The Case of the Missing Trade and Other Mysteries: Comment

By PATRICK J. CONWAY*

Daniel Trefler's article in this journal (Daniel Trefler, 1995) is an excellent investigation of observed patterns and volumes of trade. He identifies the theoretical predictions of factor-proportions models of international trade put forward by Eli F. Heckscher (1991), Bertil G. Ohlin (1991), and Jaroslav Vanek (1968) and summarizes these as the HOV model. These theoretical predictions lead to a number of "mysteries" when examined empirically—"mystery" being a code word for rejection by the data. He then introduces a number of extensions of the HOV model, and gauges empirically the extent to which the modified HOV model is rejected relative to each extension. For each extension, he examines the persistence of the mysteries; in his favored specification of country-specific neutral technological difference and preference for home goods in demand, the anomalies in the data are found to be greatly reduced.

In this paper, I demonstrate that there are alternative explanations for the mysteries that Trefler identified. I indicate the features of the data that lead to the mysteries and provide an intuitive separation of the mysteries into those observed in the pattern of trade and those observed in the volume of trade. Econometric tests demonstrate that explanations other than those put forward by Trefler are better supported by the data.[1]

There are three specific contributions of this Comment. First, alternative explanations of the success of Trefler's preferred specification in modeling variation in trade data are put forward. Second, a nonparametric method for calculating the degree of mismeasurement of factor scarcity is introduced and the improvement in explanatory power of that method is measured. Third, statistical comparison of an explanation of the observed antitrade bias rooted in factor-specific differences in domestic factor mobility with Trefler's explanation based upon country-specific productivity differences and home bias in expenditures yields the conclusion that differences in domestic factor mobility is the preferred explanation. These results, taken together, suggest that theories designed to explain observed trade patterns and volumes should reexamine the proxy for factor scarcity derived in the HOV model and should allow for the impact of factor-specific differences in the domestic mobility of factors of production.

I. Theoretical Structure

The estimating equations of the classical Heckscher-Ohlin-Vanek (HOV) trade model as used by Trefler (1993, 1995) are based on three core assumptions. First, a set of full-employment conditions is assumed to hold in each trading economy. These can be presented in matrix form for each country (denoted by subscript c) and for the world economy (subscript w) as a whole.[2]

$$(1) \qquad \mathbf{A}_c\mathbf{X}_c = \mathbf{V}_c$$

$$(2) \qquad \sum_{c=1}^{C} \mathbf{A}_c\mathbf{X}_c = \sum_{c=1}^{C} \mathbf{V}_c = \mathbf{V}_{\mathrm{w}}.$$

There are N commodities, and $\mathbf{X}_c$ is the $(N \times 1)$ vector of output produced in country c.

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[1] I use the data of Trefler (1995) in this analysis, and have replicated results from Trefler (1993) and Trefler (1995) with it. Thanks to Daniel Trefler for making these available. Detailed derivations and programs written in SAS and Gauss to generate the results of this comment can be downloaded from http://www.unc.edu/home/pconway/dload/AER-Trefler/aerindex.htm.

[2] I follow the convention that matrices and vectors will be represented in bold characters while scalars will be represented in italic characters. Transposition of a matrix is indicated by apostrophe.

There are M factors, and $\mathbf{V}_c$ is the $(M \times 1)$ vector of factor endowments in that country. $\mathbf{A}_c$ is the $(M \times N)$ matrix of unit factor coefficients observed in country c. There are C countries in the trading system, and the world production and endowment vectors are denoted $\mathbf{X}_w$ and $\mathbf{V}_w$, respectively. International trade is represented by a country-specific $(N \times 1)$ net export vector $\mathbf{T}_c = \mathbf{X}_c - \mathbf{E}_c$, with $\mathbf{E}_c$ the $(N \times 1)$ vector of purchases of goods. This vector can be restated in factor-equivalent form through premultiplication by $\mathbf{A}_c$. With net world exports of zero, world production, and purchases of each good must be equated, as is evident in (2) and (4).

$$\text{(3)} \qquad \mathbf{A}_c\mathbf{T}_c = \mathbf{V}_c - \mathbf{A}_c\mathbf{E}_c$$

$$\text{(4)} \qquad \sum_{c=1}^{C} \mathbf{A}_c\mathbf{T}_c = 0 = \sum_{c=1}^{C} \mathbf{V}_c - \sum_{c=1}^{C} \mathbf{A}_c\mathbf{E}_c$$

$$= \mathbf{V}_w - \sum_{c=1}^{C} \mathbf{A}_c\mathbf{E}_c.$$

Second, identical and homothetic preferences are assumed. With this, and for a unique world price vector, the expenditure of country c on each good will be the proportion S_c of the world production of that good.[3]

$$\text{(5)} \qquad \mathbf{A}_c\mathbf{T}_c = \mathbf{V}_c - S_c\mathbf{A}_c\mathbf{X}_w.$$

Third, a common technology matrix $\mathbf{A} = \mathbf{A}_c$ for all c is assumed.[4] This property of $\mathbf{A}$ allows a simplification of (5) by use of (2) since $\mathbf{X}_w = \sum_{c=1}^{C} \mathbf{X}_c$.

$$\text{(5')} \qquad \mathbf{A}\mathbf{T}_c = \mathbf{V}_c - S_c\mathbf{V}_w.$$

Elements of the left-hand side of the equation, representing the trade-embodied factors, will in what follows be denoted F_{jc}. Elements of the right-hand side represent the theoretical prediction of trade-embodied factors given endowments and expenditures and will be denoted Φ_{jc}.

