International Trade as an "Integrated Equilibrium": New Perspectives

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The integrated equilibrium is a paradigm that has played a central role in the field of international trade. The concept originated with Paul A. Samuelson (1949), was further developed by Avinash K. Dixit and Victor F. Norman (1980), and placed at the heart of international analysis by Elhanan Helpman and Paul R. Krugman (1985). The central idea is that a world with imperfect mobility of productive factors across regions or countries may replicate the essential equilibrium of a fully integrated economy, provided that goods are perfectly mobile. The concept of the integrated equilibrium has proved to be exceptionally tractable and useful for analytic developments, as for example in the work of Gene M. Grossman and Helpman (1992). We have found using elements of integrated equilibrium analysis useful in our own work (e.g., Davis et al., 1997).

The central figures in developing the theory of trade and growth within the integrated equilibrium framework have been quite aware of its limitations. Helpman and Krugman (1985) include a section on the cases in which factor-price equalization (FPE) breaks down. Grossman and Helpman (1992) make the distinction between national and international spillovers a key element of their theory of trade and growth. Moreover, the starting point of Krugman's work in the past decade on economic geography has been precisely to deny that the world operates as if it were an integrated economy.

This notwithstanding, we believe that the grip of integrated equilibrium analysis on the way that the economics profession conceives of world trade patterns remains very powerful and in important ways distorts one's view of trade relations, particularly among the relatively rich countries of the OECD. We do not propose to banish integrated equilibrium analysis. We believe that it is useful in the proper context. However, we do propose that it is important to have a fuller appreciation of the limits of such analysis from an empirical standpoint and thus to have a richer view of the determinants of world trade patterns.

I. World Equilibrium: Integrated or Not?

One need not look far to find the first critics of the integrated equilibrium concept. Bertil Ohlin (1933) himself is famous for having missed the FPE result. In part this lapse appears to reflect confusion arising from a count of equations and unknowns in the general-equilibrium system. But it also reflects an appreciation that the barriers between regions and countries are nontrivial and that endowment dissimilarities may be large. Samuelson (1949), of course, understood perfectly well that his FPE results could not be applied literally to the world that we actually live in. The cases in which FPE fails, as for example due to large endowment differences across countries, have continued to provide a staple topic in trade courses at all levels.

Yet the integrated-equilibrium worldview has remained remarkably resilient throughout. On the theory side, Helpman and Krugman (1985) show the remarkable flexibility of the approach, incorporating scale economies, diverse approaches to imperfect competition in product markets, multinationals, local external effects, and so forth. On the empirical side, integrated equilibrium analysis reaches its high-water mark with the influential work of Daniel Trefler (1993). He aimed to examine whether a model of adjusted FPE, where the adjustment is for cross-country differences in factor productivity, could make sense of the factor-content predictions of the Heckscher-Ohlin-Vanek model.

Trefler (1995) returned to the question of predictions for the factor content of trade. The most important breakthrough in the paper is the identification of a stylized fact in the data. He

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showed that conventional measures of the factor content of trade are an order of magnitude smaller than that predicted. This he termed the "mystery of the missing trade." This raised key questions that have been important in framing the subsequent literature. Is the factor content of trade really so small? If so, why? If not, why have we measured it to be so small? How will we reconcile the large predictions with the small measures of the factor content of trade?

II. Accounting for Global Factor Trade

In Davis and Weinstein (1998) we bring a great deal of new data to bear on the reasons for previous failures to understand the factor content of trade. The two principal hypotheses for Trefler's (1995) mystery of the missing trade concern cross-country differences in techniques of production and departures from identical and homothetic preferences. The most important prior research treated the nature of differences in techniques as a free parameter to be estimated. The actual data consisted of technology for a single country. Data on cross-country absorption patterns, while an important part of some accounts of the failures of the model, had not previously been brought to bear on the issue.

Thus our starting point was to employ new and higher-quality data. The data on production techniques consist of technology matrices constructed for ten rich OECD countries as well as for a composite rest of the world (ROW). The data cover both manufacturing and nonmanufacturing with two factors of production: capital and labor.

An examination of the technology matrices allows testing of the nature of differences in techniques across countries. These differences in techniques correspond to a variety of economic hypotheses that can be related to observed characteristics of the countries. These allow us to make inferences not only about whether efficiency differences exist across countries, but whether these efficiency differences are sufficient to capture the cross-country differences or whether one needs to take specific account of the failure of the world to replicate an integrated equilibrium. Using parameter estimates obtained from analyzing the technology matrices, one can then take the fitted technology matrices and apply them to the trade data to see which, if any, of the hypotheses may help to resolve the mystery of the missing trade.

