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A Test of the General Validity of the Heckscher-Ohlin Theorem for Trade in the European Community

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Abstract

While the Heckscher-Ohlin-Vanek (HOV) theorem has been a dominant paradigm in trade theory, the empirical evidence to support it has been weak. This paper develops a modified HOV model that allows technologies to differ across countries. The revised model significantly improves the theory's accuracy in predicting trade flows in contrast to the traditional model. The paper also illustrates that, since countries have different technologies, measures of factor contents of trade in final goods using direct and domestically produced indirect input requirements are more accurate and yield more consistent predictions than do traditional measures.

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I. INTRODUCTION

The Heckscher-Ohlin-Vanek (HOV) theorem, the multidimensional generalization of the Heckscher-Ohlin (HO) theorem, has been a dominant paradigm in trade theory. However, the empirical evidence for its main implication has been very weak. The theorem holds that a country will export the good that intensively uses the factor in which the country is relatively abundant.[1] One of the assumptions underlying the HOV theorem is that countries have identical constant-returns-to-scale technologies. This paper modifies the HOV theorem to permit differences in endowments *and* differences in production techniques and production technologies between any two countries. Using data for five European countries, it shows that this generalization significantly improves the theory's accuracy in predicting net factor contents of trade.

This paper makes four contributions to understanding and testing the importance of proper accounting of international technology differences in explaining observed patterns of trade in factor services. First, the modified HOV theorem presented here introduces a relationship between trade, factor endowments, and factor input requirements based on *a country's actual input-output matrix*. This permits unrestricted differences in technology across countries: countries may be operating either at different points on the same production function (reflecting differences in techniques of production, which imply that countries have different factor prices) or they may have different production functions (reflecting differences in technology). Earlier studies permitted no or only limited differences in technology among countries. These studies used one country's input-output matrix to estimate the factor content of trade for all countries included in the sample, or they adjusted the available technique matrix to allow for neutral, and in Trefler (1995) nonneutral, differences in technology to test modified versions of the HOV theorem. The most recent studies by Bowen, Leamer, and Sveikaukas (1987) and Trefler (1993, 1994) have rejected the strict HOV equations in favor of equations that allow for neutral technology differences and measurement errors. However, these studies rely on indirect tests of the modified HOV theorem since technical differences among countries are estimated rather than observed. In contrast, the formulations derived here are based directly on each nation's actual input-output matrices and directly test the modified HOV theorem.

Second, using detailed data on factor input requirements for five core member countries of the European Community (EC) (Belgium, France, Germany, Italy, and the Netherlands) the paper finds that the modified HOV theorem is significantly more accurate than the strict HOV theorem in predicting the net factor content of trade. Since the strict HOV equations are nested in the modified HOV equations, the paper is the first to directly contrast the results of identical tests of the strict and modified HOV theorems.

Third, by conducting empirical tests of the modified HOV theory for both 1970 and 1980, the paper addresses whether discrepancies between the predictions of the modified

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[1] Leamer and Levinsohn (1995) provide a comprehensive survey of this literature.

HOV theorem and the observed pattern of trade can be attributed to protection. The year 1970 is taken to represent the end of approximately the first decade of EC's existence, and the year 1980 is taken to represent approximately the end of its second decade in existence.[2] The main finding is that the modified HOV theorem provides only slightly more accurate predictions for 1980 over 1970.

Fourth, the paper illustrates that if countries have different technologies, the way in which the factor content of trade is measured becomes highly important. It highlights that if countries have different technologies there are different interpretations for the factor contents of trade. It also shows that calculations of factor content of trade based on the standard Leontief definition in the modified and strict models can be biased if countries have different technologies because the technology used to produce imported final and intermediate goods may be different from the technology used in the country importing the goods.[3] Measures of factor content of trade under the Leontief definition from total input requirements (direct and indirect inputs) do not take this into account: the domestic country's technology is attributed to the imported goods. The paper then illustrates that this bias may distort both the relative differences and the degree of concordance between the observed and predicted factor contents of trade in both the strict and the modified HOV theories.

The paper develops two versions of the modified HOV theory to determine the effect of attributing domestic direct input techniques to imported intermediate goods. In the paper Section II-A presents the modified HOV theory in terms of differences in relative endowments and techniques of production between two countries where the factor content of trade is measured using total input requirements (Modified HOV A). In Section II-B the modified HOV theory excludes imported intermediate goods and relies only on differences in *domestic* factor contents of trade in *final goods* between two countries, differences in their relative endowments, and differences in *domestic* techniques of production. It bases this on direct plus domestically produced nontraded indirect input requirements (Modified HOV B). The paper

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[2] Only the original six members (from) were in the EC in 1970. The other members currently in the EC joined after 1972. Thus, reductions in tariff and nontariff barriers were ongoing between the original member states and the new entrants throughout the period 1970 to 1980 since Denmark, Ireland, and the United Kingdom joined the EC in 1972. Also, although the EC was created in 1957, tariffs among the original six members were removed only in 1968. Thus, since adjustment to reforms is slow, 1970 can be taken to represent a period of more restrictions to trade.

[3] The standard Leontief definition of factor content of trade is measured using total input requirements. It, therefore, gives us the amount of the factor that is employed directly to produce net exports as well as the indirect amounts of the factor which are presumed to be employed in the production of both domestically-produced and imported intermediate goods based on the domestic technology.

provides empirical evidence that the latter version is indeed a better predictor of the factor content of trade.[4]

II. THEORETICAL FRAMEWORK AND TESTABLE IMPLICATIONS OF THE MODIFIED HOV MODEL

A. Modified HOV Model

The derivation begins with the identity expressing a country's vector of net exports as the difference between production and intermediate input use and consumption:

$$T_i = (I - B_i)Q_i - C_i$$

where T_i = $(n \times 1)$ vector of net exports of country i,

Q_i = $(n \times 1)$ vector of gross output of country i,

C_i = $(n \times 1)$ vector of country i's final consumption,[5] and

B = $(n \times n)$ matrix, which indicates the amount of output an industry j must buy from industry k to produce one dollar of its own product.

Premultiplying the equation by $A_i(I - B_i)^{-1}$, and noting that $A_iQ_i = V_i$, yields a country's net factor exports expressed as the difference between factors absorbed in production and factors absorbed in consumption:

$$A_i(I - B_i)^{-1}T_i = V_i - A_i(I - B_i)^{-1}C_i, \tag{1}$$

where V_i = $(n \times 1)$ vector of factor endowments of each country i and A_i = $(m \times n)$ matrix of primary factor requirements, which indicates only how much direct input of each of m factors is required to produce one dollar of gross output within each of the n industries for each country i; thus, $A_i(I - B_i)^{-1}$ = the $(m \times n)$ matrix of gross factor input requirements, which indicates the total (both direct and indirect) amount of each of m factors needed to produce one dollar of gross output within each of n industries.

As in the strict HOV studies, this identity is transformed into a testable hypothesis by making one or more of the following assumptions:

(1) No measurement errors.

(2) Identical and homothetic tastes across the world.

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[4] The strict HOV equations that are embedded in both versions of the modified HOV theory are tested. Since comparisons between each set of strict HOV tests and tests of the relevant modified theory were similar, only the results of the strict HOV tests using the theory in Section II-A are reported.

[5] Throughout the paper, C_i represents total goods absorption or the sum of final goods consumption, investment, and government spending.

(3) Free international trade and perfect competition exist across countries, leading to internationally equal relative prices of goods; and

(4) Identical technologies across the world so that $A_i = A$ and $B_i = B$.

The assumptions of identical and homothetic preferences and identical prices of goods imply that each country consumes commodities in the same proportion. The consumption vector can be expressed as a proportion of world net output,

$$C_i = s_i Y_W, \tag{2}$$

where s_i is the expenditure share for each country *i* in total world expenditure.[6] In a two-country model the relationship in equation (2) can be written as $C_1 = \alpha C_2$, where $\alpha = \frac{s_1}{s_2}$. To obtain the modified version of the HOV theorem the equations for two countries are combined using only assumptions one, two, and three, yielding:

$$A_1(I-B_1)^{-1}T_1 - \alpha A_2(I-B_2)^{-1}T_2 = V_1 - \alpha V_2 + [A_2(I-B_2)^{-1} - A_1(I-B_1)^{-1}]\cdot C_1,$$

or

$$F_{1t} - \alpha F_{2t} = V_1 - \alpha V_2 + [A_2(I-B_2)^{-1} - A_1(I-B_1)^{-1}]\cdot C_1, \tag{3}$$

where

$$\alpha = \frac{s_1}{s_2},\ F_{it} = A_i(I-B_i)^{-1}T_i \text{ for } i = 1, 2$$

is a relationship between the factor contents of multilateral trade in two countries.[7] The relationship is expressed in terms of the differences in both the factor endowments *and* the techniques of production of the two countries multiplied by the vector of the first country's consumption.[8] Equation (3) shows that net exports to the world of factor services abundant (scarce) in country one relative to country two, and of factor services that are relatively more (less) efficient or productive in country one relative to country two, should be greater (less)

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[6] This definition of s_i makes no assumption of trade balance.