For expository purposes I restate each of the variables in (5′) as a percentage of the appropriate world stock of the factor, and denote the resulting share by a lowercase letter.[5] Create an $(M \times 1)$ vector $\mathbf{s}_c$ with element S_c in each row. Introduce an $(M \times 1)$ random-error vector $\mathbf{e}_c$ to capture empirical deviations from the theory. The resulting relationship is

$$\text{(6)} \qquad \mathbf{a}_c = \mathbf{v}_c - \mathbf{s}_c + \mathbf{e}_c$$

for each country c.

The variable vectors for each country c are stacked into $(CM \times 1)$ vectors for cross-country estimation. A rescaling of variables distinct from that of Trefler transformed the elements of $\mathbf{e}_c$ to approximate the normal distribution for hypothesis testing. This rescaling, based upon sample variances, leads to small differences in statistics for otherwise identical calculations reported in Trefler (1995) and here.

Trefler (1995) reports divergences between theory and the empirical record for data from 33 countries for nine factors of production in the year 1983. These can be summarized as:

Missing trade: The actual variance of F_{jc} in the sample (σ_F^2) is small compared to the predicted variance (σ_Φ^2). The ratio of the two as defined here is denoted R_{MT} and is found to be $(\sigma_\Phi^2/\sigma_F^2) = 11.7$ for the full sample.[6]

Prediction error: The Pearson correlation of F_{jc} and Φ_{jc} for all 297 (i.e., $C \times M$) observations is quite low at 0.18.

Sign-HOV: The sign of Φ_{jc} is the same as the sign of F_{jc} in less than 50 percent of the 297 observations.

[3] The $(N \times 1)$ vector of international commodity prices is denoted $\mathbf{P}$. Individual-country income Y_c evaluated at world prices is defined as the scalar $Y_c = \mathbf{P'X}_c$. World income is defined as the summation of national incomes: $Y_w = \sum_{c=1}^{C} Y_c = \mathbf{P'X}_w$. World expenditure is equal to world income, but individual-country expenditures will differ from individual-country income by any trade surplus $B_c = \mathbf{P'T}_c$. Each country's share in world expenditure is denoted by the scalar $S_c = (Y_c - B_c)/Y_w$.

[4] This is an implication of commodity price equalization under the standard HOV assumptions on factor markets, consumption, and technology. Both Trefler (1993, 1995) and this Comment find it important to relax this condition when fitting the model to empirical data, as noted in detail below.

[5] For example, define the jth element of the vector $\mathbf{V}_c$ as V_{jc}. Denote $v_{jc} = V_{jc}/V_{jw}$, and create the $(M \times 1)$ vector $\mathbf{v}_c$ from the individual ratios v_{jc} retaining the same factor ordering as in $\mathbf{V}_c$. Denote the jth row of $\mathbf{A}$ as $\mathbf{A}_j$, and for each factor create the ratio $a_{jc} = \mathbf{A}_j\mathbf{T}_c/V_{jw}$. Assemble $\mathbf{a}_c$ by stacking a_{jc} in the factor ordering of $\mathbf{V}_c$.

[6] I have taken the reciprocal of the ratio as reported in Trefler (1995), but have not changed the concept.

TABLE 1—INDICATORS OF PERFORMANCE OF THE HOV MODEL AND ITS EXTENSIONS

	Pattern of Trade Mysteries Sign-HOV	Volume of Trade Mysteries Endowments paradox	Prediction error	Missing trade
	Section II: Trefler's results			
1. HOV	0.50	−0.89	0.18	11.70
2. T_1 (neutral technology)	0.62	−0.26	0.43	2.02
3. C_2 (Armington home bias)	0.65	−0.41	0.42	0.55
4. TC_2 (T_1 and C_2)	0.72	0.18	0.46	0.68
	Section III: Reinterpretations			
5. HOV (using S_c^p)	0.59	−0.73	0.34	7.60
6. T_1 (using S_c^p)	0.61	−0.19	0.41	2.63
	Section IV: Extensions			
7. HOV (using $\boldsymbol{\lambda}_c$)	0.82	−0.26	0.44	13.00
8. T_1 (maximum-score estimator)	0.89	0.25	0.41	15.80
9. Factor-specific effects (using S_c^p)	0.59	−0.73	0.57	0.08
10. Factor-specific effects (using $\boldsymbol{\lambda}_c$)	0.82	−0.26	0.63	0.13

Notes: The results are separated by the sections of the Comment in which they are references. Trefler's various specifications correspond to the hypotheses reported in Trefler (1995 Table 1). The differences in statistics reported here and in that table for R_{MT} and prediction error are brought about by the rescaling employed here. Trefler's preferred specification is TC_2 in item 4.

Endowments paradox: For each country, the share of positive observations of Φ_{jc} out of the nine observations is strongly negatively correlated with per capita gross domestic product (GDP). The Pearson correlation coefficient is -0.89.

These results are reported in item 1 (row 1) of Table 1. While the statistics for the first two measures differ somewhat from those in Trefler (1995 Table 1) due to rescaling, the message is strikingly similar—the theory does a poor job of predicting observed trade flows.

