2 Testing the Theories of International Comparative Advantage

Chapter 1 has formulated the working hypothesis that serves as a foundation for the analysis of trade data to be presented and has also listed a large number of complicating factors. The impression that should have been created is that the working hypothesis summarized by the Heckscher-Ohlin-Vanek equations is extremely tidy, but also quite fragile. The set of alternative hypotheses generated by the relaxation of one or more of the unlikely assumptions underlying the HOV equations is vast, and none of the alternatives provides neat predictions of the composition of trade in a multicommodity, multifactor world. Formal statistical methods of testing hypotheses presuppose the existence of maintained and alternative hypotheses that are precisely defined, and consequently these formal methods cannot be used in our data analysis, unless they are amended to allow incredible maintained hypotheses and vague alternatives. The purpose of this chapter is to discuss what role data may play in such a setting and thereby to serve as a bridge between the theory of the previous chapter and the empirical work in the subsequent chapters. It is argued here that the HOV model is clearly incredible and can be rejected as a perfect description of reality without recourse to any data. The only credible theory entertained by economists is a vague amalgam of the many models that we use to illustrate distinct features of the workings of the economy. Though we can reject at the outset the HOV model as a complete description of reality, an empirical examination of the HOV proposition can nonetheless be fruitful if it focuses on the hypothesis that the HOV model is a sufficiently close approximation to reality that it can be useful for forecasting, for policy analysis, or for some other purpose. In order to test this hypothesis we would have to build an approximation to a complete model of the world to determine whether the simple HOV model serves our purposes as well as the more complex model or we would have to construct an alternative simple model and test to see which is the more useful. Neither of these can be done because the present state of economic theory does not allow us to articulate fully and precisely even simple alternative models of trade. As a result, the empirical analysis must focus on measuring the accuracy of the HOV model, but leave unstudied the accuracy of the unstated alternatives, and also leave untested the proposition that the HOV model is useful. However, if it were shown that the HOV model is very inaccurate, then it seems appropriate to suspect that the model is not very useful for predictions and policy. In that limited sense, the hypothesis that the HOV model is useful can and is tested.

Though the game of international economics has primarily been played at the theoretical level, there are nonetheless a fairly substantial number of recent papers that purport to offer tests of trade theories. This book may also be viewed as a test of the Heckscher-Ohlin model, though I think that is something of an overstatement. In this chapter I discuss what it would mean to test the theory, and I offer methodological comments on the empirical literature relating to testing the theory. Deardorff (1982b) and Stern (1975) also provide reviews of the empirical testing of trade theories, including summaries of the principal findings.

2.1 What Are the Hypotheses?

A careful formulation of a maintained hypothesis is the first step in a proper empirical test. This may seem so obvious that it need not be stated, but, as will be discussed subsequently, much of the literature on testing trade theory flounders precisely because inadequate effort was made to define the theory to be tested. The second step is to formulate an alternative hypothesis and to identify observable phenomena about which the maintained hypothesis and the alternative offer different predictions. As a matter of fact, the trade theories have usually been examined empirically without a clear statement of any alternative. In that event, whether the maintained hypothesis is accepted or rejected is a matter of aesthetics and judgment.

For example, suppose that there were only 2 goods and 2 factors in the world, and let us construct a program for testing the Heckscher-Ohlin hypothesis: "A country will export the commodity that uses intensively its relatively abundant factor." This is a statement about three separately measurable quantities (factor intensities, factor abundance, and trade), and a test of the theory would begin by measuring these three concepts and would then determine the extent to which they conform to the predictions of the theory. No one expects the theory to be exactly correct, and it would be mistaken to claim that the theory failed if it offered an incorrect prediction in only a single instance. Suppose that 35 out of a total of 60 countries have trade in conformance with the theory. Does the theory pass or fail? A proper answer to this question requires an alternative hypothesis, for example, the scale economy hypothesis:

"Countries with relatively large labor forces have a comparative advantage in the commodity that exhibits relatively large scale economies." Measurement difficulties may be supposed to force us to specialize this hypothesis to "There exists a critical value for the labor force, say L^*, such that all countries with labor forces in excess of L^* will export one good and all other countries will export the other good." Suppose this alternative hypothesis correctly predicts the trade pattern of only 30 of the 60 countries. Formal statistical analysis would then have us conclude that the Heckscher-Ohlin hypothesis is favored by the data as compared with the scale economies model. But let us consider whether this makes much sense. Suppose that out of the 25 incorrect predictions of the HO model, the scale economy model makes 20 correct predictions. This suggests that a combined theory would be greatly favored over either individually. When you stop to think about it, neither of the simpler hypotheses is really credible, the first since it makes the unlikely assumption that returns to scale are absolutely constant, the second since it makes the unlikely assumption that factor intensities in the two industries are identical. We therefore began this hypothesis-testing exercise with two incredible theories, and each can be rejected without appeal to any observations.

A hypothesis that cannot be rejected at the outset is the following: "The Heckscher-Ohlin model is more useful than the scale economies model." To test this kind of hypothesis, we shall have to identify the uses to which the theory is to be put. The principal function that the trade theory serves is to introduce students to the sometimes surprising implications of a general equilibrium analysis of an economic system. Without a doubt, the HO model is greatly superior to the scale economies theory for pedagogical purposes. Why else would it fill our textbooks? Another function of the HO model is the derivation of policy conclusions, especially the support of free trade, which appeals to conservative economists, who generally suppose that government intervention works to the disadvantage of some and probably all. The policy implications of the scale economy model can be quite different, which suggests this hypothesis: "The HO model serves as a more accurate guide for trade policy than the scale economy model." How is such a hypothesis to be tested? The answer is that the more general model that allows both scale economies and differences in factor intensities would have to be formulated and estimated, and the consequences of acting as if one of the simpler models were true would have to be computed. The model that is least misleading would be the one favored by the data.

The attempt to test the usefulness of the HO model properly requires us to identify a reasonably complete general model of international trade and to determine whether the restrictions implied by the simple HO model do great damage to policy decisions. The complete model includes such things as scale economies, nontraded goods, externalities, imperfect competition . . . . Unfortunately we are currently in the situation in which only the simple HO model can be fully defined. Even the inclusion of scale economies causes great difficulties in estimation. Therefore the kind of data analysis we can perform unfortunately terminates with statements about the quality of the model such as this: "The HO model correctly predicts the trade of 35 of 60 countries." To put this another way, we are able only to measure the accuracy of the HO model, when what we really want to do is to test the usefulness of this model compared with some other model. But it does seem reasonable to infer that an accurate model is likely also to be a useful model or, at least, the converse, that an inaccurate model is unlikely to be a useful model. For example, if the HO model correctly predicted the trade of 55 out of 60 countries, we may intuitively, though without a complete formal justification, conclude that the model is likely to serve as a useful guide for policy action, since there does not seem to be much role left for other factors such as scale economies. The exact degree of accuracy at which the data can be said to cast doubt on the usefulness of the HO model is a matter of judgment. It is my hope that the data analysis reported subsequently reveals that the HOV model is surprisingly accurate, so much so that the model seems more useful than it did at the outset.

2.2 Measuring the Accuracy of the Heckscher-Ohlin Predictions

If there were only 2 goods and 2 factors, the accuracy of the HO model could be easily determined. The model predicts that a country would export the commodity that uses intensively the relatively abundant resource. We could therefore measure the three concepts intensities, factor abundance, and trade and could report the number of countries that conform to the prediction. However, the multifactor, multigood model does not generate clear predictions about which goods are exported and which are imported. A convenient generalization of the HO model

that applies to the 2×2 world as well as to the $n \times m$ world is summarized by the HOV equations

$$AT = V - sV_w, \tag{2.1}$$

where A is the matrix of factor intensities, T is the vector of net exports, V is the vector of factor endowments, V_w is the world's factor endowments, and s is the consumption share. A proper measure of the accuracy of the theory begins with independent measures of these three concepts and determines the extent to which they conform to the HOV equations. But what is meant by conformity? In the 2×2 model we have proposed in effect a comparison of the predicted trade vector $\hat{T} = A^{-1}(V - sV_w)$ with the actual trade vector. If the signs conform, the model is said to be perfectly accurate. Otherwise it is inaccurate. As a measure of the conformity of the data to the Vanek equations, this leaves much to be desired even in the 2×2 case, since it deals with only one aspect of the theory—namely, which good is exported—when, as a matter of fact, the theory offers much more precise predictions about the quantitative relations among the three measurable phenomena. Moreover, in more realistic settings, a measured A matrix is usually not square and it is impossible to compute the predicted trade. It is therefore essential to abandon the version of the 2×2 model that predicts which good will be exported in favor of the general HOV model.