Having gone this far purely from examining the technology matrices, one can take the further step of asking how much additional gain would come from a model that more accurately predicts the volume of trade than the frictionless model traditionally used. That is, how much of the missing net factor trade is due to the low volume of product trade? Here we estimate a gravity model and use the fitted values, in addition to our preferred model of production, to predict the factor content of trade.

Our estimation strongly rejects the traditional assumption of identical technologies, even for the ten rich OECD countries. Allowing for Hicks-neutral productivity differences greatly improves the fit of the production model but surprisingly does very little to eliminate the mystery of the missing trade. An hypothesis that industry input usage is correlated with country factor abundance, which would not hold in conventional HOV models, is strongly confirmed in the data. If this held only in tradable sectors, then it would be possible that this correlation reflects only aggregation. But it holds about as strongly in nontradable sectors as well, which indicates a breakdown in FPE and hence a departure from the integrated equilibrium. Once this departure from FPE is recognized, it is crucial to reexamine the treatment of nontraded goods within the predictions. In the conventional model in which all countries use the same techniques of production and preferences are identical and homothetic, the factor content of trade is invariant to the presence of nontraded goods. However, this is not true when FPE breaks down. In this case, capital-abundant countries use more capital per worker in nontraded sectors, which diminishes the residual available for production of tradables and so lowers the predicted factor content of trade. Allowing for the fact, very evident in the production data, that industry input usage is correlated with country capital abundance dramatically improves the performance of the model. The major previous research efforts had left measured factor trade as a minuscule proportion of predicted factor trade. In this last exercise, predicted factor trade is approximately 60 percent of predicted net factor trade. If one goes further to incorporate the fact that the volume of trade is smaller than predicted by the frictionless model, then measured factor trade rises to roughly 80 percent of that predicted.

In short, a few simple modifications provide a dramatically improved ability of the model to match the data. These modifications include: cross-country Hicks-neutral efficiency differences; a breakdown of FPE with the consequence that industry input usage is correlated with country factor abundance; a recognition that the breakdown of FPE has important consequences for factor usage in nontradables; and the fact that trade volumes are smaller than predicted by the frictionless model. Suitably modified, HOV works well.

III. New Results

The paper just described makes important advances in allowing the HOV model to work. However, it leaves unanswered a large number of key questions. Why did the mystery of the missing trade arise in the first place? What do the results have to say about the meaning of intra-industry trade, a dominant form of exchange among the rich OECD countries? Is relative factor abundance important only for North–South trade, or is it likewise important for trade among the rich OECD countries? What implications do the answers to these questions have for the view of world trade as replicating an integrated equilibrium? We turn to these issues next.

Allowing c and c' to index countries, $\mathbf{B}_{fc}$ to be the fth row of the total-factor-input matrix of country c, $\mathbf{E}_c$ to be gross exports from c, and $\mathbf{M}_{cc'}$ to be gross imports by c from c', the conventional measure of country c's factor content of trade has been

$$\mathbf{F}_{fc}^{\text{Conv}} = \mathbf{B}_{f\text{US}}\left(\mathbf{E}_c - \sum_{c' \neq c} \mathbf{M}_{cc'}\right).$$

Alan Deardorff (1982) and Helpman (1984) have developed more general measures of the factor content of trade for cases where FPE fails to obtain. 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. The Deardorff-Helpman measure

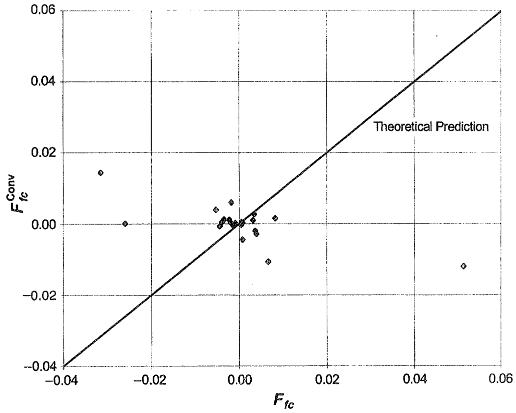

FIGURE 1. F_{fc}^{Conv} VERSUS TRUE FACTOR CONTENT OF TRADE, F_{fc}

of the factor content of trade for country c in this case with no FPE is

$$\mathbf{F}_{fc} = \mathbf{B}_{fc}\mathbf{E}_c - \sum_{c' \neq c} \mathbf{B}_{fc'}\mathbf{M}_{cc'}.$$

Note that, for the case with FPE, $\mathbf{B}_{fc} = \mathbf{B}_{fc'} = \mathbf{B}_{f\text{US}}$, so this reduces to the standard 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 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.