[7] By substituting equation (2) into equation (3), the relationship between the relative net factor contents of trade can be expressed in terms of the vector of world output and the ratio of country one's expenditure in world expenditure. However, data for the vector of world production levels and world expenditure levels would need to be approximated by summing production and expenditure levels across many countries since no readily available data exist on world production and world expenditure. Thus, expressing the relationship in the form of equation (3) conveniently eliminates the need to measure world production and world expenditure since s_i is eliminated and α is simply the ratio of country one's expenditure to country two's expenditure.

[8] It is important to realize that the second term on the right-hand side of equation (3) also captures homotheticity issues, although in this paper, it is referred to as encompassing differences in technology between countries.

than the net exports of factor services from country two, or $F_1 - \alpha F_2 \underset{>}{\overset{<}{=}} 0$ as

$V_1 - \alpha V_2 + [A_2(I - B_2)^{-1} - A_1(I - B_1)^{-1}]C_1 \underset{>}{\overset{<}{=}} 0$ for each factor m. If a factor is relatively more efficient in a particular country so that $[A_2(I - B_2)^{-1} - A_1(I - B_1)^{-1}]C_1 > 0$, but scarce so that $V_1 - \alpha V_2 < 0$, the overall effect on the net exports of the services of the factor depends on the relative magnitudes of the two effects. The ratio of the expenditure levels, α, controls for differences in country size.

The right-hand side of equation (3) can be viewed as predicting the relative factor content of trade (denoted by a hat) between two countries, which can be tested by obtaining data for net exports, factor input requirements, consumption, and endowments and by comparing the extent to which the estimates violate the equality given by equation (3). The prediction error associated with equation (3) can be calculated as:

$$\varepsilon = (\hat{F}_1 - \alpha \hat{F}_2) - (F_1 - \alpha F_2) = (V_1 - \alpha V_2) + \left\{ [A_2(I - B_2)^{-1} - A_1(I - B_1)^{-1}]C_1 \right\} - (F_1 - \alpha F_2) \quad (4)$$

The prediction error tests the three assumptions adopted. If preferences are not homothetic and identical across the world and the relative prices of goods are not the same across the world or if measurement errors appear, the equation will fail to accurately predict the actual relative factor content of trade between the two countries.

The theory derived here allows that countries have different direct and indirect input-output matrices, A_i and B_i, either because they use different production techniques but have the same production technology or because they have different production technologies altogether. Countries' production techniques can differ because of trade and domestic distortions, such as variations in the amount of subsidy an industry enjoys in a country or the degree of influence labor unions wield.

From equation (3), it is clear that adding assumption four of identical technologies across countries yields the strict HOV result, because the second term on the right-hand side of equation (3) drops out: net exports of a factor depend only on relative factor abundances.[9] With identical techniques of production, equation (3) can be interpreted as saying that net exports from country one to the world of services of factors abundant (scarce) in country one relative to country two should be greater (less) than net exports from country two to the world of the services of those factors. In that case the relative efficiency and productivity of a factor in one country relative to another is no longer of consequence for determining the pattern of trade. The prediction error corresponding to this case in equation (4) would be a

[9] The expression is in the same form as that derived and empirically tested by Staiger, Deardorff, and Stern (1987).

test of assumptions one to four. Thus, differences in the predictive power of the strict and modified HOV equations would reflect the validity of the assumption that technologies are identical across countries.[10]

There are several ways to define and interpret the factor content of trade when countries have different technologies.[11] This paper uses the standard Leontief (1953) definition to test the HOV model. According to this definition, the factor content of trade is measured in terms of both direct and indirect total input requirements. This, however, may not provide an ideal measure of the relative net factor content of trade when countries have different technologies because, under this definition, a country may appear to be a net importer of a factor when it is, in fact, a net exporter and vice versa. For example, if a country uses labor-intensive techniques to produce an imported good while the country where the good is produced uses capital-intensive techniques, the calculations based on this definition would show the country as a net importer of labor rather than of capital. Once international technology differences are permitted, an ideal measure of factor content of trade would impute to traded goods those factors actually used in their production wherever that may have taken place. This would require tracing the production history of all traded goods and all the intermediate inputs used in the production of those goods. In addition, it would require obtaining data on factor input requirements for all countries that engage in international trade. Since these are difficult tasks, the paper reverts to the standard Leontief definition, even though it may not be conceptually ideal. Nevertheless, it is useful because it makes economic use of data and shows the importance of technology differences for predicting trade patterns.

In light of the discussion above, what is the advantage of the modified HOV theory over the strict HOV theory? First, employing a country's actual input-output matrix provides more accurate estimates of the factor content of each nation's exports than if a representative matrix or the U.S. input-output matrix were used (as is the norm with the strict HOV model).

[10] Inserting assumptions two and three directly into equation (3) yields the generalized HOV theorem in terms of the factor content of trade of a single country. Traditional HOV equations are also nested in the single-country equations. Empirical tests of the single-country equations can be conducted in the same manner as that of the two-country equations. The advantage of the two-country equations is that they permit a nice interpretation of relative factor contents of trade as being determined by relative differences in the endowments of the two countries and relative differences in their technologies under homothetic preferences and common goods prices across the world. Also, the empirical tests of the two-country equations do not require an estimate of world output, and the same data (the vector of national consumption, the vector of national endowments, and an input-output matrix) can be used to test both the strict and modified hypotheses. The pairwise tests thus isolate the role of international technology differences and exclude the possibility of measurement errors being the cause of differences in the strict and modified HOV results.

[11] Deardorff (1982) discusses the implications of dropping the assumption of identical technologies and alternative definitions of the factor content of trade when technologies differ across countries.

Nevertheless, as already mentioned, using a nation's input-output matrix may not adequately capture the factor content of a country's imports because imports can be produced with a technology that is different from that used in the importing country. In fact, a country is likely to import goods that it is less efficient in producing domestically.[12] In this case, measures of the net factor content of trade will have larger negative components than if the input requirement matrix of the country where the good was produced were used instead. Furthermore, the factor content of a country's exports will be biased to the extent that imported intermediate goods are used in the production of exports. However, using a country's actual input-output matrix rather than the U.S. equivalent improves on past studies of the HOV theorem if production techniques are more similar among the European countries than between them and the U.S., especially since most of the trade in Europe is intra-EC trade.

There is no need to assume equal factor prices across countries under either the strict or the modified HOV theories. Differences in factor prices can, therefore, explain why countries produce different subsets of products if they have identical technologies, as under the strict HOV theorem, but not necessarily if they have different technologies, as under the modified HOV theorem. Also, differences in factor prices can explain why techniques of production may differ across countries, as under the modified HOV theorem.

It is also important to note that when assumption two and assumption three are made less restrictive so that they hold across five original members of the EC (EC5) only, equation (3) remains valid.[13] This implies that consumption in each country is proportional to aggregate EC5 consumption, $C_i = s_{EUi} C_{EU5}$, where s_{ECi} is the share of country i's expenditure in total EC5 expenditure. In a two-country model, this relationship can be expressed as $C_1 = \alpha C_2$. It is identical to the two-country relationship obtained under the stricter versions of assumptions two and three. Thus, theoretically, it is irrelevant whether the modified HOV model in equation (3) is tested across the stronger or weaker versions of assumptions two and three, since they should yield the same results when applied to members of the EC5.

The paper uses the sign test and the rank test typically employed in studies of the strict HOV theorem to test the predictive powers of both the strict and modified HOV equations. In terms of equation (3), the sign test compares the sign of the actual relative factor contents of trade between two countries with the sign of the predicted relative factor contents of trade.

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[12] This can occur if the range of techniques of production available to a country is limited by their endowments. Also, trade or domestic distortions such as labor unions, can cause countries to use different techniques even if they have the same technologies available to them.

[13] Luxembourg is also an original member of the EC but is excluded from this study because the data for it were unavailable.

The idea behind the rank test is that for a given pair of countries, if country one is found to be relatively more abundant and more efficient in factor f than factor g relative to country two, then net exports by country one relative to country two of factor f will be greater than net exports by country one relative to country two of factor g. This can be stated as follows: If

$$V_1^f - \alpha V_2^f + [A_2^f(I - B_2)^{-1} - A_1^f(I - B_1)^{-1}]C_1 > V_1^g - \alpha V_2^g + [A_2^g(I - B_2^g)^{-1} - A_1^g(I - B_1^g)^{-1}]C_1$$

then

$$F_1^f - \alpha F_2^f > F_1^g - \alpha F_2^g.$$

Pearson correlations, Kendall rank correlations, and the proportion of correct rankings can then be calculated.

In addition to examining the predictive powers of the strict and modified HOV theorems, the paper explores the influence of trade barriers on the performance of both theories by conducting tests for 1970 and 1980, which capture the pre- and post- trade liberalization periods in the EC respectively. The evidence on pre- and post- liberalization allows us to compare the predictive powers of the strict and modified theorems both in the presence and absence of trade barriers.

Trade barriers violate assumption three and thus cause a discrepancy in both theories. Also, when factor prices differ across countries, trade barriers, by inducing countries to produce the same subset of goods, encourage countries to use different techniques of production. Thus, violation of assumption three leads to violation of assumption four because of different factor prices. We, therefore, would expect that if technology is the same between the five EC countries (which is plausible given the countries' relative homogeneity), the modified HOV would perform better than would the strict HOV in 1970 (because it accounts for departures from assumption four) but both would perform equally well in 1980. But, if technology is not the same, the modified HOV would do better than the strict HOV in both 1970 and 1980.

