

Discussion Paper No. 8210

June 1982

FACTOR PROPORTIONS AND THE DIRECTION OF
INTERNATIONAL TRADE: AN APPLICATION
OF FACTOR ANALYSIS

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Abstract

In this paper, a method which is different from that used by Leontief in testing the validity of the conclusions of the Heckscher-Ohlin theorem is recommended. We note that the empirical significance of the theorem can be established only if both its assumptions and its conclusions are satisfied. However, Robinson observes that these assumptions are too demanding to be likely to fit any real-life circumstances. Thus, only the empirical significance of the conclusions of the theorem, rather than the theorem itself, can be established or nullified. Nevertheless, the test results could be useful in a study of the allocation of a country's relatively abundant and scarce resources and possibly, as pointed out by Leontief, its participation in the international division of labor.

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Introduction

The Heckscher-Ohlin theorem explains the direction of a country's trade in terms of comparative advantage. Ohlin¹ says:

"Generally, abundant factors are relatively cheap, scanty factors are relatively dear, in each region. Commodities requiring for their production much of the former and little of the latter are exported in exchange for goods that call for factors in the opposite proportions, thus, indirectly, factors in abundant supply are exported and factors in scanty supply are imported."

The assumptions of the theorem are stated by Bharadwaj² as follows:

1. All round perfect competitive conditions prevail
2. production functions are the same for the same commodity in both the countries and are different

*Comments of Dean José Encarnación, Jr., Dr. Marcelo Orense and Dr. Ernesto Pernia on an earlier draft of this paper are gratefully acknowledged. However, any remaining shortcomings of this paper are the author's sole responsibility.

¹Bertil Ohlin, Interregional and International Trade (Cambridge Mass.: Harvard University Press, 1933), p. 63.

²R. Bharadwaj, "Factor Proportions and the Structure of Indo - U.S. Trade," The Indian Economic Journal (1962), 105-106.

for different commodities

3. production functions are homogeneous of degree one
4. production functions are technologically distinct, meaning that the commodities would be distinguished by factor intensity
5. factor quantities are given and fully employed
6. there is complete free trade and transport and other costs are zero
7. preference functions are similarly shaped in both the countries.

Is the Heckscher-Ohlin theorem empirically relevant?

The validity of the theorem is determined, not only by the accuracy of its conclusions, but also by the satisfaction of its assumptions. A test of the empirical relevance of the theorem must include a proof that its assumptions are satisfied. Otherwise, a test of the accuracy of its conclusions merely establishes the empirical significance or insignificance of the conclusions of the theorem, not the theorem itself. Are there real-life circumstances which satisfy the assumptions of the theorem? Robinson³ says:

"I shall try to argue that this factor proportions account of trade considered in terms of production functions, taste functions and the like, rests on a tenuous base. Its assumptions

³ Romney Robinson, "Factor Proportions and Comparative Advantage," Readings in International Economics (Homewood, Ill.: Irwin, 1968), p. 3.

are too demanding to be likely to fit any real-life circumstances. In consequence, and particularly where the factor 'capital' is involved, its account of the nature of comparative advantage and of international trade is seriously misleading."

Thus, only the 'empirical validity of the conclusions of the theorem, rather than the theorem itself, can be established or nullified. Nevertheless, the test results could be useful in a study of the allocation of a country's relatively abundant and scarce resources and possibly, as pointed out by Leontief, its participation in the international division of labor.

Chenery⁴ says:

"The simplest approach to any allocation problem is to concentrate on the scarcest factor. Since this is often capital in underdeveloped countries, it seems reasonable to choose the technique that uses the least capital to produce a given output ... An underdeveloped country is advised to produce and export commodities that use relatively less capital per unit of output and to import items requiring more capital ... If the same production functions exist in all countries and if capital is scarce relative to labor in the underdeveloped countries, comparative advantage in the latter can be identified by low capital-labor ratios."

⁴Hollis B. Chenery, "Comparative Advantage and Development Policy," American Economic Review, (1961), 26-27.