There are two sources of disappointment in the theory's empirical performance. The "Missing trade" and "Prediction error" mysteries are statements about the poor predictive power of the HOV theory on the volume of trade; in terms of (6), there is a poor match in the size of the corresponding elements of $\mathbf{a}_c$ and factor-scarcity measure $(\mathbf{v}_c - \mathbf{s}_c)$. The "Sign-HOV" and "Endowments paradox" mysteries are evidence of the poor predictive power of the HOV theory on the pattern of trade. In terms of (6), the sign of the elements of $\mathbf{a}_c$ is not with sufficient regularity the same as that of the corresponding elements of the factor-scarcity measure $(\mathbf{v}_c - \mathbf{s}_c)$.

II. Trefler's Explanations of the Mysteries

Trefler (1995) concludes that there are two major sources of the mysteries: country-specific productivity differences, and Armington bias in consumption toward home goods.

1. *Country-Specific Productivity Differences.*—This analysis, building on Trefler (1993), posited that the unit factor coefficients appropriate in each country differed by a country-specific productivity adjustment δ_c from those in the common technology matrix $\mathbf{A}$. With the United States chosen to have $\delta_{US} = 1$, the others in the sample were predicted to have $\delta_c < 1$.[7] The vector equation used in estimation was as given in (7), or as restated in percent of factor endowment in (8).[8] It generated the hypothesis test entitled T_1 in Trefler (1995

[7] Trefler also investigates the possibility that developing countries additionally faced factor-specific differences in technology from developed countries. This hypothesis (T_2 in his notation) was rejected in his paper in favor of the one outlined in the text.

[8] Define the coefficient k_j for factor j as $k_j = \Sigma_{c=1}^{C} \delta_c V_{jc} / V_{jw}$. It is thus defined by endowments and δ_c, and does not represent an additional degree of freedom in estimation. The matrix $\mathbf{k}_j$ is defined as an $(M \times M)$ diagonal matrix with elements k_j in appropriate order along the diagonal.

Table 1, with results restated in item 2 of Table 1 in this Comment).

$$(7)\quad \mathbf{AT}_c = \delta_c\mathbf{V}_c - S_c\left[\sum_{j=1}^{C}\delta_j\mathbf{V}_j\right] + \mathbf{U}_c$$

$$(8)\quad \mathbf{a}_c = \{\delta_c\mathbf{v}_c - \mathbf{k}_j\mathbf{s}_c\} + \mathbf{u}_c.$$

This productivity-based explanation has the potential to address both pattern-of-trade and volume-of-trade mysteries. Improvement was achieved on both fronts as indicated by the results reported in item 2 of Table 1.

2. *The Importance of the Armington Specification.*—Trefler in his hypotheses C_2 and TC_2 introduces an Armington specification of preference for home goods in consumption through a country-specific coefficient α_c^*; values less than unity indicate a preference for home goods. Trefler's [1995, equation (11) p. 1041] specification is reproduced in vector form in (9).

$$(9)\quad \mathbf{AT}_c = \mathbf{V}_c - S_c[(1-\alpha_c^*)(Y_w/Y_c)\mathbf{V}_c + \alpha_c^*\mathbf{V}_w] + \boldsymbol{\mu}_c.$$

Full-employment conditions place additional restrictions on the α_c^* in the estimation procedure. Inclusion of this hypothesis is important in improving the explanatory power of the expanded HOV model, as is evident in the results reported in item 3 of Table 1. However, the estimated values reported by Trefler (1995 Table 5) introduce their own mysteries. Six countries have estimates of α_c^* that indicate more than 100-percent consumption of home goods (i.e., selling foreign goods "short"), and the level of home bias (α_c^* far from unity) is striking. As Trefler says (1995 p. 1043), "These results point to the benefits of more research into the Armington sources of the case of the missing trade. For present purposes, I am not bothered by this: my main point is that the bias is important and must be confronted theoretically and empirically."

III. New Interpretations of Trefler's Estimation Equations

While the specifications of equations (7) and (9) are consistent with the explanations put forward by Trefler, there are other interesting interpretations that can be drawn from the specifications and results.

1. *What Role Does δ_c Play in Estimation?*—The coefficients δ_c in equation (7) are posited to be country-specific productivity differences. There are, however, alternative explanations of the coefficients as estimated. Consider an alternative model of the data that was characterized by true country-specific differences in productivity and errors in estimating the true consumption share of country c. Denote the true productivity coefficients as δ_c^* and the true consumption shares as S_c^*. The observed consumption shares are denoted S_c. The appropriate model derived from (8) for factor j in country c will then be (10). The equation estimated, however, will be as in (10′) based upon the observed consumption share S_c.

$$(10)\quad a_{jc} = \{\delta_c^* v_{jc} - k_c^* S_c^*\} + e_{jc}^*$$

$$(10')\quad a_{jc} = \delta_c v_{jc} - k_j S_c + \{(1 - (\delta_c/\delta_c^*))\delta_c^* v_{jc} - k_c^* S_c^*[(S_c/S_c^*) - (k_j/k_j^*)] + e_{jc}^*\}.$$