The HOV equations are a set of relations between factor intensities and trade and resource endowments. Most studies of trade have used measures of two of these sets of variables and have inferred the third. Factor content studies, the most famous of which is Leontief (1953), take measures of trade T and factor intensities A and from them infer the factor abundance vector $V - sV_w$. Cross-section regression studies such as Baldwin (1971) also use measures of A and T to infer $V - sV_w$. Cross-section studies such as Chenery (1960) and Leamer (1974), as well as this book, use measures of trade T and endowments V and implicitly infer the inverse of the matrix of intensities A. But the way to measure the accuracy of the theory would be to obtain direct and independent measures of all three concepts and to determine the extent to which these measurements conform to the HOV equations. These studies, which use measures of only two of the three concepts, cannot be said to be measuring the accuracy of the HOV theory. Though Hufbauer (1970) does use measures of all three concepts, his method of calculating their conformity to the HOV equations is not entirely correct—actually the HOV equations are never explicitly acknowledged as the foundation for any of this work. Only Bowen, Leamer, and Sveikauskus (1982) use measures of all three concepts and explicitly refer to the HOV equations.

In addition to measuring only two of the three theoretical concepts, many studies use inappropriate generalizations of the 2×2 model to worlds with more factors and/or more goods, and these studies consequently make inappropriate inferences about the third, unmeasured, concept. The classic example is Leontief's (1953) "test," which compares the capital per man embodied in \$1 million worth of imports with the capital per man embodied in \$1 million worth of exports. This comparison is shown in Leamer (1980) not to reveal the relative abundance of capital and labor in a multifactor world.

A second measurement of the accuracy of the theory involves regressions for a given country across commodities of net exports on factor input intensities, as in Baldwin (1971), Branson and Monoyios (1977), Harkness (1978), and others. If the estimated coefficient of some factor is positive, the country is inferred to be abundantly supplied in that resource. This too is an inappropriate inference in a multifactor world, as shown in Leamer and Bowen (1981).

A third variety of study regresses net exports across countries on measures of factor endowments, as in Leamer (1974), Chenery and Syrquin (1975), and in this book. This type of study, though conceptually appropriate, cannot be said to be a complete measurement of the accuracy of the theory because it uses no data on factor intensities. The approach can be said to be measuring the accuracy of a weaker version of the theory that does not depend on factor intensities, namely: "There exists a matrix A such that $AT = V - sV_w$."

Each of these approaches is now discussed in detail.

2.2.1 Factor Content Studies

The classic empirical measurement of the accuracy of the HO model produced a result that appeared to contradict the theory. Leontief's (1953) calculation that U.S. imports were more capital intensive than her exports was interpreted to mean that trade revealed the United States to be scarce in capital compared with labor, when it was taken for granted that the reverse was true. This result was so upsetting to trade theorists at the time that it was given the provocative name "the Leontief paradox," and

it spawned an enormous literature that sought to explain the finding by enlarging or altering the simple theory to include such things as tariffs, human capital, knowledge capital, monopolistic competition, and so on. It is hard to identify another empirical finding in economics that has had such an enormous impact on how economists have spent their time. Alas, the paradox rests on a simple conceptual misunderstanding, as is shown in Leamer (1980). If the correct calculations are done, the United States is revealed by trade to be relatively abundant in capital compared with labor. But, as Brecher and Choudri (1982) point out, correct calculations also imply that the United States was labor abundant, not compared with capital, but rather compared with an average of all resources. This is difficult to square with the facts, and the U.S. export of labor services embodied in trade has to be regarded as an observation in contradiction of the theory.