In addition, the paper calculates the prediction error, ε, and compares it across each period. Since all of the variables in the equation grow over time (trade, endowments of factors, levels of net output, factor accumulation), the prediction error will grow as well, even if the economy stays the same otherwise. Thus, measures of ε for each period will be normalized by dividing by the sum of the GDPs of the five founding EC member countries for the relevant year. If trade has grown faster than GDP there may still be a bias toward the normalized prediction error growing over time. Thus, the paper's results are strengthened if the normalized prediction error falls over time. Moreover, if the prediction error is smaller in absolute value following trade liberalization, the implication would be that trade barriers account for the deviations of the predictions of the HOV theorem from the actual patterns of trade.

B. An Extension of the Modified HOV Model

The theoretical derivation in Section II-A implicitly but incorrectly attributes the direct input techniques of the domestic country to imported intermediate goods. This can lead to false rejection of the theory that countries net export the services of factors in which they are relatively abundant or in which they are more efficient in cases where substantial differences exist between the techniques used to produce the imported goods and their domestic equivalents.[14] For example, if a country uses more labor (l) to produce an intermediate good than does the country from which it imports the intermediate good, and if this imported intermediate good is subsequently used to produce exports, the measured (m) total (direct plus indirect) labor content of net exports from country one will be greater than it actually is (a), $F_1^{lm} > F_1^{la}$, in terms of the actual amount of labor that was employed to produce the good. If $F_1^{la} - \alpha F_2^{la} < 0$ and $V_1^{la} - \alpha V_2^{la} < 0$ and $[A_2^{la}(I - B_2)^{-1} - A_1^{la}(I - B_1)^{-1}]C_1 < 0$, but now $F_1^{lm} > F_1^{la}$ and country two's factor content of trade is measured correctly, we may find $F_1^{lm} - \alpha F_2^{lm} > 0$ when it should really be negative in the same way that

$$V_1^l - \alpha V_2^l + [A_2(I - B_2)^{-1} - A_1(I - B_1)^{-1}]^l C_1 < 0$$

(both actual and measured) is negative. If country one is less endowed with labor relative to country two, measurements of $V_1 - \alpha V_2 < 0$ are unaffected, even if direct inputs are incorrectly attributed to imported indirect input requirements. Also, the sign of the term involving differences in technology between countries would be unchanged from its true sign by incorrectly attributing domestic direct inputs to indirect imported inputs. It now appears that country one needs more labor than it actually does to produce a dollar of output. It, thus, would appear that country one is even more inefficient in producing labor-intensive goods than it actually is, or that the difference in techniques between the two countries is a larger negative number.[15]

Thus, the methodology in this section solves for an equation that predicts the actual factor content of trade in final goods (exports minus imports only for consumption or re-export) in terms of differences in endowments between countries and differences in domestic input requirements (direct inputs plus indirect inputs used to produce domestic goods). The equation does not require measuring the factor content of imported intermediate goods using the importing country's techniques of production.[16]

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[14] Helpman (1998) provides a recent proof of a similar point for the case where countries have identical technologies but operate at different points on the same production function.

[15] The overall distortion caused by measuring relative factor contents of trade using direct plus all indirect requirements will depend on the relative effect on both countries.

[16] Appendix II provides a numerical example illustrating how the alternative definition of factor content of trade defined here may provide a more appropriate interpretation than the standard Leontief definition.

As in Section II-A the derivation begins with the definition of the vector of net exports,

$$T_i = (I - B_i)Q_i - C_i . \tag{5}$$

The vector of net exports can be rewritten to reflect that two kinds of imports exist: imports for immediate consumption, M_C, and imports for use as intermediate goods, M_I. As defined in Section II-A, B is the $(n \times n)$ matrix reflecting the distribution of intermediate goods across sectors. Since intermediate goods can either be produced domestically or imported, the definition of B encompasses both types of intermediate inputs. Decomposing B into its two components, B_d (the $(n \times n)$ matrix representing the distribution of domestically produced intermediate goods across sectors) and B_f (the $(n \times n)$ matrix representing the distribution of imported intermediate goods across sectors), equation (5) can be rewritten as:

$$X_i - M_{Ii} - M_{Ci} = Q_i - B_{di}Q_i - B_{fi}Q_i - C_i \tag{6}$$

Recognizing that $B_{fi}Q_i = M_I$ yields an expression for net trade in final goods only,

$$T_i' = (I - B_{di})Q_i - C_i , \tag{7}$$

where T_i' represents total exports minus imports of goods that are domestically consumed only. Premultiplying equation (7) by $A_i(I - B_{di})^{-1}$, and noting that $A_iQ_i = V_i$, yields

$$A_i(I - B_{di})^{-1}T_i' = V_i - A_i(I - B_{di})^{-1}C_i . \tag{8}$$

Adopting the same assumptions as for the modified HOV model in Section II-A and following the same remaining steps, the following bilateral relationship of factor content of trade can be obtained from equation (8):

$$F_{1t}' - \alpha F_{2t}' = V_1 - \alpha V_2 + [A_2(I - B_{d2})^{-1} - A_1(I - B_{d1})^{-1}]C_1 ; \tag{9}$$

where F_{it}' represents the factor content of final goods trade for each country i that is calculated using direct plus nontraded indirect input requirements for each industry. Equation (9) has a similar interpretation as equation (3) in Section II-A. However, in this case the factor content of trade is calculated using direct and domestically produced (nontraded) indirect input requirements and net exports is defined and measured as total exports minus imports for final consumption. Also, the second term on the right-hand side is the difference in the direct plus nontraded indirect input requirements between two countries multiplied by the vector of consumption.

A version of the strict HOV model is also nested in equation (9). Although not presented here, the results of the tests of the strict HOV versus the modified HOV equations outlined in this section show the same pattern as those discussed in Section II-A.

Since the factor content of trade in final goods does not include the importing country's factor content of imported intermediate goods instead of the factor content that would be obtained when the techniques of the country where the imported goods are produced is used, this should eliminate the discrepancy between observed and predicted factor contents of trade. If imports for intermediate use constitute most of imports, differences in technologies between countries for producing intermediate goods will have a large impact on the discrepancy between predicted and actual factor contents of trade.

Table 1 shows that imports for intermediate use constitute most of the imports into each of the countries examined. The average proportion of imported intermediate goods to total imports is 0.70 in 1970 and 0.68 in 1980 for the EC5. This suggests that a large part of the empirical shortcomings of the modified HOV theory that arise from incorrectly attributing direct inputs to indirect inputs or to overall imports will be eliminated. Only the problem of incorrectly attributing domestic techniques of production to imports for final consumption remains.

Table 1.

Proportion of Imported Intermediate Goods from Total Imports
(In percent)

Country	1980	1970
Belgium	63	70
Germany	69	71
France	68	69
Italy	78	75
Netherlands	65	67

III. TEST RESULTS

Assumptions two and three together imply the relationship in equation (2). Thus, the validity of both assumptions is tested directly by comparing the predicted consumption levels from equation (2) with actual national consumption levels. Since the data on world net output to predict consumption from equation (2) are not available (and it was shown that the same modified HOV equation holds when assumptions two and three hold across the EC5) the paper examines the predictions of national consumption only as a proportion of EC5 consumption. Table 2 shows the Pearson and Kendall rank correlations between actual and predicted final consumption in five selected EC countries obtained by multiplying each country's expenditure share in EC5 expenditure by total EC5 consumption. The table shows a high correlation between actual and predicted consumption for all five countries, suggesting that tastes across the region may indeed be homothetic (assumption two).

Figures 1–6 graph the predicted versus the actual factor contents of trade, obtained by calculating equations (3) and (9) for the three versions of the HOV theorem. Figures 1 and 2 plot the results obtained from the strict HOV version of equation (3) for 1970 and 1980 respectively. These are obtained under the assumption that all five countries have the German technology matrix.[17] Figures 3 and 4 represent the counterparts to the modified HOV theorem in equation (3) (modified HOV A), and Figures 5 and 6 represent the counterparts to the modified HOV theorem in equation (9) (modified HOV B).[18] Six factors are used to generate the results: land, capital, manual workers, professional and administrative workers, sales and technical workers, and clerical staff. The Sign HOV theorem predicts that all observations will lie in either the top-right quadrant or the bottom-left quadrant, either

where $F_1 - \alpha F_2 > 0$ and $V_1 - \alpha V_2 + (A_2(I-B_2)^{-1} - A_1(I-B_1)^{-1})C_1 > 0$ or,

where $F_1 - \alpha F_2 < 0$ and $V_1 - \alpha V_2 + (A_2(I-B_2)^{-1} - A_1(I-B_1)^{-1})C_1 < 0$.[19]

Under the stronger version of the HOV theorem,

$$F_{1t} - \alpha F_{2t} = V_1 - \alpha V_2 + [A_2(I-B_2)^{-1} - A_1(I-B_1)^{-1}]\cdot C_1.$$

That is, all the observations lie on a diagonal (45 degree) line through the origin. To determine the exact number of observations lying in the demarcated quadrants, Table 3 presents the results obtained from the sign tests. For each year examined, Table 3 is divided into three columns which report the number of times the sign of the left hand side matches the sign of the right hand side of the equation that is relevant for each of the three versions of the HOV theory for the six factors in each pair of countries.