A least-squares estimation procedure will choose values δ_c (and thus k_j) to minimize the sum of squared errors in (10′). The error in estimation is given by the bracketed term on the right-hand side. If e_{jc}^* is assumed independently distributed of the ratio (S_c/S_c^*), there are two magnitudes driving the estimated value of δ_c: the value δ_c^*, as postulated by Trefler, and the ratio (S_c/S_c^*) representing the error in observing consumption shares. When the ratio (S_c/S_c^*) is equal to 1 for all c, then least squares will provide a consistent estimator δ_c of δ_c^*. As the ratio (S_c/S_c^*) diverges from unity, the least-squares estimate δ_c differs systematically from δ_c^*.[9]

Trefler's (1993, 1995) use of the country's share of world income evaluated at official ex-

[9] For $(S_c/S_c^*) = 1$, then $(\delta_c/\delta_c^*) = 1$ as well. As the ratio (S_c/S_c^*) diverges, the ratio (δ_c/δ_c^*) will move in the same direction to minimize squared errors on average. In the extreme case of $\delta_c^* = 1$ for all countries (and thus $k_j = 1$ for all factors of production), so that there is in reality no productivity differential, the estimates of δ_c will be derived solely to offset the country-specific mismeasurement in consumption shares.

change rates to define S_c is one possible source of deviation of S_c and S_c^*.[10] In Table 1, item 5, I report the results of revising the test of the classical HOV model to include Robert Summers and Alan Heston's (1991, hereafter Summers/Heston) purchasing-power-parity-adjusted expenditure shares S_c^p without estimation of any coefficients.[11] These adjustments lead to improvement in all—but do not eliminate any—of the mysteries. Item 6 reports the results of reestimating Trefler's T_1 specification using the S_c^p shares. When compared with Trefler's original results for that specification (reported in item 2 in Table 1) there is little difference in explaining the mysteries between the two specifications. Of the δ_c coefficients estimated using S_c^p as the consumption shares, the values for low-income countries are uniformly above those obtained by Trefler (Table 2 p. 1037) while the values for the high-income countries are on average below those of Trefler—as would be expected if the values of S_c^p were closer to S_c^* than were the values of Trefler's S_c.[12]

2. *What Role Does α_c^* Play in Estimation?*—The "home preference" correction plays two different roles in estimation, as is evident in (11) below. In this equality I rescale the variables of (9) as in earlier sections, substitute an equivalent expression for the scalar $(S_c Y_w / Y_c)$, and both add and subtract $\alpha_c^* \mathbf{v}_c$. In (12) I simplify by restating $B_c / Y_c = b_c$.

$$(11)\quad \mathbf{a}_c = \alpha_c^*(\mathbf{v}_c - \mathbf{s}_c) - \{\alpha_c^* + (1 - \alpha_c^*) \times ((Y_c - B_c)/Y_c)\}\mathbf{v}_c + \mathbf{e}_c$$

$$(12)\quad = \alpha_c^*(\mathbf{v}_c - \mathbf{s}_c) + (1 - \alpha_c^*) b_c \mathbf{v}_c + \mathbf{e}_c.$$

The first component of the right-hand side represents the "home preference" role as Trefler describes it. The second term captures the impact of unbalanced trade. Trefler estimates country-specific α_c^* in a cross-country stacking of (12), and obtains the improvements in predictive power reported in Table 1, item 3.

The estimation of α_c^* can then be attributed either to home preference or to unbalanced trade. Three pieces of evidence point to the importance of the trade imbalance term in explaining the estimated α_c^* values. First, the home preference hypothesis as Trefler advances it is designed to address the mystery of small observed volumes of trade. In that guise it will not, as is evident in (11), affect the ability of the HOV model to predict trade patterns—the "sign-HOV" criterion, for example, should be unaffected. In Trefler's estimates as reported in Table 1, however, he achieves greater improvement in "sign-HOV" through this channel (model C_2) than through the δ_c correction (model T_1). Second, the α_c^* term represents country-specific difference in attitudes toward trade. I would then a priori expect that the estimated α_c^* would be correlated with exogenous measures of outward orientation if the first term were dominant. However, there is a Pearson correlation of only 0.02 between the David Dollar (1992) measure of outward orientation available for 31 of these countries and the α_c^* value reported by Trefler.[13] Third, if α_c^* works in estimation rather through capturing the effects of trade imbalance, there will be positive correlation between the estimate of α_c^* and the absolute value of the trade balance. I find a correlation of 0.37 between Trefler's α_c^* and the absolute value of per capita trade surplus in Trefler's data. This is significant at the 95-percent level of confidence.

IV. Alternative Explanations of the HOV Mysteries

Trefler's efforts can be extended by separate consideration of the two categories of mysteries: those concerning the pattern of trade, and those concerning the volume of trade. Improved

[10] The theory represented in the text discussion [e.g., equation (4)] considers the total purchasing power of the national actors. It will be more appropriate to use purchasing-power-parity measures of income in investigating the HOV model. Failure to do so will introduce the "Endowments paradox," since purchasing power is relatively undervalued (and hence S_c artificially low) for low-income countries when exchange-rate conversions are used.

[11] These data are made available in the Penn Tables for the countries under consideration for 1983. Summers and Heston (1991) provide an overview of methodology.

[12] These coefficients are not reported here, but are available from the URL cited above. Both Trefler's T_1 specification and that of item 6 share the odd feature that the sum of squared residuals from the regression is larger than the sum of squared deviations in the dependent variable around its mean. Imposition of $\delta_{US} = 1$ introduces this result.