On the other hand, Leontief⁵ mentions the widely held views that the U.S. has comparative advantage in the production of commodities which require for their manufacture large quantities of capital and relatively small amounts of labor and that the economic relationships of the U.S. with other countries are supposed to be based mainly on the export of such "capital intensive" goods in exchange for "labor intensive" products since the United States possesses a relatively large amount of capital and a comparatively small amount of labor. Leontief's test of the above mentioned prediction on the structure of U.S. trade indicates the contrary.⁶

According to Heller⁷ Leontief-type tests have also been conducted for a number of other countries, namely:

<u>Country</u>	<u>Investigator</u>
India	R. Bharadwaj
Japan	M. Tatemoto and S. Ichimura

⁵Wassily Leontief, "Domestic Production and Foreign Trade; the American Capital Position Re-examined," Readings in International Economics (Homewood, Ill.: Irwin, 1968), pp. 503-527.

⁶See Wassily Leontief, "Domestic Production and Foreign Trade; the American Position Re-examined."

⁷H. Robert Heller, International Trade Theory and Empirical Evidence, 2nd ed. (New Jersey: Prentice-Hall, Inc. 1973), pp. 68-70.

<u>Country</u>	<u>Investigator</u>
Canada	D. F. Wahl
East Germany	W. Stolper and K. Roskamp

Referring to these tests, Heller says:

"Of all the empirical studies undertaken only the cases of direct trade between Japan and the United States and between East Germany and Eastern Europe can be taken to confirm the predictions of the Heckscher-Ohlin theory. In all other studies we find that the empirical evidence contradicts the predictions based on the most elementary version of the theory. We can conclude that in its simplest form the Heckscher-Ohlin theory is not supported by empirical evidence ... It should be noted here that much criticism can be leveled against the tests referred to."

Leontief's method of testing the conclusions of the Heckscher-Ohlin theorem will be presented in this paper after which an alternative method of doing so-based on Oster's test of the Theory of the Dual Economy - will be recommended. The importance of capital and labor in the present state of duality in some of the developed, as well as developing, countries is taken into consideration in the proposed model.

Definitions of "capital intensive" and "labor intensive" goods will be proposed in section 1. Leontief's and Oster's tests will be presented in sections 2 and 3, respectively. The proposed test of the conclusions of the Heckscher-Ohlin theorem will be discussed in section 4.

Section 1

Capital and Labor Intensiveness

Oster⁸ says:

"Proponents of the theory of the dual economy have suggested that the American economy is composed of two distinct industrial groups: a core of powerful, concentrated, unionized, capital intensive, technologically progressive industries, and a periphery composed of industries marked by the absence of these features."

On the other hand, Singer⁹ says:

"The export industries in underdeveloped countries, whether they be metal mines, plantations, etc., are often highly capital intensive industries supported by a great deal of imported foreign technology. By contrast, production for domestic use, specially of food and clothing, is often of a very primitive subsistence nature. Thus the economy of the underdeveloped countries often presents the spectacle of a dualistic economic structure: a high productivity sector producing for export coexisting with a low productivity sector producing for the domestic market The productive facilities for producing export goods in underdeveloped countries are often foreign owned as a result of previous investment in these countries."

Let us consider the capital-labor ratios

$$K_1/L_1, K_2/L_2, \dots, K_n/L_n$$

⁸Gerry Oster, "A Factor Analytic Test of the Theory of the Dual Economy," Review of Economics and Statistics (1979), 33.

⁹H.W. Singer, "The Distribution of Gains between Investing and Borrowing Countries," Readings in International Economics (Homewood, Ill.: Irwin, 1968), pp. 306-307.

of n commodities under consideration. Our problem is to determine the critical value $(K/L)_c$ such that if

(1.1) $\frac{K_j}{L_j} < (\frac{K}{L})_c$ then the j th good is labor intensive and may be identified with the periphery sector

(1.2) $\frac{K_r}{L_r} > (\frac{K}{L})_c$ then the r th good is capital intensive and may be identified with the core sector.

The procedure for partitioning a given set of industries into core and periphery sectors is described in section 3. If duality does not exist then the n goods under consideration are of the same factor intensity (i.e. all are capital intensive or all are labor intensive).

Our approach differs from that of Samuelson who considers the relative values of capital-labor ratios. Robinson¹⁰ says:

"This is the definition of factor intensity which Samuelson has used: X is capital-intensive relative to Y when for each and any factor price ratio, X 's equilibrium capital-labor ratio exceeds Y 's."