It is evident from Figures 1 and 2 of the strict HOV theory that the observations do not lie mainly in the top-right and bottom-left quadrants. Also, the observations do not lie along the diagonal (45 degree) line. Table 3 confirms these results. It shows that the signs only match about 58 percent and 42 percent of the time for all 10 pairs of countries in 1970 and 1980 respectively for the strict HOV theory developed in Section II-A. Although not reported in Table 3 or in the figures, the sign tests of the strict HOV theory embedded in the modified HOV B theory match correctly 50 percent of the time for both years. Therefore, on average, sign tests of the strict HOV theorem perform no better than the probability obtained from a coin toss and replicate the results of previous HOV studies regardless of the theoretical derivation used.

Turning to the plots of the modified HOV A equations in Figures 3 and 4, we find that the number of observations lying outside the demarcated quadrants is dramatically reduced, particularly for 1970. Also, the distance of the observations to the diagonal line are reduced in comparison with the observations of the strict HOV theory. Table 3 shows that signs match 78 percent of the time for 1970 and 70 percent of the time for 1980 for the modified HOV A theory. These results present a dramatic improvement over the tests of the strict HOV theory

[17] The results of the strict HOV test were similar regardless of which country's technology matrix was taken to be representative for all countries. Therefore, results were reported only when all of the countries examined were assumed to have the German technology matrix.

[18] In order to plot the observations all of the equations must be expressed in comparable units. Therefore, the equations representing each factor are scaled by the total endowments of the factors in the EC5. The equations are already adjusted for differences in country sizes.

[19] Three versions of the HOV theorem are being tested here. However, in this section of the text, the generalized HOV equation (4) version is used for making the explanation.

and are unlikely to be obtained randomly as would a 50 percent chance of getting a head or tail in a coin toss. It is important to note that when the country pairs that include Italy are removed from the sample for the modified HOV A theory, the percentage of correct sign matches increase dramatically to 94.4 percent for 1970 and 86 percent for 1980. Thus, it appears that Italy has a strong downward effect on the proportion of correct sign matches. This may be caused by the fact that when individual country factor input requirements are used to measure the factor content of trade in countries where imports tend to be inefficiently produced domestically, the calculations will be biased and will distort the test results. Another possibility is that the assumption of homothetic preferences across the EC5 or across the world does not hold as well for Italy. However, Table 2 reveals an extremely high correlation between actual and predicted consumption under the assumption of homothetic preferences in the EC5 even though the correlations are slightly lower for Italy than for the other countries.

A comparison of the two modified versions of the HOV theory presented in Section II can be made by viewing Figures 3 and 5 for 1970 and Figures 4 and 6 for 1980. More observations lie in the demarcated quadrants in Figure 6 than Figure 4. Moreover, the observations tend to lie along the diagonal line instead of around the line. Figures 3 and 5 for 1970 show less evidence of an improvement in the predictions of the theory when the direct and nontraded indirect inputs are used to measure the factor content of trade in final goods. Thus, the fit of the equations generally improves under the modified HOV B theory relative to the modified HOV A theory. Excluding Italy from the sample further improves the performance of the modified HOV B sign test: for 1970 the signs match 80 percent of the time and for 1980 they match 94 percent of the time. The test shows very little difference between the percentage of correct sign matches for 1970 and 1980 when the country pairs that include Italy are in the sample. Excluding the equations with Italy results in the percentage of correct sign matches in 1980 to increase somewhat over 1970, suggesting that removal of protection has a small impact in improving the predictions of the modified HOV theory for the observed patterns of trade.

These results indicate that a distinction needs to be made between traded and nontraded intermediate inputs to avoid distortion. Otherwise, the direct inputs of the domestic country will be ascribed to the imported intermediate inputs, leading to erroneous predictions of relative factor contents of trade and relative differences in technology.[20] Once the effect of incorrectly attributing direct input techniques to imported intermediate goods is removed, the modified theory B becomes a better predictor of trade patterns for 1980 and is no worse as a predictor for 1970. It is possible that the increasing trade among EC member nations is encouraging countries to import the intermediate goods in which they are not efficient

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[20] Table 1 shows that Italy has the highest proportion of imports for use as intermediates in production, particularly in 1980.

producers. That may be why tests show a stronger impact on the predictions of the modified HOV theorem for 1980 than for 1970.[21]

For each version of the modified HOV theory, the paper calculated the proportion of times the sign of the actual factor content of trade matched that of trade predicted by endowments and the sign of trade predicted by differences in technology (and implicitly the homotheticity assumption). The signs of each term matched the observed relative factor contents of trade approximately the same number of times for the whole sample (approximately 60 percent of the time under the modified HOV B theory). Also, estimating the factor content of trade in final goods using direct plus nontraded indirect inputs yields a substantial increase in the proportion of sign matches between the relative factor content of trade in final goods and the relative endowments term, in contrast to the modified HOV A theory. This confirms the a priori prediction that measuring the factor content of trade using total input requirements will primarily distort the relationship between relative endowments and relative factor contents of trade.

Tables 4 and 5 present Pearson and Kendall's tau rank correlations between observed (left-hand side) and predicted (right-hand side) factor content of trade calculated from differences in relative endowments and in technology between two countries. The equations representing each factor are scaled by the total endowment of the factor in the EC5. This is because the factors must be expressed in comparable units to satisfy the statistical hypothesis of homoskedasticity. Table 4 reports the results when direct plus indirect inputs are used as in equation (3). The Pearson and Kendall tau rank correlations were also estimated under the strict HOV assumptions (but they are not reported here). Correlations obtained from the strict tests of the HOV theory were lower for most of the country pairs than those obtained from the modified HOV theorem. It can be seen that for most country pairs the Pearson correlation between the two sides of the equation from the modified HOV A theorem are extremely high for both 1970 and 1980 and slightly higher for 1980 than for 1970. However, for the country pairs that include Italy the correlation is negative rather than positive. The average correlation between the left-hand side and the right-hand side of equation (3) is 0.313 in 1970 and 0.384 in 1980, but jumps to 0.792 in 1970 and 0.913 in 1980 when pairs that include Italy are removed from the sample. The rank correlations are also high in most cases, particularly in

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[21] Following Trefler (1995) and Davis et al. (1995), the net factor trade residual $\varepsilon = F_1 - \alpha F_2 - [V_1 - \alpha V_2 + (A_2(I-B_2)^{-1} - A_1(I-B_1)^{-1})C_1]$ was plotted against the predicted net factor trade $V_1 - \alpha V_2 + [A_2(I-B_2)^{-1} - A_1(I-B_1)^{-1}]C_1$ under each of the three scenarios of the HOV theorem examined in this paper. In all three cases, the theory tells us that the observations should be a horizontal line at zero. For the observations obtained under the strict HOV assumptions, the observations lie along the $F_1 - \alpha F_2 = 0$ line. Thus, "the case of the missing trade" identified by Trefler (1995) is also encountered here. This pattern is slightly diminished in the plots of the generalized HOV tests for both of the years examined. However, the main finding, as in Davis et al., is that the magnitude of the errors is greatly diminished under the generalized HOV tests.

1980, but there are still cases where the correlations are negative. The negative correlations for the country pairs with Italy may simply be an artifact of an outlier. The proportion of pairwise comparisons is extremely high for almost all of the countries, but are higher for 1980 than for 1970.[22]

Table 5 presents the results based on use of direct plus nontraded inputs as expressed in equation (9). The results are similar to those in Table 4 and almost all of the negative correlations disappear, except in a few cases for the country pairs that include Italy. The average Pearson correlation between the left-hand side and the right-hand side is 0.545 in 1970 and 0.598 for 1980 (0.743 for 1970 and 0.923 for 1980, when Italy is excluded). The Kendall rank correlations are also high, as are the proportions of correct pairwise comparisons, particularly for 1980. Thus, it appears that the predicted factor content of trade explains almost all of the variations in the actual observed factor contents of trade for almost all of the cases except for the pairs that include Italy. Thus, the equations are a vast improvement on the strict HOV equations and are a slight improvement on the modified HOV A equations.

Since the figures, sign tests and rank tests clearly portray the contrast between the predictive powers of the strict and modified HOV theories, and since the modified HOV B theory performs better than the modified HOV A theory, the remaining analysis is conducted only for the modified HOV B theory.

For each factor, there are 10 equations that predict relative factor contents of trade where each equation represents a country pair. If the theory is correct, the 10 equations should give a consistent ranking of countries in terms of the observed factor contents of their trade in final goods relative to the other countries examined. For example, if Germany is found to be a greater net exporter of products intensive in manual workers than Belgium in the equation relating German-Belgian relative factor trade, and Belgium is found to be a greater net exporter of the services of manual workers than Italy in the equation relating Belgian-Italian trade, then we can infer that Germany must also be a net exporter of the services of manual workers relative to Italy. This can also be verified from the equation relating German-Italian factor trade. The 10 equations also yield a ranking of the countries from the predicted relative factor contents of trade in final goods from differences in endowments and differences in technology. However, this ranking may not be consistent.[23] Thus, Table 6 reports the ranking of countries from largest to smallest net exporters of a factor to the world relative to the other four countries examined for the modified HOV B theory. The rankings are obtained from the observed and predicted factor contents of trade in final goods. In two cases the tests did not yield consistent predictions for the ranking of countries for 1970, but the rankings were all consistent for 1980. So, for example, it appears that Germany is both observed and predicted to be the greatest relative exporter of professional and administrative worker

[22] The proportions are based on estimates of Kendall's tau for six factors so there are 15 possible ways observations can be paired for each country pair.
[23] See Appendix II.C in Hakura (1995).

intensive products in 1980 and is followed by Belgium. France, on the other hand, is found to be the largest net exporter of land-intensive products. Finally, the observed and predicted rankings of countries by their relative factor contents are different in 1970 than in 1980, suggesting changes occurred in the trading patterns of the countries between the two periods. Table 6 also makes clear that most of the problem with Italy not fitting the model is related to land. Direct land input requirements for each country were imputed from the input-output tables and are the weakest link.