[13] Trefler's own empirical investigation of trade-related determinants of α_c^* (Trefler, 1995 Table 6) led to a similar rejection of the link between openness and trade bias as measured by α_c^*.

predictions of the pattern of trade will only be possible in this framework through a systematic correction to the sign of the factor-scarcity measure $(\mathbf{v}_c - \mathbf{s}_c)$. Improved predictions of the volume of trade will only be possible if there is a systematic reduction in the size of this factor-scarcity measure relative to $\mathbf{a}_c$. Denote the $(M \times 1)$ vector of systematic corrections to the sign of the factor-scarcity measure as $\boldsymbol{\lambda}_c$. Denote the systematic correction to the size of the factor-scarcity measure as the $(M \times M)$ matrix $\boldsymbol{\kappa}_{jc}$. The necessary corrections to the simple HOV theory in (6) for country c can be represented in general form by the vector expression (13)[14]:

$$(13)\qquad \mathbf{a}_c = \boldsymbol{\kappa}_{jc}(\mathbf{v}_c - \mathbf{s}_c + \boldsymbol{\lambda}_c) + \mathbf{e}_c.$$

1. *Correcting the Measure of Factor Scarcity.*—As noted in the discussion of (6) above, the classical HOV equation does a poor job in predicting the observed pattern of trade: i.e., in obtaining matching signs of the elements of $\mathbf{a}_c$ and of $(\mathbf{v}_c - \mathbf{s}_c)$. This ineffectiveness of the theory in predicting the pattern of trade is underscored by the "Endowments paradox." Rich countries as measured by per capita income are "scarce" (i.e., $v_{jc} < S_c$ for factor j in country c) in a strikingly large proportion of factors, while poor countries are "abundant" in a strikingly large proportion. Trefler's extensions to the theory estimate values for the factor-scarcity correction vector $\boldsymbol{\lambda}_c$ using least-squares statistical techniques. In his hypothesis T_1, as noted above, he posits that $\boldsymbol{\lambda}_c = (\delta_c - 1)\mathbf{v}_c + S_c(\mathbf{1} - \mathbf{k}_j)$ for all c. In hypothesis T_2 he posits that there is an additional factor-specific component to $\boldsymbol{\lambda}_c$ as well. In hypothesis C_1 he posits that $\boldsymbol{\lambda}_c$ is an $(M \times 1)$ vector for each country with identical elements $(S_c - \beta_c)$.

The Trefler use of S_c is one potential source of the errors-in-variables vector $\boldsymbol{\lambda}_c$. However, as the results reported in Table 1 (the first two columns for item 5) indicate, replacing this with S_c^p reduces but does not eliminate the imprecision in predicting the pattern of trade. Another source of imprecision in calculating the elements of $\boldsymbol{\lambda}_c$ may come from Trefler's use of least-squares estimation. Such estimation in hypotheses T_1, C_1, and TC_2 with the volume of (factors embodied in) net trade as dependent variable derives a correction to the factor-scarcity measure that is contingent upon the assumption made about $\boldsymbol{\kappa}_{jc}$. If this assumption is incorrect, then the correction to factor scarcity will be biased.

Predictions of the pattern of trade are predictions of inequalities: factor abundance will lead to net exports, while factor scarcity will lead to net imports. Charles Manski (1985) and Manski and T. Scott Thompson (1986) demonstrate a robust maximum-score estimation technique appropriate to this problem. Choosing $\boldsymbol{\lambda}_c$ to maximize the percentage of sign matches [i.e., $\mathrm{sgn}(a_{jc}) = \mathrm{sgn}(v_{jc} - S_c + \lambda_c)$ for all j and c] subject to the constraint $\sum_{c=1}^{C} \lambda_c = 0$ will yield a consistent estimator of the factor-scarcity correction robust to the modeling choices embodied in the statistician's assumptions about $\boldsymbol{\kappa}_{jc}$.[15] An estimate of the elements of $\boldsymbol{\lambda}_c$ can be obtained in this context by the equivalent in terms of inequalities of a numerical "hill-climbing" exercise: maximizing the percentage of sign matches in (13).[16] Given the existence of nonzero elements of $\mathbf{e}_c$ there will not be 100-percent correct matches; however, it is instructive to examine the degree of improvement possible with a maximum-score estimator of $\boldsymbol{\lambda}_c$.[17] The existence of nonzero $\boldsymbol{\lambda}_c$ in (13)

[14] The terms of the matrix $\boldsymbol{\kappa}_{jc}$ could be either country specific or factor specific, as investigated below. $\boldsymbol{\lambda}_c$ could also be factor specific, but the "Endowments paradox" suggests the country-specific form taken in (12).

[15] This estimator is itself an application of the α-quantile regression estimator investigated by Roger W. Koenker and Gilbert Bassett, Jr. (1978), and elaborated upon in Koenker and Kevin F. Hallock (2001).

[16] Sydney N. Afriat (1967) and Hal R. Varian (1982) provide the foundations of an inequality-based empirical theory of consumer demand derived from the axioms of revealed preference. Donald J. Brown and Rosa L. Matzkin (1996) derive testable implications of general-equilibrium theory for the pure-trade model.