That is, X is capital intensive relative to Y in Samuelson's sense if

¹⁰ Romney Robinson, "Factor Proportions and Comparative Advantage," Readings in International Economics, p. 9.

$$(1.3) \quad \frac{K_X}{L_X} > \frac{K_Y}{L_Y}$$

We note that inequality (1.3) may hold simultaneously with any one of the following conditions:

1. X and Y are capital intensive because

$$\frac{K_X}{L_X} > \left(\frac{K}{L}\right)_c \quad \text{and} \quad \frac{K_Y}{L_Y} > \left(\frac{K}{L}\right)_c$$

2. X and Y are labor intensive because

$$\frac{K_X}{L_X} < \left(\frac{K}{L}\right)_c \quad \text{and} \quad \frac{K_Y}{L_Y} < \left(\frac{K}{L}\right)_c$$

3. X is capital intensive and Y is labor intensive because

$$\frac{K_X}{L_X} > \left(\frac{K}{L}\right)_c \quad \text{and} \quad \frac{K_Y}{L_Y} < \left(\frac{K}{L}\right)_c$$

Section 2

Leontief's Test of the Conclusions of the Heckscher-Ohlin Theorem¹¹

Using the 1947 input-output structure of the U.S. economy for 1947, Leontief tested the validity of the conclusions of the Heckscher-Ohlin theorem. His method may be

¹¹As discussed in Wassily Leontief, "Domestic Production and Foreign Trade; the American Capital Position Re-examined," Readings in International Economics, pp. 503-527.

Described as follows:

Let K_i = direct and indirect capital requirements for domestic production of one million dollars worth of final output of the i th U.S. industry.

L_i = direct and indirect labor requirements for domestic production of one million dollars worth of final output of the i th U.S. industry.

E_i = value of exports from the i th industry per million dollars of total U.S. exports.

I_i = value of competitive imports in the i th industry per million dollars of total U.S. competitive imports.

$A = \sum_{i=1}^n K_i E_i$ = total capital requirements for domestic production of one million dollars worth of U.S. exports.

$B = \sum_{j=1}^m K_j I_j$ = total capital requirements for domestic production of one million dollars worth of U.S. competitive imports.

$C = \sum_{i=1}^n L_i E_i$ = total labor requirements for domestic production of one million dollars worth of U.S. exports.

$D = \sum_{j=1}^m L_j I_j$ = total labor requirements for domestic production of one million dollars worth of U.S. competitive imports.

n = the number of U.S. industries which export their products.

m = the number of U.S. industries wherein there are competitive imports.

Leontief's findings are as follows:

A = \$2,550,780

B = \$3,091,339

C = 182.313 man years

D = 170.004 man years

He says:

"These figures show that an average million dollars worth of our exports embodies considerably less capital and somewhat more labor than would be required to replace from domestic production an equivalent amount of our competitive imports. America's participation in the international division of labor is based on its specialization on labor intensive, rather than capital intensive, lines of production. In other words, this country resorts to foreign trade in order to economize its capital and dispose of its surplus labor, rather than vice versa. The widely held opinion that - as compared with the rest of the world - the United States' economy is characterized by a relative surplus of capital and a relative shortage of labor proves to be wrong. As a matter of fact, the opposite is true."

Let us discuss Leontief's method as applied, in general, to any economy.

The ratio

$$\frac{A}{C} = \frac{\sum_{i=1}^n K_i E_i}{\sum_{i=1}^n L_i E_i}$$

is implicitly compared with

$$\frac{B}{D} = \frac{\sum_{j=1}^m K_j I_j}{\sum_{j=1}^m L_j I_j}$$

to determine the nature of factor intensity - capital or labor intensive - of exports and of competitive imports in a relative sense, similar to Samuelson's relative way of defining factor intensity as discussed in section 1. The direction of inequality between $\frac{A}{C}$ and $\frac{B}{D}$ is considered as the criterion for capital intensiveness or labor intensiveness of all export goods and of all competitive import goods.

Criticizing Leontief's method, Ellsworth¹² says that

1. it is inappropriate to take the capital-labor

¹²P.T. Ellsworth, "The Structure of American Trade: A New View Re-examined," Review of Economics and Statistics 36 (1954), 279-285. See also Romney Robinson, "Factor Proportions and Comparative Advantage," Readings in International Economics, p. 11.