The paper also conducted a rank test to determine the correlation between the rankings of the five countries for each factor obtained from the observed and the predicted relative factor contents of trade. The Pearson and Kendall rank correlations are presented in Table 7. The proportion of correct pairwise comparisons are also calculated. Again, it is evident that the proportion of correct pairwise comparisons is high for all of the factors in both 1970 and 1980. Table 6 shows that the composition of trade changed between 1970 and 1980 since the implied observed and predicted rankings are different for each year. This may be due to a number of factors, including trade liberalization or other changes in the economy between 1970 and 1980, such as the oil shocks.

Table 8 shows the change in the prediction error associated with equation (9) (which employs direct plus nontraded indirect input requirements) between 1980 and 1970 as a percent of the prediction error in 1970 for each country pair and for each factor. A positive prediction error implies that relative to the second country, the first country net exports to the world less of the services of factor m than would be predicted by the modified HOV B theory. Conversely, a negative error implies that relative to the second country, the first country net exports to the world more of the services of a factor m than would be predicted from relative endowments in the two countries or differences in the technologies of production between the two countries. Thus, the percent change in the prediction error between 1980 and 1970 relative to 1970 allows us to view the effects of ongoing reductions in protection (whether tariff or non-tariff barriers) between all of the EC member countries for the five countries examined.

Almost all of the percent changes in the prediction errors lie between zero and minus one, where a value of minus one signifies that the prediction error is completely eliminated for 1980. Positive values of the percent change in the prediction errors signify an increase in the absolute value of the prediction error for 1980 over that for 1970. There are few cases where this occurs. For example, the magnitude of the prediction error increases for total workers for multilateral trade between Germany and France. Values for the percentage change in the prediction error between minus one and minus two signify that the prediction error changed sign between 1970 and 1980 but that it is smaller in absolute value for 1980. A value of minus two implies that the prediction error for 1980 is equal in magnitude to the prediction error for 1970 but is of the opposite sign. Values larger than minus two imply that the prediction error changed sign in 1980 and became larger in absolute value in comparison with the prediction error in 1970.

Table 8 clearly shows that the prediction error mainly declined from 1970 to 1980. Figures 1–6 also show that the observations lie closer to the diagonal line for 1980 than for 1970 in each of the three HOV cases. However, the decline in the absolute values of the prediction errors cannot be attributed solely to trade liberalization. Anything that changed between 1970 and 1980 may also have affected the results.

The same trends also show up in tests of the strict HOV equations (although they are not reported here): the prediction errors decline slightly in 1980 relative to 1970. It is possible, therefore, that as trade barriers were removed, countries used increasingly similar production techniques, which is why the strict HOV results also slightly improve. As mentioned earlier, under the modified HOV models, countries may use different techniques not only because they are operating at different points on the same production function but also because they may have different production technologies altogether. It is not surprising, therefore, that the prediction errors decline under the strict HOV model from 1970 to 1980 although the strict HOV model continues to perform below the modified models under the sign and rank tests. The slight decline in the prediction errors in 1980 relative to 1970 suggests that barriers to trade played a role in the failure of the HOV model, although their role is not as significant as that of international differences in technology. Different prices could have explained the inferior performance of the strict HOV in 1970 but not in 1980. Thus technological differences play an important role.

IV. CONCLUSIONS

Three main conclusions can be drawn from the empirical results in Section IV. First, the strict HOV equations accurately predict trade patterns about 50 percent of the time compared with the modified HOV theory, which predicts trade patterns between 70 and 90 percent of the time, depending on the version of the modified HOV theorem used and whether Italy is included or excluded from the sample.[24] Second, the evidence shows that the modified HOV B theory which draws a distinction between traded and nontraded goods, performs better than the modified HOV A theory. Third, the modified HOV theory provides slightly more accurate predictions for trade in 1980 over 1970 when factor contents of trade are measured only for final goods using direct and domestic indirect inputs. However, not all of this small difference can be attributed to trade liberalization, since anything that occurred between the two years could also have affected the results.

Thus, overall, the theoretical derivations and the empirical evidence support the notion that it is important to correctly attribute direct inputs to traded intermediate inputs in HOV tests and that this is the main role that trade plays in affecting the empirical results. For instance, it was found that the tests of the modified HOV B theory mainly improved the

[24] Although the problem with Italy is largely due to the land factor for which the land input requirements are roughly estimated.

predictions for 1980 rather than for 1970 over the modified HOV A theory. Lower barriers to trade permit countries to import more of the goods that they are inefficient in producing and to export more of the goods that they are efficient in producing. This leads to biased results when direct plus total indirect inputs are used to measure factor contents of trade. The downward impact of Italy may simply be due to the fact that large differences exist between the technology used in Italy to produce imports for consumption and the technology used in the producing countries. However, this cannot be shown theoretically and can only be proven empirically when complete information is available on the technology used to produce imports for consumption.[25] If such information is lacking the results presented in this paper present the best that the HOV theorem can do since the EC member countries are more likely to have similar technologies and endowments than would a group comprising both developed and developing countries.

[25] Collecting data on the origin of imports in countries and the technologies used to produce them is a very difficult, if not impossible, task.

Table 2. Correlation of Final Consumption with Predicted Consumption

Country	Pearson Correlation 1970	Rank Correlation 1970	Pearson Correlation 1980	Rank Correlation 1980
Belgium	0.989	0.866	0.992	0.858
Germany	0.992	0.881	0.994	0.905
France	0.994	0.889	0.995	0.897
Italy	0.984	0.866	0.960	0.818
Netherlands	0.987	0.818	0.976	0.889

Note: All correlations are significant at the 1-percent level.

Table 3. Sign Tests of the Three HOV Theories: For Country Pairs

	Number of Correct Sign Matches (1970)		
	Traditional HOV A 1/	Modified HOV A	Modified HOV B 2/
	lhs/rhs	lhs/rhs	lhs/rhs
Belgium/Germany	4	4	5
Belgium/France	4	6	5
Belgium/Italy	6	4	5
Belgium/Netherlands	4	6	4
Germany/France	1	6	6
Germany/Italy	3	4	4
Germany/Netherlands	3	6	5
France/Italy	1	4	3
France/Netherlands	5	6	4
Netherlands/Italy	4	1	5
Total	35	47	46
Percent	58	78	77
Percent (excl. Italy)	58	94	81

	Number of Correct Sign Matches (1980)		
	Traditional HOV A	Modified HOV A	Modified HOV B
	lhs/rhs	lhs/rhs	lhs/rhs
Belgium/Germany	4	6	6
Belgium/France	5	6	6
Belgium/Italy	3	4	4
Belgium/Netherlands	1	5	5
Germany/France	2	5	5
Germany/Italy	2	3	4
Germany/Netherlands	3	5	6
France/Italy	2	3	3
France/Netherlands	2	4	6
Netherlands/Italy	1	1	2
Total	25	42	47
Percent	42	70	78
Percent (excl. Italy)	47	86	94

Note: Six factors are used to generate results: land, capital, manual workers, professional and administrative workers, sales technical workers, and clerical workers. For each country pair the number of correct sign matches out of six possible are reported. Therefore, there are a total of 60 observations for a particular year. The traditional HOV results are derived under the assumption that all of the countries have the German technology matrix.

1/ HOV A represents the HOV theory developed in Section II-A.

2/ HOV B represents the HOV theory developed in Section II-B.

Table 4. Correlations of Observed and Predicted Relative Factor Contents of Trade: For Country Pairs
Modified HOV A

Country Pairs	1970 Pearson Correlations	1970 Rank Correlations	Percent of Correct Pairwise Comparisons	1980 Pearson Correlations	1980 Rank Correlations	Percent of Correct Pairwise Comparisons
Belgium/Germany	0.730 *	0.467 *	0.734	0.913 **	0.867 **	0.933
Belgium/France	0.343	0.600 **	0.800	0.970 **	0.600 **	0.800
Belgium/Italy	-0.343	-0.200	0.400	-0.414	-0.067	0.467
Belgium/Netherlands	0.931 **	0.333	0.667	0.952 **	0.467 *	0.734
Germany/France	0.983 **	0.600 **	0.800	0.989 **	0.733 **	0.867
Germany/Italy	0.309	0.200	0.600	-0.116	-0.067	0.467
Germany/Netherlands	0.959 **	0.333	0.667	0.946 **	0.600 **	0.800
France/Italy	-0.812 *	-0.200	0.400	-0.585	-0.333	0.334
France/Netherlands	0.805 *	0.333	0.667	0.707	0.467 *	0.734
Netherlands/Italy	-0.772 *	-0.600	0.200	-0.525	-0.200	0.400
Average	0.313	0.187	0.593	0.384	0.307	0.653
Average (excl. Italy)	0.792	0.444	0.722	0.913	0.622	0.811

Note: Two asterisks denote estimates that are significant at the 5% level. One asterisk denotes estimates significant at the 10% level. Tests of significance for the Kendall rank correlations are based on quantiles of the Kendall test statistic in Conover (1971).