[17] For this study I created a simulation exercise to investigate the sampling properties of the maximum-score estimator in this model. In Monte Carlo simulations using this structure, the maximum-score estimators converge in mean to the true value of the coefficient. When the functional distribution is appropriately modeled through ordinary least squares (OLS), the OLS estimator has a roughly 40-percent lower standard error. However, when the OLS structure is inappropriate, the bias in estimation is significant. For example, consider a simulation that has 100 replications of an economy with $C = 40$ and $M = 9$. The dependent variable y_{jc} is derived from the equation $y_{jc} = k_j(\beta x_{jc} - S_c) + \varepsilon_{jc}$. I specify the values $k_j = 0.1 * j$ for $j \in (1, \ldots, M)$. x_{jc} is created from a unit normal distribution centered at 1, while

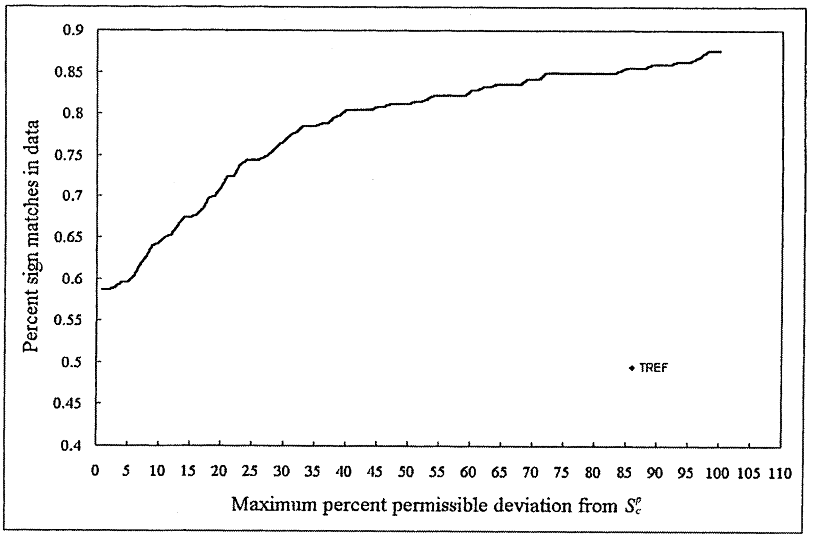

FIGURE 1. THE POTENTIAL FOR IMPROVING THE PREDICTION OF THE PATTERN OF TRADE THROUGH ADJUSTING THE SUMMERS/HESTON EXPENDITURE SHARES

could be due to mismeasurement of the true consumption share S_c^* either through use of Trefler's S_c or the Summers/Heston S_c^p.[18] The "hill-climbing" exercise begins from S_c^p, and measures $\boldsymbol{\lambda}_c$ as a percentage deviation from S_c^p. Figure 1 illustrates the degree to which the percent of correct predictions rises (i.e., "Sign-HOV" rises) as deviations $\boldsymbol{\lambda}_c$ from S_c^p are allowed.[19] The estimates chosen to illustrate $\boldsymbol{\lambda}_c$ in item 7 of Table 1 (and in the tests reported in Table 3) were the $\boldsymbol{\lambda}_c$ values consistent with a maximum 60-percent deviation from S_c^p. As the results reported in item 7 of Table 1 indicate, these adjustments improve the performance of the HOV model in predicting the pattern of trade as indicated by "Sign-HOV" and "Endowments paradox" criteria.[20] They do,

$S_c = 0.05 * c$ for $c \in (1, \ldots, C)$. β_c is set to be equal to unity in all cases. ε_{jc} is drawn from a unit normal distribution centered on zero and multiplied by 0.2. Two maximum-score estimators b_c of β_c were generated: the first (b_{1c}) took an average of all values b_c that yield a maximum number of matches, and the second (b_{2c}) selected the value of b_c that both maximized this product and minimized deviations from the anticipated value of unity. Both led to positive matches in 87 percent of the cases. The means and standard deviations of the estimators over the 100 samples were 1.007 and 0.09 for b_{1c}, 1.003 and 0.08 for b_{2c}, and 0.76 and 0.02 for the OLS estimator. Details are available at the URL cited above.

[18] Steve Dowrick and John Quiggin (1997) point out that calculated indices like S_c^p will be subject to country-specific substitution bias. This bias will be observed as nonzero elements of $\boldsymbol{\lambda}_c$ even when S_c^p is used.

[19] Trefler (1995) reported 147 sign matches for F_{jc} and Φ_{jc} using his measure of S_c. I found that the number of matches rose to 173 with use of the Summers/Heston estimate S_c^p. The specific experiment underlying Figure 1 was as follows. Through grid search, the S_c values were allowed to vary by at most a maximum percent from the Summers/Heston estimates to increase the number of matches, while the sum of S_c over all countries was required to equal 1. The new matches were added to the matches under Summers/Heston to calculate the percent in Figure 1, while the maximum allowed deviation (in percent) from Summers/Heston estimates was indicated upon the horizontal axis. For example, allowing at most 20-percent deviation of individual S_c values from the Summers/Heston estimates led to 37 additional matches, with an average deviation of 9.5 percent. I take the figures generated by a maximum 60 percent allowed deviation of individual S_c from Summers/Heston estimates as the $\boldsymbol{\lambda}_c$ results reported in Table 1; this led to 73 additional matches and an average deviation of 27 percent from the Summers/Heston estimates.