The impropriety of the Leontief inference is a consequence of the fact that the inference is made without benefit of a fully articulated theory.* The HOV equations (2.1) serve as a logically sound foundation for a study of trade-revealed factor abundance. Two of these equations describe the relation between capital and labor endowments and the implicit trade in capital and labor services:

$$K_T = K - sK_w, \tag{2.2}$$

$$L_T = L - sL_w, \tag{2.3}$$

where K_T and L_T are capital and labor services embodied in net exports, K and L are the factor endowments of the country in question, K_w and L_w are the world's factor endowments, and s is the country's consumption share. These two equations can be manipulated to obtain the conditions under which trade reveals the country to be capital abundant:

THEOREM 2.1 Capital is revealed by trade to be abundant relative to labor, $K/K_w > L/L_w$, if and only if

$$K/(K - K_T) > L/(L - L_T). \tag{2.4}$$

Proof Equations (2.2) and (2.3) can be rewritten as $K/K_w = sK/(K - K_T)$ and $L/L_w = sL/(L - L_T)$, from which (2.4) is a direct consequence. ∎

*The following material, until the end of the proof of Corollary 2, is taken in part from Leamer (1980).

There are three useful ways of rewriting (2.4). If $K_c = sK_w$ is the amount of capital embodied in the commodities used in the country, then $K - K_T = K_c$ and, similarly, $L - L_T = L_c$. Then (2.4) is equivalent to

$$K/L > K_c/L_c = K_w/L_w, \tag{2.4a}$$

which means that a country is revealed to be capital abundant if its production is more capital intensive than its consumption.

Another way to rewrite (2.3) is $K(L - L_T) > L(K - K_T)$, or

$$-KL_T > -LK_T. \tag{2.4b}$$

If L_T is positive, then this inequality becomes $K_T/L_T > K/L$, or $K_T/K > L_T/L$. Thus a country that is an exporter of both labor services and capital services is revealed by trade to be relatively capital abundant if trade is more capital intensive than production, or, equivalently, if the share of capital exported exceeds the share of labor exported. If L_T is negative, the last two inequalities are reversed.

Yet another possibility is to rewrite (2.4) as $-(K_c + K_T)L_T > -(L_c + L_T)K_T$, or

$$-K_cL_T > -L_cK_T. \tag{2.4c}$$

Thus a country that is an exporter of both labor services and capital services is revealed by trade to be relatively capital abundant if the capital intensity of net exports exceeds the capital intensity of consumption, $K_T/L_T > K_c/L_c$, and a country that is an importer of both capital and labor services is revealed by trade to be capital abundant if the capital intensity of net exports is less than the capital intensity of consumption, $K_T/L_T < K_c/L_c$.

Inequalities (2.4a), (2.4b), and (2.4c) identify three equivalent ways of computing trade-revealed factor abundance. Trade even more directly reveals relative capital abundance if the services of one factor are exported and the services of the other are imported, since inequality (2.4b) is satisfied if $K_T > 0$ and $L_T < 0$ and is violated if $K_T < 0$ and $L_T > 0$. For reference, this will be stated as a corollary.

COROLLARY 1 If the net export of capital services and the net export of labor services are opposite in sign, then the factor with positive net exports is revealed to be the relatively abundant factor.

Theorem 2.1 and corollary 1 imply that one should be examining the factor content of *net* exports, but the tradition beginning with Leontief is to distinguish exports from imports. In some cases, this is an equivalent procedure.

COROLLARY 2 Given that the net export of capital services and the net export of labor services are opposite in sign, the capital per man embodied in exports (K_x/L_x) exceeds the capital per man embodied in imports (K_m/L_m) if and only if the country is relatively abundant in capital, $K/K_w > L/L_w$.

Proof Suppose first that $K_T > 0$ and $L_T < 0$; then by corollary 1, $K/K_w > L/L_w$. But $0 < K_T = K_x - K_m$ implies $K_x/K_m > 1$, and $0 > L_T = L_x - L_m$ implies $1 > L_x/L_m$. Thus $K_x/K_m > L_x/L_m$, and $K_x/L_x > K_m/L_m$. Similarly, $K_T < 0$ and $L_T > 0$ imply both $K/K_w < L/L_w$ and $K_x/L_x < K_m/L_m$. ■

A substantial practical defect of corollary 2 is that it assumes that K_T and L_T are opposite in sign. In fact, using Leontief's 1947 U.S. data, K_T and L_T are both positive; the United States exported both capital services and labor services. In that event, the ordering $K_x/L_x < K_m/L_m$ reveals nothing about the relative magnitudes of K/K_w and L/L_w. See Leamer (1980) for an example of the paradoxical case: $K_x/L_x < K_m/L_m$ and $K/K_w > L/L_w$. A proper procedure when $K_T > 0$ and $L_T > 0$ is to compare K_T/L_T with K/L or with K_c/L_c. As it turns out, using Leontief's data and measures of endowments, we find that $K_T/L_T > K/L > K_c/L_c$, and the United States is revealed to be more abundant in capital than in labor.