Table 5. Correlations of Observed and Predicted Relative Factor Contents of Trade: For Country Pairs
Modified HOV B

Country Pairs	1970 Pearson Correlations	1970 Rank Correlations	Percent of Correct Pairwise Comparisons	1980 Pearson Correlations	1980 Rank Correlations	Percent of Correct Pairwise Comparisons
Belgium/Germany	0.563	0.333	0.667	0.840 **	0.467 *	0.734
Belgium/France	0.816 **	0.867 **	0.934	0.996 **	0.867 **	0.934
Belgium/Italy	0.893 **	0.333	0.667	0.732 *	0.467 *	0.734
Belgium/Netherlands	0.730 *	0.467 *	0.734	0.873 **	0.467 *	0.734
Germany/France	0.983 **	0.600 **	0.800	0.985 **	0.600 **	0.800
Germany/Italy	0.816 *	0.600 **	0.800	0.749 *	0.333	0.667
Germany/Netherlands	0.788 **	0.733 **	0.867	0.893 **	0.733 **	0.867
France/Italy	-0.655	0.067	0.534	-0.585	-0.333	0.333
France/Netherlands	0.579	0.467 *	0.734	0.952 **	0.867 **	0.934
Netherlands/Italy	-0.059	-0.067	0.467	-0.451	-0.333	0.333
Average	0.545	0.440	0.720	0.598	0.413	0.707
Average (excl. Italy)	0.743	0.578	0.789	0.923	0.667	0.833

Note: Two asterisks denote estimates that are significant at the 5% level. One asterisk denotes estimates significant at the 10% level. Tests of significance for the Kendall rank correlations are based on quantiles of the Kendall test statistic in Conover (1971).

Table 6. Implied Ranking of Countries from Largest to Smallest Net Exporters

1970

Factor		Factor Content of Trade Largest	⟶			Smallest
Manual workers	Observed	Belgium	Netherlands	Italy	Germany	France
	Predicted	Belgium	Germany	Netherlands	France	Italy
Nonmanual workers	Observed	Netherlands	Belgium	Germany	France	Italy
	Predicted	Belgium	Netherlands	Germany	France	Italy
Clerical Staff	Observed	Netherlands	Belgium	Germany	France	Italy
	Predicted	Belgium	Netherlands	Germany	France	Italy
Professionals, Administrative	Observed	Belgium	Germany	Netherlands	France	Italy
& Managerial Workers	Predicted	Germany	Belgium	France	Netherlands	Italy
Sales & technical workers	Observed	Netherlands	Belgium	Germany	France	Italy
	Predicted 1	Belgium	Germany	France	Netherlands	Italy
	Predicted 2	Belgium	France	Netherlands	Germany	Italy
Total employment	Observed	Belgium	Netherlands	Germany	Italy	France
	Predicted	Belgium	Germany	Netherlands	France	Italy
Capital	Observed	Belgium	Netherlands	Italy	Germany	France
	Predicted	Belgium	Netherlands	Germany	France	Italy
Land	Observed	France	Netherlands	Belgium	Italy	Germany
	Predicted 1	Italy	Belgium	France	Netherlands	Germany
	Predicted 2	Italy	France	Netherlands	Belgium	Germany
	Predicted 3	Italy	Netherlands	Belgium	France	Germany

1980

Factor		Factor Content of Trade Largest	⟶			Smallest
Manual workers	Observed	France	Germany	Belgium	Netherlands	Italy
	Predicted	Italy	France	Netherlands	Belgium	Germany
Nonmanual workers	Observed	Belgium	Germany	Netherlands	France	Italy
	Predicted	Netherlands	Belgium	Germany	France	Italy
Clerical Staff	Observed	Belgium	Italy	Netherlands	France	Germany
	Predicted	Belgium	Netherlands	Germany	France	Italy
Professionals, Administrative	Observed	Germany	Belgium	France	Italy	Netherlands
& Managerial Workers	Predicted	Germany	Belgium	Netherlands	France	Italy
Sales & technical workers	Observed	Belgium	Germany	France	Italy	Netherlands
	Predicted	Belgium	Germany	France	Netherlands	Italy
	Observed	France	Belgium	Germany	Netherlands	Italy
Total employment	Predicted	Belgium	Germany	France	Italy	Netherlands
	Observed	Belgium	France	Germany	Netherlands	Italy
Capital	Predicted	Netherlands	Belgium	France	Germany	Italy
	Observed	France	Netherlands	Belgium	Germany	Italy
Land	Predicted	Italy	France	Netherland	Belgium	Germany

Note: Factor contents of trade in final goods are measured using direct and nontraded indirect input requirements.

Table 7. Correlation with Direct Plus Nontraded Indirect Input Requirements: For Factors

Factor	1970 Pearson Correlations	1970 Rank Correlations	Percent of Correct Pairwise Comparisons	1980 Pearson Correlations	1980 Rank Correlations	Percent of Correct Pairwise Comparisons
MAN	0.50	0.40	0.70	0.50	0.40	0.70
NONMAN	0.90 **	0.80 **	0.90	0.90 *	0.80 **	0.90
CLERICAL	0.90 **	0.80 **	0.90	0.60	0.40	0.70
PROF+ADMIN	0.80 *	0.60 **	0.80	1.00 **	1.00 **	1.00
SALES+TECH	0.4-0.5	0.40		0.90 **	0.80 **	0.90
TOTAL	0.50	0.40	0.70	0.90 **	0.80 **	0.90
CAP	0.61	0.53	0.76	0.20	0.20	0.60
LAND	0.1-0.4	0-0.4		0.40	0.40	0.70
Average	0.70	0.59	0.79	0.68	0.60	0.80

Note: The factor codes are as follows: CLERICAL -clerical staff, PROF+ADMIN -professionals, administrative and managerial workers, SALES+TECH -sales and technical workers NONMAN -nonmanual workers, MAN -manual workers, CAP -capital, TOTAL -total employment. Two asterisks denote estimates that are significant at the 5% level. One asterisk denotes estimates significant at the 10% level. Tests of significance for the Kendall rank correlations are based on quantiles of the Kendall test statistic in Conover, W.J.

Table 8. Change in Prediction Errors of Modified HOV B, (1980-1970)/1970

(In percent)

Sector	Belgium/ Germany	Belgium/ France	Belgium/ Italy	Belgium/ Netherlands	Germany/ France	Germany/ Italy	Germany/ Netherlands	France/ Italy	France/ Netherlands	Netherlands/ Italy
CLERICAL	-2.41	0.36	-0.75	-1.08	-0.20	-0.79	-1.02	-0.86	-1.18	-0.67
PROF	-0.76	-1.41	-0.67	-2.15	0.03	-0.75	-0.90	-0.79	-1.25	-0.66
SALES+TECH	-0.81	-1.37	-0.87	-0.97	-1.32	-0.87	-1.02	-0.89	-0.99	-0.76
NONMAN	-0.47	-1.75	-0.78	-1.11	0.26	-0.81	-1.18	-0.86	-1.13	-0.69
MAN	-0.97	-2.17	-1.13	-0.90	-0.68	-1.24	-0.91	-1.14	-0.99	-2.69
CAP	-0.60	0.57	-0.61	-1.49	-0.58	-0.64	-3.84	-0.64	-1.50	-0.15
LAND	-0.73	-0.75	-0.48	-0.86	-0.83	-0.64	-1.10	-0.56	-1.00	-0.70
TOTAL	-1.04	-1.21	-0.94	-1.01	1.38	-0.97	-0.98	-1.00	-1.04	-0.97

Note: The factor codes are as follows: CLERICAL -clerical staff, PROF+ADMIN -professionals, administrative and managerial workers, SALES+TECH -sales and technical workers NONMAN -nonmanual workers, MAN -manual workers, CAP -capital stock, LAND - land, and TOTAL -total employment.