[20] It is also possible to use the maximum-score technique to estimate δ_c as found in Trefler's hypothesis T_1. The results are reported in item 8 of Table 1. The productivity adjustment permits a greater percent of correct matches than the expenditure adjustment because there is no cross-country restriction on the size of these coefficients. With the adjusted expenditure share results of item 7, the elements of $\boldsymbol{\lambda}_c$ for the included countries were required to sum to zero. There were thus general-equilibrium effects of each deviation from the Summers/Heston estimates.

however, imply rather large mismeasurement in current measures of per capita purchasing power.[21]

2. *Correcting the Predicted Volume of Trade.*—Trefler recognized the substantial overprediction of trade volumes from the original specification of the HOV model. His preferred specification C_2 to correct for this overprediction is based upon home bias in consumption. As noted in item 3 of Table 1 estimation of C_2 alone is effective in reversing the "Missing trade" mystery and reduces "Prediction error." When it is combined with hypothesis T_1 to obtain joint hypothesis TC_2, it yields results reported in item 4 in Table 1 that substantially reduce the magnitude of the mysteries. It takes the form represented by equation (14a) below with random-error vector $\boldsymbol{\mu}_c$, and the contraction mapping $\boldsymbol{\kappa}_{jc}$ of equation (13) is represented by the estimated term $(\alpha_c^*\delta_c)$. The estimation results introduce their own mysteries as discussed above.

Sluggishness in reallocating productive factors within each country is an alternative hypothesis for explaining the lower-than-predicted volume of trade. Conway (2002) provides a detailed theoretical rationale for this, but its essence can be seen clearly in considering the movement from autarky to trade for two small economies, identical except that in one country factors are freely mobile and in the other factors are productive only in original use. The volume of trade will differ in the two countries for given **P** by the degree of supply response in the country with mobile factors.

If the sluggishness in factor reallocation is specific to the factor but identical across countries, then the appropriate estimating equation includes the $(M \times M)$ diagonal matrix $\boldsymbol{\kappa}_j$ as in (14b).[22] This equation is also written to include $\boldsymbol{\lambda}_c$ as the correction to measurement of factor scarcity from the previous section and the random-error vector $\mathbf{e}_c$.

$$\text{(14a)} \qquad \mathbf{a}_c = \alpha_c^*(\delta_c \mathbf{v}_c - S_c \mathbf{k}_j) + \boldsymbol{\mu}_c$$

$$\text{(14b)} \qquad \mathbf{a}_c = \boldsymbol{\kappa}_j(\mathbf{v}_c - \mathbf{s}_c + \boldsymbol{\lambda}_c) + \mathbf{e}_c.$$

Evidence in favor of the latter specification is found in Table 2, where the volume-of-trade mysteries on the HOV equation (6) using S_c^p and on that equation adjusted to include the maximum-score estimates of $\boldsymbol{\lambda}_c$ are broken down by factor of production. The size of deviations indicate substantial factor-specific heteroskedasticity.[23] While all R_{MT} statistics indicate an overprediction of trade, the degree of overprediction varies from quite small for cropland (NCR) to extremely large for sales labor (LSA). Similarly, the "Prediction error" statistic indicates that predictions for land variables are not far from the mark, while predictions for labor-embodied flows are less precise.

TABLE 2—ESTIMATES OF R_{MT} AND PREDICTION ERROR (PE) BY FACTOR

	S_c^p Shares		λ_c Shares	
	R_{MT}	PE	R_{MT}	PE
K	8.5	0.10	29.9	0.57
LPT	51.5	0.31	107.6	0.70
LCL	19.5	0.39	64.3	0.82
LSA	1890.6	0.16	2486.0	0.52
LSE	158.3	0.03	251.4	0.53
LAG	1524.5	0.24	1488.2	0.29
LPR	27.7	0.10	39.7	0.48
NCR	1.8	0.64	2.0	0.63
NPA	7.3	0.58	7.4	0.62
All	7.6	0.34	13.0	0.44

Notes: Scaling used is that of the results of Table 1. Factor acronyms: K—capital, LPT—professional and technical labor, LCL—clerical labor, LSA—sales labor, LSE—service labor, LAG—agricultural labor, LPR—production labor, NCR—cropland, NPA—pastureland. Factor differences are defined in the data annex to Trefler (1995).
Source: Author's calculations.

[21] The point in Figure 1 labeled TREF indicates the sign-matching characteristics of the Trefler HOV result reported in Trefler (1995) and stated in item 1 of Table 1. There were 147 matches in that analysis, and the maximum deviation of Trefler's S_c estimates from S_c^p was 84 percent (for Bangladesh).

[22] A detailed test of the sluggishness of factor reallocation as a determinant of trade volumes is presented in Conway (2002). The present estimation is consistent with that hypothesis, or with any alternative that generates a factor-specific (but not country-specific) difference in trade volumes.

[23] Trefler (1995 p. 1045) examines the residuals of the regression based on (8) with a White test once the δ_c have been estimated and finds no evidence of heteroskedasticity. However, the standard White test (G. S. Maddala, 1992 p. 204) will detect only country-specific heteroskedasticity in Trefler's case; factor-specific differences will go undetected.