Still, as Brecher and Choudri (1982) observe, it seems surprising that the United States was a net exporter of labor services. Using (2.3), we may derive the conclusion that $L_T > 0$ implies $L/L_w > s$. If the trade balance is denoted $B = p'T$, then the Vanek equations imply that the consumption share is $s = (Y - B)/Y_w$, where Y is GNP and Y_w is world GNP. The condition $L/L_w > s$ can therefore be written as $Y_w/L_w > (Y - B)/L$. Thus U.S. trade revealed that world per capita output exceeded U.S. per capita output, adjusted for the trade balance. As a matter of fact, U.S. per capita GNP was surely in excess of world per capita GNP, even after adjustment for the trade surplus, and this finding contradicts the theory. A natural explanation is Leontief's own explanation for his nonparadox: U.S. workers were more skilled than their foreign counterparts. Though aggregation across skill groups cannot explain this finding, it may be suspected that the U.S. exports the services of skilled workers but imports the services of unskilled workers. Information reported in table 2.1 from Keesing (1966) can be used to check this conjecture. The first row in this table reveals that even after disaggregation, the United States was a net exporter of labor services in every skill category. But the third row indicates that the proportion of the domestic supply embodied in net exports is large only for scientists and engineers, and technicians and draftsmen. These are consequently revealed by trade to be most abundant. Though the lower skilled categories have positive net exports, the numbers are so small that they may be explainable by the trade surplus. In another study, Stern and Maskus (1981) found that the United States was a net exporter of the services of physical capital, human capital, and labor in 1958, but a net importer of all three in 1972. The revealed abundance ordering in 1958 was human capital > labor > physical capital, and in 1972 was physical capital > human capital > labor.

Notes on the Literature A number of other studies have applied the Leontief approach to other data sets. Tatemoto and Ichimura (1959) find that 1951 Japanese exports were more capital intensive than imports. Roskamp (1963) report that 1954 West German exports were more labor intensive than imports. Vanek (1963) finds 1947 U.S. exports to be less intensive in natural resources than imports. Keesing (1965, 1966) studies the skill content of trade of several OECD countries and reports that the U.S. exports have relatively high skill inputs compared to imports. Fareed (1972) also examines the "human capital" intensity of U.S. trade, using cost of schooling as a measure of human capital. He, like Keesing, finds exports more skill intensive than imports. Weiser (1968) for the United States and Heller (1976) for Japan report changes in factor content of trade over time. Baldwin's (1971) study of the United States is particularly noteworthy in extending the list of "resources" to include "unionization" and "concentration" and "scale economies", and also in studying the factor content of bilateral trade. But all of this research lacks a completely adequate conceptual foundation.

2.2.2 Cross-Commodity Studies of Trade and Input Intensities

Much of the empirical analysis of trade composition has sought an explanation of the trade of a particular country, often the United States,

Table 2.1
U.S. net exports of labor services by skill group (thousands of man-years; 1960 U.S. skill intensities): 1962[a]

	I	II	III	IV	V	VI	VII	VIII
(1) Net exports[b]	24.7	13.8	11.7	16.9	43.7	53.6	55.3	108.9
(2) Factor supply[c]	1,091.3	798.7	5,579.0	7,067	1,037	7,517	13,986	28,702
(1)/(2)	.0226	.0173	.0021	.0024	.0421	.0071	.0040	.0038

a. Skill classes are I = scientists and engineers, II = technicians and draftsmen, III = other professionals, IV = managers, V = machinists, electricians, and tool and diemakers, VI = other skilled manual workers, VII = clerical workers, VIII = unskilled and semiskilled workers.
b. Source: Keesing (1966, p. 257).
c. Source: U.S. Bureau of Labor Statistics, *Occupational Employment Statistics*, 1960–1967.