Traditional HOV A

Figure 1: Actual vs. Predicted Relative FCT - 1970

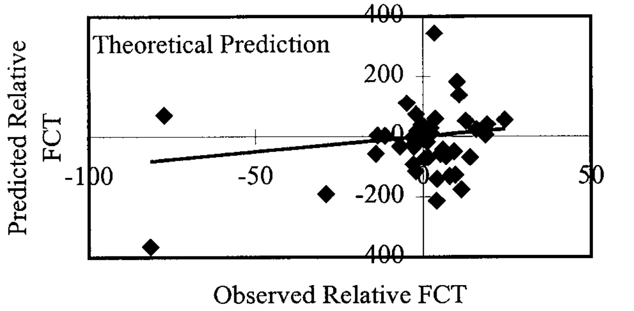
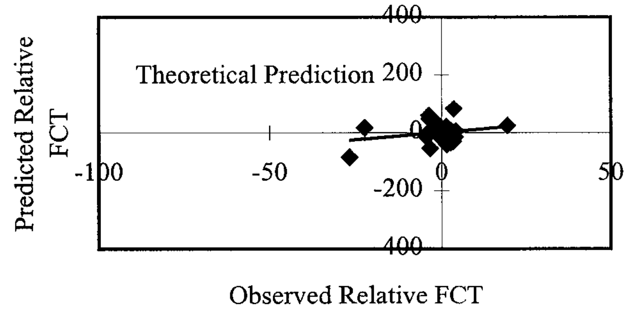


Figure 2: Actual vs. Predicted Relative FCT - 1980



Modified HOV A

Figure 3: Actual vs. Predicted Relative FCT - 1970

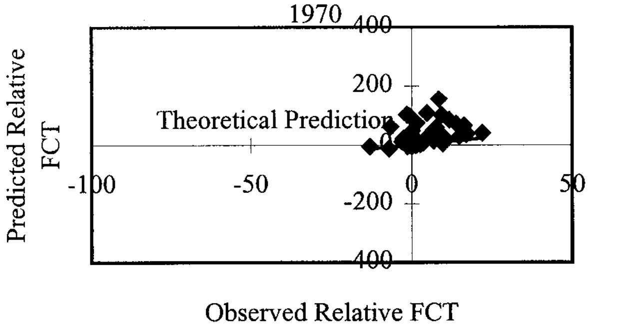
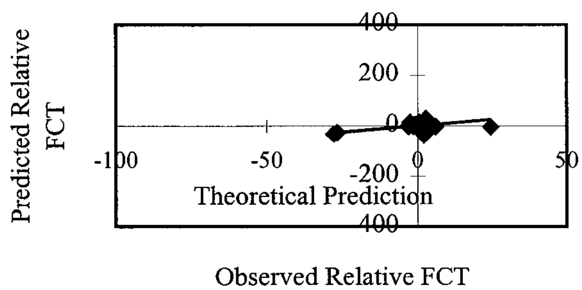


Figure 4: Actual vs. Predicted Relative FCT - 1980



Modified HOV B

Figure 5: Actual vs. Predicted Relative FCT' - 1970

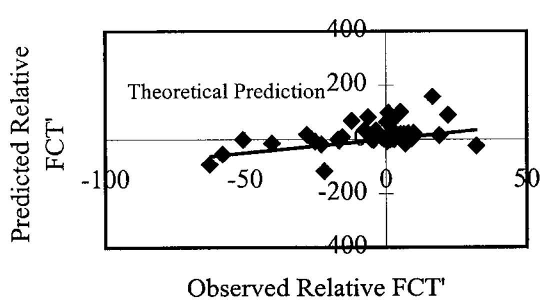
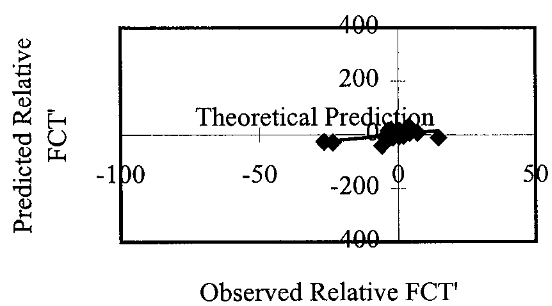


Figure 6: Actual vs. Predicted Relative FCT' - 1980



Data Sources

Input-output tables for the years 1970 and 1980 for Belgium, France, Germany, Italy and Netherlands are obtained from the Statistical Office of the European Communities (Eurostat).[26] The tables use the NACE/CLIO classification containing 44 or 59 branches of activity. The tables were aggregated to 23 branches of activity for all of the countries in both of the years studied. The 23 categories correspond to the categories used in the International Sectoral Databank (ISDB) of the OECD which uses the ISIC classification system.[27] The sum of final consumption in the five countries studied is taken to represent the original EC members' total net output. A list of the branches is presented in Table A.1. Trade data (used to obtain net exports) and final consumption of products from each branch are obtained from the input-output tables. Final consumption is defined as total goods absorption, which is calculated as the total of final consumption of households in the economic territory, the collective consumption of general government and private nonprofit institutions serving households, gross fixed-capital formation and changes in stocks.[28] The input-output tables also provide information on total (both domestic and imported) intermediate inputs used in the production of goods as well as the breakdown between the domestic intermediate inputs and the imported intermediate inputs. The data in each table are in national currencies. All of the data are converted into U.S. dollars using average period exchange rates from the *International Financial Statistics.*

Matrices of individual country direct factor input requirements are constructed as follows. Data on eight factors are collected.[29] The factors are gross capital stock; total labor; manual workers; nonmanual workers; clerical workers; professional, administrative, and managerial workers; sales and technical workers; and land. Gross capital stocks by branch obtained from Eurostat's SEC2 database are in constant 1985 prices of the national currencies. The gross capital stocks in constant national currencies are converted to gross capital stocks in constant 1985 U.S. dollars using 1985 gross fixed capital formation purchasing power parity exchange rates.[30]

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[26] The input-output tables for 1970 are in producers prices including all taxes and the input-output tables for 1980 are in producers prices net of all VAT.

[27] The ISDB uses the ISIC classification system but was also itself partially created using data classified according to the NACE classification system provided by Eurostat. An OECD working paper by Meyer zu Schloctern (1994) presents a table that matches the ISIC sectors against the NACE sectors. This was used to develop the sector groupings in the ISDB.

[28] Total goods absorption is the difference between total absorption and intermediate inputs absorption.

[29] See Hakura (1995) for explanatory notes on individual country differences in data collection and tabulation.

[30] The purchasing power parity exchange rates are available in the OECD National Accounts publication entitled *Main Aggregates* Volume 1, part seven.

Total labor input requirements are calculated using data on total employment by branch from Eurostat's *National Accounts ESA: Detailed Tables.*[31] The number of workers in each occupation category is obtained from the *Structure of Earnings* (Eurostat) and the International Labor Offices (ILO) *Yearbook of Labor Statistics*. The *Structure of Earnings* (SOE) was published only in 1972 and 1978/79.[32] It is assumed that the distribution of workers by occupational qualification in each industry does not vary much over time. The information from the 1978/1979 survey is used with the 1980 input-output tables and the 1972 survey is used with the 1970 input-output tables. The SOE publications present the distribution of employees (wage and salary earners) with different occupational qualifications using the NACE industrial classification system for manufacturing and building and construction only.[33] The distribution of workers across different occupational groups for agriculture, forestry and fishing, mining and quarrying, electricity gas and water, and the service sectors are obtained from the ILO's *Yearbook of Labor Statistics*.

The ILO *Yearbook* contains information on workers by industry and occupational status for various years for Belgium, Germany, Italy, and Netherlands.[34] Information on the distribution of workers by industry and occupation in France was obtained from the *Labor Force Survey* by Eurostat in 1992.[35] Since the data are intermittent in nature, a similar approach to Bowen (1984)[36] was used to estimate or impute the share of workers in each occupation category to total workers in an industry for the years of the current study. The shares for 1970 and 1980 are estimated from regressions of the occupational shares for each industry on a time trend. The specification of the regression, for example, whether it is log-linear, is determined by comparing the R^2 of the various regression specifications. In the cases where the occupational shares are available only for one census year, the shares are used as a proxy for the year of study. Thus, total employment in the agriculture, forestry, and fishing sectors, the fuel and power product sectors, and the service sectors are multiplied by the

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[31] Total employment in the National Accounts tables is defined as total occupied population, wage and salary earners. The occupied population covers all persons engaged, whether these persons are civilians or military personnel. The total employment figures match those in the ISDB. Since Eurostat only provides aggregated total employment figures for mining and quarrying, and the electricity, gas and water groups, the data on total employment for these two groups was supplemented with total employment data from the ISDB.

[32] They were also published in 1966 but only for a small subset of workers.

[33] Although the SOE only provides information on the number of employees by occupation in each industry, this should not pose a problem since the proportion of self-employed workers in the manufacturing and building and construction sectors is quite small or nonexistent.

[34] The ILO contains such tables for 1981 for Belgium, 1951 and 1981 for Italy, 1975, 1977, 1979, 1981, 1987, 1991, and 1993 for Netherlands, and 1961, 1978, 1980, 1982, 1984, 1985, 1986, 1991 for Germany.

[35] Tables that cross-tabulate occupation by sector for each country currently in the EC (except Belgium) are available in the LFS only for 1992.

[36] Bowen and later on papers by BLS (1987) and Trefler (1993, 1994) use this approach to impute factor abundances in countries.

relevant estimated shares to obtain the number of workers in each of the industries by occupational status for 1970 and 1980.[37]

A concordance was developed to match the occupational categories in the SOE with the categories defined at the one digit level of the ILO's International Standard of Occupations (ISCO). The paper defines five categories of occupation: manual workers, nonmanual workers, professionals and managerial workers, sales and technical workers, and clerical workers. Table A.2 presents the matching of the occupational categories in the SOE against the ILO's ISCO categories and lists all of the factors and their abbreviations. The only problem with the categories is that in the SOE professional workers and technical workers are placed in different categories while in the ILO the number of professional and technical workers is reported in one category. In order to disaggregate the professional and technical worker category in the ILO for the agriculture, fuel, power, and service sectors and to allocate the professional and technical workers to match the SOE categories, the paper used information on the proportion of professional (technical) workers relative to total professional and technical workers in 1992 obtained from Eurostat's *Labor Force Survey*. This assumes that the proportion of professional and technical workers are the same in those categories for all years.