3. *Comparing Trefler's Specification to an Alternative.*—Trefler's preferred specification (14a) improves the performance of the HOV model in predicting both the pattern and the volume of trade as reported in item 4 of Table 1. The preceding sections of this Comment provide evidence that the combination of imperfect factor mobility across domestic industries and adjustment of the observed consumption shares for mismeasurement is a justifiable alternative hypothesis. As (14a) and (14b) indicate, these are not nested. I investigate their relative importance through use of the J test (William Griffiths et al., 1993 p. 343). If (14b) is the correct specification, then the predicted value calculated from (14b) will be a significant regressor when added to (14a). Similarly, if (14a) is the correct specification, then the predicted value derived from (14a) will be a significant regressor when added to (14b).[24] The statistics generated by the J test are reported in Table 3.[25] As these statistics indicate, the Trefler specification adds insignificantly to the (14b) specification. By contrast, the factor-immobility model adds a significant component to the analysis of specification (14a).

An additional and less model-specific comparison of explanatory power is possible. Equations (14a) and (14b) are estimated by GLS regression. The residuals from these estimations are derived. If factor-specific effects alone matter in $\boldsymbol{\kappa}_j$ then there will be no systematic country-specific component to the residuals. If the Trefler specification of (14a) is complete, then the residuals from (14a) will have no systematic factor-specific component. Items 3 and 4 of Table 3 indicate that both of these statements can be rejected in these data.[26] There is thus gain in explanatory power in both factor-specific and country-specific corrections to the classic HOV model.

V. Conclusions and Extensions: More Mysteries?

Trefler has provided a forceful argument for examining the possible causes of the failure of the HOV model to predict trade. In this paper I confirm his insight that the relative size of endowments and expenditure is at the heart of the rejection. I extend his insight by separating the mysteries into two groups. The first, that of prediction of the pattern of trade, I found best addressed through an adjustment that could be either a restatement of relative purchasing power or a restatement of relative productivity. These have very similar implications in the data of this study. The second, that of prediction of the volume of trade, I found better addressed by a contraction mapping $\boldsymbol{\kappa}_j$ identical for all countries but differing by factors than by the country-specific home bias posited by Trefler.

The results of this Comment do not diminish the importance of the work Trefler has done in identifying empirical regularities in the trade data. They do suggest, however, that the factor-specific variation in trade volumes is a stylized fact that should be incorporated into theoretical modeling efforts. While my own work (summarized in Conway, 2002) has focused upon the-

[24] This is a deliberate bias of the test in favor of the Trefler specification. Factor immobility at this level of aggregation can also generate country-specific components to the elements of $\boldsymbol{\kappa}_{jc}$ that will not be attributed here to (14b).

[25] Given the great dispersion in factor-specific and country-specific variances I use an iterative generalized least-squares (IGLS) procedure. Each observation is divided by the product of the standard deviation of errors of that factor and that country in the preceding iteration. For each hypothesis test, I first in an iterative process derive under the null hypothesis new country- and factor-specific weights for the regression that cause the sampling error to approximate most closely the normal distribution. (In each case the Shapiro-Wilk statistic rises from a value less than 0.8 with the original weighting matrix to 0.99 after this reweighting.) I then calculate the J statistic and regressions on residuals reported in Table 3.

The coefficients estimated in TC_2 of Trefler (1995) are quite sensitive to the scaling chosen, with the Pearson correlation of the α_c^* estimated using the Trefler scaling and using the rescaling reported here is -0.32. If Trefler's scaling is used, the estimated coefficient on the predicted value of (14b) is -3.47, with standard error of 0.64. The J test thus cannot reject the importance of the factor-immobility hypothesis using either scaling strategy.

[26] There is no contradiction between the results of Table 3. Items 1 and 2 are specified to compare two exact models, while items 3 and 4 examine the residuals from one model against an unspecified country-specific, or factor-specific, alternative. The results of items 1 and 3 indicate that although Trefler's precise hypothesis TC_2 has no additional explanatory power for the factor-immobility model, a more general country-specific alternative will improve explanatory power.

TABLE 3—TESTS OF COMPETING SPECIFICATIONS

J Test Results		
1. The predicted value of (14a) when included as separate linear regressor in (14b):	Coefficient:	0.16
	Standard error:	0.16
	Prob > *t*:	0.33
2. Including the predicted value of (14b) when included as separate linear regressor in (14a):	Coefficient:	−1.58
	Standard error:	0.37
	Prob > *t*:	0.00
Examination of Residuals		
3. Significance of country-specific explanation of residuals from (14b)	$F(32, 265)$	3.95
	Prob > F	0.00
4. Significance of factor-specific explanation of residuals from (14a)	$F(8, 288)$	16.38
	Prob > F	0.00

Note: The predicted value of (14a) was created using Trefler's coefficients from Trefler (1995 Table 5).

oretical specifications that admit costs to domestic factor mobility that induce sluggishness in response (even in the long run) to the incentives offered by international trade, other factor-specific explanations will also be consistent with the data.

Examination of the data also reveals a final regularity inconsistent with the HOV model: a strong regularity in the covariation of errors across factors within a country. Conway (1997) demonstrates that this pattern of covariation is consistent with the amendment to the HOV model suggested by Peter B. Kenen (1965) in his proposal that capital be treated as a factor used only to improve other factors.

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