While Davis and Weinstein (1998) demonstrate that F_{fc}^{Conv} is much smaller than predicted factor trade and that biases exist in the technology matrices, the paper did not explore whether these biases are critical to understanding the missing-trade phenomenon. This is because in Davis and Weinstein (1998), both the left- and right-hand sides change as they move across specifications. In this section, we show that this error in the measurement of net factor trade alone suffices to generate 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

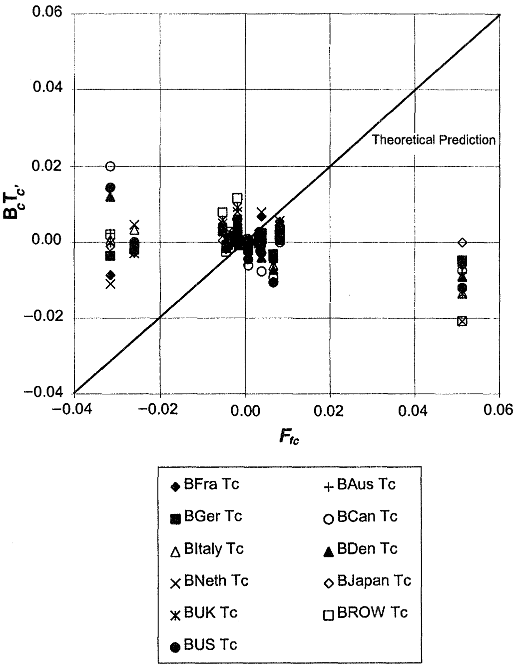

FIGURE 2. MEASURED VERSUS TRUE FACTOR CONTENT OF TRADE USING EACH COUNTRY'S TECHNOLOGY MATRIX

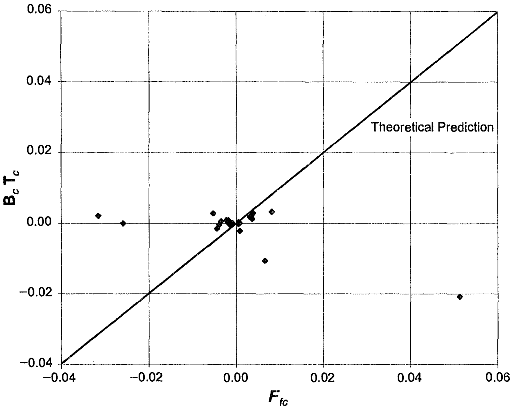

FIGURE 3. MEASURED FACTOR TRADE USING OWN TECHNOLOGY MATRIX VERSUS ACTUAL FACTOR TRADE

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 1 and 3. A quick scan of the plot reveals that 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. Fewer than one-third of the points lie in quadrants 1 and 3.

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 carry 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 U.S. 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 mismeasurement of net factor trade is a consequence of using the U.S. 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 United States 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 U.S. 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 mismeasurement of net factor trade is not simply a consequence of the choice of the U.S. technology matrix.

A third issue arises regarding the conventional measure of net factor trade. Theory suggests that the mismeasurement 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 relation between the conventional measure and true net factor trade is absent even when we restrict the sample to the country whose technology matrix we employ.

So why did the mystery of the missing trade arise in the first place? In Davis and Weinstein (1999), we argue that errors in the measurement of net factor trade arise for three reasons: (i) exports from countries are measured with the U.S. instead of the exporter technology matrix; (ii) imports to countries are measured with the U.S. instead of the importer technology matrix; and (iii) matched intra-industry trade has zero factor content in the conventional measures as a matter of construction. It is worth emphasizing this last point because the definition of intra-industry trade as trade in goods of similar factor content derived from the theoretical approaches founded on integrated equilibrium analysis—not from any conviction based on analysis of the data.

The decomposition of net factor trade shows that, contrary to conventional analysis, intra-industry trade is a major conduit of net factor trade, especially for the rich OECD countries. For the United States, approximately two-thirds of the factor content of trade takes place through intra-industry exchange. Properly measured, net factor contents are large, particularly when measured as a share of resources devoted to the tradable sectors. Moreover, we show that a focus purely on the net factor content of trade may strongly understate the importance of endowments in motivating the trade of a country. The reason is that in our model, with a high degree of specialization in tradables, countries are expected to be net exporters of the services of a factor to the set of countries less abundant in that factor, and simultaneously net importers of the services of other factors from countries more abundant in those factors. This feature is strongly confirmed in the data, indicating that even our much higher measures of the net factor content of trade understate the true importance of the exchange of factor services in motivating international trade.

IV. Conclusions

Taken together, these new strands of work strongly militate against an integrated equilibrium view of the world. A major area of research will continue to investigate the relatively small degree of world product-market integration. A breakdown of FPE and a multiple-cone view of the world will importantly inform additional work on the Heckscher-Ohlin-Vanek model.

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