Once the data on the gross capital stock by industry and the numbers of workers by industry branch are collected, capital and labor input requirements are calculated per million dollars of output. For example, if there are 100,000 workers in an industry and $100 million of output, this implies that there are 1,000 workers per $1 million of output. If 2,000 of the workers are clerical, it implies that 20 clerical workers are used for each $1 million of output. In order to determine the entries of the B matrix, which represent the direct intermediate inputs required from each industry to produce a $1 million of gross output, the following was done: if an industry uses $5.212 billion of agricultural products and the value of output from the industry is $300 billion dollars, that means that $0.01737 (5.212/300) of agricultural products are needed per dollar of output.

There is no information available on the amount of land input by industry for each country studied. Thus, land input requirements are imputed from the input-output tables in the same way as in most factor content studies. Land is assumed to be an input only into the agriculture, forestry, and fishery sector following Harkness (1978) and Trefler (1993a), among others. Also, using the fact that the derivation of the generalized HOV theory described in Section II assumes full employment of factors, the input of land (in hectares per million dollars of output) into the agriculture forestry and fishery sector was solved for by setting the demand for land equal to the supply or endowment of land. Each country's endowment of land comes from the relevant issues of the United Nation's *Food and*

[37] Since the ILO aggregates the retail and wholesale trade sector with the restaurants and hotel sector, and the other market service sector with the non-market service sector, it is assumed that the shares of workers with different occupations among total workers are the same for each pair of sectors.

Agriculture Organization Production Yearbook. Land endowment is defined as all arable land, land under permanent crops, permanent meadows and pastures, forest and woodland, and includes land area under inland water bodies.

Endowments of capital and each type of labor are obtained by summing across all of the sectors of the economy. This is consistent with the theory which assumes full employment of factors. It is a theory of how employed factors are allocated across sectors in the presence of trade.[38]

GNP data and data on the trade balance are acquired from the World Bank's *World Tables*. These are used to measure the ratio of expenditure shares for each pair of countries, α_i. GDP data and the data on average period exchange rates that are used to convert the GDP data as well as most of the other variables collected into current U.S. dollars are obtained from the IMF's *International Financial Statistics*. Since the relationship is tested when either the final individual countries consumption is included in the equations or under the assumption that consumption is homothetic for the EC5, a measure of EC5 final consumption and expenditure shares, s_i, for each country that is defined as the share of a country's expenditure in total EC5 expenditure are calculated.

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[38] The papers by Bowen, Leamer and Sveikauskas (1987) and Trefler (1993, 1994) impute a measure of endowment from the ILO. From the ILO tables they obtain occupational shares of the economically active population for various years. They then use the method described earlier which was originated by Bowen (1984) in order to impute the share of workers employed in different occupational categories to the totally economically active population in the year of interest. Multiplying the estimated share by the number of economically active workers in the year of interest yields a measure of the endowment of a particular occupational type of worker. BLS and Trefler did not have information on the number of workers and the value of capital in each sector of the economy for each country studied and thus were unable to directly estimate the endowment of the factors.

Numerical Example to Compare the Interpretation of Each Definition of Factor Content of Trade

Start by supposing that there are two countries, country 1 and country 2, and two goods in the economy, X and Y. Preferences in each country are defined as,

$U_1 = Y$ and $U_2 = X$.

There are two factors, capital and labor. Country 1 is endowed with one unit of labor and one unit of capital. Country 2 only has capital, which it can use to produce two-thirds of a unit of X and one unit of Y. Country 1 needs some of both X and Y as intermediate inputs to produce both goods X and Y, so it is dependent on country 2 to be able to produce at all. In country 1 the production of one unit of good X requires one unit of labor and one-third unit of imported X and one-third unit of imported Y. The production of good Y requires one unit of capital and one-third unit of imported X and one-third unit of imported Y. It is evident therefore, that the technology for producing good X in country 1 must be different from the technology used by country 2 since country 2, has no labor at all.

The direct input matrices $(f \times n)$ and the endowment vectors $(f \times 1)$ for country 1 where $f = k, l$ respectively, and $n = X, Y$ respectively are given as:

$$A_1 = \begin{bmatrix} 1 & 0 \\ 0 & 1 \end{bmatrix} \text{ and } V_1 = \begin{bmatrix} 1 \\ 1 \end{bmatrix}.$$

The total intermediate input (all indirect inputs) requirements matrix for country 1 is given as, $B_1 = \begin{bmatrix} 1/3 & 1/3 \\ 1/3 & 1/3 \end{bmatrix}$ while the domestic intermediate (domestic indirect inputs) requirements matrix, B_d, is the null matrix.

Since country 1 only consumes Y, any X that it produces will be exported to country 2. Therefore, in equilibrium, the production vectors, the consumption vectors, and the trade vectors for country 1 are:

$$Q_1 = \begin{bmatrix} 1 \\ 1 \end{bmatrix}, C_1 = \begin{bmatrix} 0 \\ 1\tfrac{1}{3} \end{bmatrix}, \text{ and } T_1 = \begin{bmatrix} 1/3 \\ -1 \end{bmatrix}.$$

Since country 1 uses all of the two-thirds of X that it imports and two-thirds of the unit of Y that it imports in domestic production, its final trade vector is given as, $T_1' = \begin{bmatrix} 1 \\ -1/3 \end{bmatrix}$.

If the factor content of trade is defined and measured in terms of total input requirements, we will find that $A_1(I - B_1)^{-1} T = \begin{bmatrix} -1/3 \\ -1\tfrac{2}{3} \end{bmatrix}$. This definition of net factor trade suggests that country 1 net imports both capital and labor, which is impossible since country 2 has no labor.

On the other hand, if the factor content of trade is defined as those in final goods only, measured in terms of direct and nontraded inputs, we will find that $A_2(I - B_{d2})^{-1} T' = \begin{bmatrix} 1 \\ -1/3 \end{bmatrix}$ correctly implies that country 1 net exports labor.

This example clearly illustrates that if countries have different technologies, calculations of the factor content of trade using total (direct plus all indirect) input requirements could lead to incorrect conclusions about the net factor content of trade, while those based on factor contents in final goods using direct and nontraded indirect inputs may provide more accurate results.

Table A.I. The NACE/CLIO Classification for each Industry, Description and Codes

Sector Code	NACE CLIO Code R6* R25	Description
AGR	1	Agriculture, forestry and fishery products
FUEL	6	Fuel and power products
MID	12, 13, 14	Mining and Quarrying
EGW	15, 16 17	Electricity, gas and water
MAN	30	Manufactured Products
BMI	13	Ferrous and non-ferrous ores and metals, other than radioactive
MNM	15	Non-metallic minerals and mineral products
CHE	17	Chemical products
BMA	19	Metal products, except mchinery and transport equipment
MAI	21	Agriculture and Industrial Machinery
MIO	23	Office and data-processing machines, precision and optical equipment
MEL	25	Electrical goods
MTR	28	Transport Equipment
FOD	36	Food, beverages, tobacco
TEX	42	Textiles and clothing, leather and footwear
PAP	47	Paper and printing products
RUB	49	Rubber and plastic products
MOT	48	Other manufacturing products
CST	53	Building and construction
SER	68	Market Services
RWH	56	Recovery and repair services, wholesale and retail trade services
HOT	59	Lodging and catering services
TRS	61,63, 65, 67	All transport and communication services
FNS	69A	Services of credit and insurance institutions
SOC	74	Other market services
OTHS	86	Non-market Services

Note: The data are classified using NACE/CLIO R6* R25. The codes for MID and EGW are NACE codes. Where possible, the same sector codes are used as in the ISDB. The definition of the chemicals sector differs from the ISDB since rubber and plastic products are placed in a separate category. Also, the wood products sector defined in the ISDB is included with other manufacturing products.

Table A.2. Occupation Categories Used and Relation Between the Structure of Earnings (SOE) and the ILO's ISCO Occupation Groups

Occupation Code	Description	Source	Correspondence of the SOE groups to occupation groups used in this study	Correspondence of the ISCO groups to occupation groups used in this study	Corresponding ISCO group numbers
MAN	Manual workers	SOE for MAN & CST ILO for AGR, FUEL, SER	Manual workers+Foremen	Production & related workers, transport equpt operators & laborers, service workers, agriculture, animal husbandry, forestry workers, fishermen & hunters	5+6+7+8+9
NONMAN	Nonmanual workers	& OTHS	Nonmanual workers-Foremen	Professional, technical, administrative & mangerial workers, clerical, sales & related workers	1+2+3+4
CLERICAL	Clerical staff		Clerical staff	Clerical staff & related workers	3
PROF+ ADMIN	Professionals, Administrative & Managerial workers		Management Executives & Executives	Administrative & managerial workers, & professionals	2+professionals in group 1
SALES+ TECH	Sales & Technical workers		Assistants	Sales workers & technical workers	4+technical workers in group 1
TOTAL	Total Employment	Eurostat's National Accounts			
CAP	Gross Capital Stock	SEC2			

Note: The occupation categories are based on the SOE categories and definitions.

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