odds ratio of two hypotheses. The posterior odds ratios of equation (17) versus (18), as well as the classical $F$-tests of the restrictions (19), are reported in table 4.

For both specifications and in all industries, table 4 indicates that the data cast doubt on the
validity of the factor endowments model. The low posterior odds for even prior odds indicates that the data strongly prefer the purely random model. This implies that only a very strong prior attachment to the factor endowments model relative to the purely random model will survive confrontation with the data.

A final question that can be asked about the two models is whether they lead to different inferences about matters of interest. One such question, addressed by Lawrence (1987), Saxonhouse (1989), Saxonhouse and Stern (1989), and Harrigan (1993) is whether Japan’s trading behavior is somehow different from the rest of the advanced industrial economies. Saxonhouse and Stern have argued that Japan’s gross imports of manufactured goods are less than other countries because of her distinctive factor endowments, and they have criticized the conclusions of Lawrence (1987) and Harrigan (1993) for not considering this issue. Harrigan (1993) used the simple version of the monopolistic competition model and a fixed effects framework, and reached the conclusion that Japan imports about 28% as much as the United States does, controlling for country size and exporter production. To see how the model of this paper might alter that conclusion, table 5 reports the results of an analysis of the residuals from estimates of the log-linear version of (16). The residuals were pooled and regressed on importer dummy variables. This procedure can be viewed as an attempt to explain as much as possible of the differences in import volumes between countries by the importer’s factor endowments, and then looking for patterns in the remaining residual variation. Table 5 reports the estimated fixed effects and tests of whether the fixed effects are statistically significantly different from zero; since the United States is the excluded dummy variable, this amounts to a test of whether the country’s import behavior differs from that of the United States. The proportionate difference between each country and the United States can be estimated by exponentiating that country’s estimated fixed effect; this is reported in the last column of table 5. The conclusion is that Japan imported about 24% as much as the United States after taking account of factor endowments; this is in the same neighborhood as the 28% reported in Harrigan (1993). In other words, even if the factor endowments model is preferred to the fixed effects model despite the evidence of table 4, Japan is still found to import an unusually low amount of manufactured goods.5

For some other countries, accounting for factor endowments leads to the conclusion that the United States is relatively more open. For example, in Harrigan (1993) Britain and France are estimated to have larger import volumes than the United States, where in table 5 they are not different from the United States.

III. Conclusion

This paper developed a model which shows how the bilateral volume of trade in manufac-

5 This does not necessarily imply that Japan is somehow less “open” or more protectionist than other OECD countries. For more on this issue, see Harrigan (1993).
Table 5.—Residual Analysis

<table>
<thead>
<tr>
<th>Country</th>
<th>Coefficient</th>
<th>t</th>
<th>Posterior Odds</th>
<th>Proportionate Difference from U.S.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Canada</td>
<td>-0.514</td>
<td>-3.86</td>
<td>0.03</td>
<td>0.60</td>
</tr>
<tr>
<td>Japan</td>
<td>-1.422</td>
<td>-10.70</td>
<td>0.00</td>
<td>0.24</td>
</tr>
<tr>
<td>Australia</td>
<td>-0.029</td>
<td>-0.22</td>
<td>59.52</td>
<td>0.97</td>
</tr>
<tr>
<td>New Zealand</td>
<td>-0.357</td>
<td>-2.65</td>
<td>1.77</td>
<td>0.70</td>
</tr>
<tr>
<td>Austria</td>
<td>-0.006</td>
<td>-0.05</td>
<td>60.93</td>
<td>0.99</td>
</tr>
<tr>
<td>Belgium</td>
<td>0.156</td>
<td>1.18</td>
<td>30.43</td>
<td>1.17</td>
</tr>
<tr>
<td>Denmark</td>
<td>-0.445</td>
<td>-3.34</td>
<td>0.23</td>
<td>0.64</td>
</tr>
<tr>
<td>Finland</td>
<td>-0.750</td>
<td>-5.62</td>
<td>0.00</td>
<td>0.47</td>
</tr>
<tr>
<td>France</td>
<td>0.067</td>
<td>0.50</td>
<td>53.66</td>
<td>1.07</td>
</tr>
<tr>
<td>Germany</td>
<td>0.169</td>
<td>1.27</td>
<td>27.12</td>
<td>1.18</td>
</tr>
<tr>
<td>Greece</td>
<td>-0.186</td>
<td>-1.39</td>
<td>23.12</td>
<td>0.83</td>
</tr>
<tr>
<td>Ireland</td>
<td>0.504</td>
<td>3.77</td>
<td>0.05</td>
<td>1.66</td>
</tr>
<tr>
<td>Italy</td>
<td>-0.488</td>
<td>-3.67</td>
<td>0.07</td>
<td>0.61</td>
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<tr>
<td>Netherlands</td>
<td>-0.418</td>
<td>-3.15</td>
<td>0.42</td>
<td>0.86</td>
</tr>
<tr>
<td>Norway</td>
<td>-0.324</td>
<td>-2.43</td>
<td>3.18</td>
<td>0.72</td>
</tr>
<tr>
<td>Portugal</td>
<td>-0.308</td>
<td>-2.28</td>
<td>4.44</td>
<td>0.73</td>
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<tr>
<td>Spain</td>
<td>-0.426</td>
<td>-3.20</td>
<td>0.36</td>
<td>0.65</td>
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<tr>
<td>Sweden</td>
<td>-0.779</td>
<td>-5.85</td>
<td>0.00</td>
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<td>Turkey</td>
<td>-0.510</td>
<td>-3.79</td>
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<td>0.60</td>
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<tr>
<td>Britain</td>
<td>-0.040</td>
<td>-0.30</td>
<td>58.28</td>
<td>0.96</td>
</tr>
<tr>
<td>United States</td>
<td>0.291</td>
<td>3.09</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Notes: This table reports an analysis of the residuals from the log-linear version of (16). Residuals for all industries were pooled and regressed on country dummy variables. Column 3 reports the t-test statistic of the null hypothesis that the coefficient is equal to zero, and column 4 reports the posterior odds in favor of the null. Column 5 reports the estimated proportionate difference from the United States, which is the exponential of column 2.

Text (continues):

atured goods could depend systematically on the structure of the importing country's industrial sector. Using disaggregated data on trade and production, the model was rejected. A more general model, where the bilateral volume of trade in manufactured goods was hypothesized to depend systematically on the importing country's factor endowments, was estimated. This model was dominated statistically by a model of purely random variation in bilateral trade, once country size and exporter production were controlled for. It was also concluded that accounting for factor endowments did not substantially alter the conclusions of earlier studies using the simpler version of the monopolistic competition trade model.

The failure of this paper to find an important empirical relationship between an importing country's structure of production and its bilateral volume of trade is a surprising result. It is consistent with the surprising results of Hummels and Levinsohn (1993) who conclude that the bilateral volume of trade is explained perhaps too well by a simple version of the monopolistic competition trade model. Understanding these surprises is a subject for future research.

REFERENCES
Harrigan, James, "Openness to Trade in Manufactures in the OECD," mimeo (an earlier version of this paper circulated as University of Pittsburgh Working Paper No. 272) (1993).