in terms of characteristics of the traded commodities. For example, a typical result is Baldwin's (1971) regression:

$$T_j = -1.37k_j - 421s_j + 343u_j + \cdots, \qquad R^2 = .44,$$
$$(-4.35) \qquad (-1.25) \quad (1.11)$$

where T_j = U.S. net exports of commodity j in 1962, k_j = capital per man in industry j, s_j = scale index, and u_j = unionization index. The negative sign of the capital intensity variable means that export success is negatively related to capital intensity. This seems surprising if the United States is thought of as a capital abundant country, and Baldwin uses this result as regression confirmation of the Leontief paradox. This conclusion rests on the intuitively appealing, but nonetheless false, proposition that the signs of the estimated regression coefficients are the same as the signs of the excess factor supplies $V - sV_w$. Suppose, as in Leamer and Bowen (1981), that we maintain the HOV equations and ask what can be expected if the trade vector is regressed on the factor intensities. The proposition, in the form of a regression equation, is $T = A'b$, which says that the net exports of each commodity is a linear function of the factor intensities in the production of that commodity. The least-squares estimate of the vector of coefficients b is $b = (AA')^{-1}AT$, which can be written using the HOV equations as $b = (AA')^{-1}(V - sV_w)$. The claim that b and $V - sV_w$ have the same signs is mathematically equivalent to the assertion that the transformation matrix $(AA')^{-1}$ preserves the signs of the elements of $V - sV_w$. The assumptions of the HOV theorem do imply that A is a positive matrix, but except in the 2-factor case, this is not sufficient to guarantee that b and $V - sV_w$ have the same signs. Leamer and Bowen (1981) offer a counterexample.

Aside from the fact that the cross-section regressions cannot yield reliable measures of the excess factor supply vector $V - sV_w$, it is distinctly peculiar to resort to a regression analysis to measure factor abundance when a direct computation of the factor content of trade AT is in theory exactly equal to the excess factor supply vector $V - sV_w$. But this conclusion that it makes little sense to run cross-section regressions of measures of trade performance on measures of factor intensities is derived within the context of a model in which factor prices are equalized. Hilton (1982) sketches a logic for running this type of regression when factor prices are not equalized. Suppose all countries share the same fixed input intensities but have different factor costs. The vector of zero-profit prices offered by

country c is then $p_c = A'w_c$, where A is the matrix of factor intensities, assumed to be the same in all countries, and w_c is the vector of factor returns in country c. Country c will be a producer and maybe an exporter of commodity j if it is a low cost producer, that is, if $p_{jc} < p_{jc'}$, for all $c' \neq c$. If there were only two distinct possible values for the vector of factor returns, then this condition can be written as $\sum_i A_{ij}(w_{ic} - w_{ic'}) \leq 0$. If only a subset of the factor intensities is observable, then this condition can be written probabilistically as

$$\text{Prob(commodity } j \text{ is produced)} = \text{Prob}\left(\sum_{i \in I} A_{ij}(w_{ic} - w_{ic'}) \leq z \right),$$

where I is the subset of observable factor intensities with complement $\bar{I}$ and z is the unobservable "random" variable $z = \sum_{i \in \bar{I}} A_{ij}(w_{ic} - w_{ic'})$. This suggests doing an analysis with a zero-one dependent variable indicating whether the item is exported or imported, and with factor intensities as explanatory variables. The estimated coefficients are then interpreted as factor cost differences, and in that sense this type of analysis can be said to be appropriately measuring factor abundance. This is exactly the type of analysis suggested by Harkness and Kyle (1975), who argue somewhat inconclusively that the HO model should be interpreted as predicting the sign of net exports, not the level. The defects of this approach at a conceptual level should be clear from the derivation just presented. Namely, the data analysis improperly uses trade data when production data are required by the theory. At any sensible level of aggregation all products are produced, and either the sharp theory can be rejected at the outset or it must be inferred that all countries have the same factor costs. Furthermore, if there are more than two possible factor cost vectors, a more complex analysis is required.[1]

It is therefore rather difficult to provide much theoretical support for these cross-commodity regression studies, and this serves as a second illustration of the need for a fully articulated theoretical structure to support a data analysis. Though these regression equations have a surface plausibility, the need for a theory is further apparent when you try to select a precise econometric specification, a task that necessarily requires answers to questions such as the following: How should the dependent variable be scaled since there are some very large industries and some very small? To put it differently: How can I set up the analysis so that my conclusions do not depend on an arbitrarily chosen level of aggregation? Should my explanatory variables be factor intensities, factor shares, or the ratio of intensities (like capital per man)? Should I distinguish exports from imports?

Another type of ad hoc cross-section data analysis involving measures of A and T uses simple correlation rather than multiple correlation. For example, Keesing (1967) reports that the cross-commodity correlation between the variable (U.S. exports/group of 10 exports) and the variable (research and development expenditures/sales) is .90, and he uses this as evidence that the United States is abundantly supplied in knowledge capital. This is actually very close to a factor content calculation. The cross-commodity correlation between net exports and a row of the intensity matrix, say A_i, is $= \mathrm{cov}(T, A_i)/(\sqrt{\mathrm{var}(T)}\sqrt{\mathrm{var}(A_i)})$, where cov is the covariance and var is the variance. If trade is measured in value terms and if trade is balanced, then average trade $\bar{T}$ is zero and $\mathrm{cov}(T, A_i) = A_i'T_i/n - \overline{TA} = A_i'T/n$. Then the sign of the correlation is necessarily equal to the sign of the factor content $A_i'T$. In that sense, a simple cross-commodity correlation study can be said to be an indirect factor content study, but again the question needs to be asked why a direct calculation of factor content is not done instead.

The one study that comes closest to providing a proper measure of the accuracy of the HOV model is Hufbauer's (1970). Among other things, Hufbauer computes y_1 = capital per man embodied in exports, y_2 = capital per man embodied in imports, and x = capital per man endowments for each of 24 countries. He reports that y_1 and x have a cross-country correlation of .625 and that y_2 and x have a cross-country correlation of $-.353$, and he uses this as evidence in favor of the factor abundance theory. This is not completely in harmony with the HOV model, though it is pretty close. Using the HOV model, we would not distinguish exports from imports and we would not necessarily combine capital and labor. The HOV equation (2.2) suggests regressing capital embodied in net exports on capital abundance and GNP adjusted for the trade balance. If the multiple correlation is high and if the sign of the GNP coefficient is negative, the theory can be said to be accurate.

Cross-commodity regression studies not heretofore referred to include Branson (1971), Branson and Junz (1971), Lowinger (1975), Branson and Monoyios (1977), and Stern and Maskus (1981).

2.2.3 Cross-Country Studies of Trade and Resource Endowments

The factor content studies and the cross-commodity regressions use measures of factor intensities A and trade T to infer factor endowments V.

The other major type of data analysis computes cross-country regressions with data on T and V, implicitly inferring A. Examples of cross-country regressions include Chenery (1960), Chenery and Taylor (1968), Leamer (1974), Chenery and Syrquin (1975), and Bowen (1981). This is the approach taken in this book, and a full discussion of the empirical issues is presented in chapters 5 and 6. Here it suffices to observe that the maintained hypothesis is the even model, which allows us to write the trade vector as $T = A^{-1}(V - sV_w)$. This implies that cross-country regressions of net exports on excess factor supplies $V - sV_w$ provide estimates of A^{-1}. The HOV model is then judged to be accurate if the R^2 values of these regressions are high, though it needs to be understood that this is a weakened form of the model, which makes no reference to factor intensities. In place of the hypothesis that A, T, and V fit together as predicted by the HOV equation, we substitute the hypothesis that T is a linear function of V. Interpreted as sharp hypotheses, these statements are virtually identical. The even HOV model implies linearity, and conversely, linearity almost surely implies the even HOV model. However, interpreted as approximations, these two hypotheses may be quite different. It is conceivable that trade is "approximately" a linear function of endowments, but at the same time the HOV equations do not hold, even "approximately." I shall ignore this possibility, since it depends on fuzzy notions concerning the adequacy of an approximation, and I shall proceed as if the demonstration of the accuracy of the estimated linear trade model were necessarily a demonstration of the accuracy of the HOV model.