For views of other Leontief critics, see the following: Boris C. Swerling, "Capital Shortage and Labor Surplus in the United States?" Review of Economics and Statistics 36 (1954), 286-289 and Stefan Valavanis-Vail, "Leontief's Scarce Factor Paradox," Journal of Political Economy 52 (1954), 523-528.

in the absence of dualism in the trading countries.

intensive or labor intensive. This may happen
exported and imported goods are either capital-
same nature of factor intensity. That is, all

1. The possibility that all traded goods have the

concerned, namely:

facets of the structure of trade between the countries
by Ellsworth - does not enable us to see other important
form the country of origin of imported goods, as suggested
with the corresponding appropriate figure $\frac{B}{D}$ - measured
Consequently, the method of comparing $\frac{A}{C}$ with $\frac{B}{D}$ or even
may be capital intensive and the rest, labor intensive.
rest, labor intensive. Similarly, some of the imported goods
ting where some export goods are capital intensive and the
sity of all exports may be inappropriate in a dualistic set-
a single aggregate figure, $\frac{A}{C}$, to determine the factor inten-
lying goods according to their factor intensity. The use of
In section 1, we considered the possibility of classi-

much greater labor intensity.

a substantially lower capital-labor ratio i.e.

3. If available, this figure would probably reveal

U.S. imports

capital-labor ratio for actual production of such

2. the appropriate figure would be the foreign

ratio in the United States for import production

2. The volume and proportion of exports and of imports which are capital intensive.
3. The volume and proportion of exports and of imports which are labor intensive.

Section 3

Oster's Test of the Theory of the Dual Economy

Oster's method of determining the existence of industrial dualism and of identifying the industries which belong to the core and to the periphery sectors, may be generalized for any economy as follows:

Let $X_1, X_2, \dots, X_t$

be variables which are central to the description of core and periphery industries or characteristics that might capture patterns of structural variation. Twenty-five industrial characteristics (that is, $t = 25$) were chosen by Oster and are listed in the appendix.

The factor pattern

$$X_i = \sum_{j=1}^k a_{ij} F_j + e_i, \quad i = 1, 2, \dots, t$$

is determined by the principal factor method of factor analysis.¹³ In a factor pattern, the coefficient a_{ij} - called a "loading" - of the unobserved common factor F_j is the correlation coefficient of X_i and F_j .¹⁴

Should industrial dualism exist in the economy, a tentative dual economy factor, F_Q , may be identified among the common factors through the signs of its loadings with the variables $X_1, X_2, \dots, X_t$. In Oster's paper, for example, the tentative dual economy factor loads positively with the following variables, among others: depreciable assets/production worker, percentage industry unionization and government purchases plus exports/total industry receipts. The dual economy factor is expected to load positively with characteristics which are indicative of higher levels of wealth and negatively with those which are indicative of higher levels of poverty.

¹³For a discussion of the principal factor method of factor analysis, see Harry Harman, Modern Factor Analysis, 2nd ed. (Chicago: The University of Chicago Press, 1967).

¹⁴In the maximum likelihood method of factor analysis, a_{ij} may either be $\hat{\rho}_{X_i F_j}$, the correlation coefficient of X_i and F_j or $\hat{\rho}_{X_i F_j}$ times the standard deviation of X_i . See Susan Navarro, "On the Maximum Likelihood Method of Factor Analysis," U.P. School of Economics Discussion Paper 7922 (1979), 10.

Pearson's method of moments is then used to construct the probability density function of the industry scores on F_q , the tentative dual economy factor, which is assumed to be of the form

$$(3.2) \quad z_1 n(\mu_1, \sigma_1^2) + z_2 n(\mu_2, \sigma_2^2)$$

where $z_1 + z_2 = 1$ and

$n(\mu_1, \sigma_1^2)$ and $n(\mu_2, \sigma_2^2)$ are the normally distributed scores on F_q of the core and the periphery industries, respectively. If the hypothesis that the industries were drawn from a mixture of two normal distributions of scores on F_q cannot be rejected, then the existence of industrial dualism is accepted. The critical value of F_q , which partitions the factor space-and consequently, the industries - into core and periphery sectors, is then identified.

Sector 4

Proposed Test of the Conclusions of the Heckscher-Ohlin Theorem¹⁵

Oster's method - discussed in section 3 - of classifying industries into core and periphery sectors may be used

¹⁵Other factors of production may be substituted for capital and/or labor in our proposed model.

in testing the validity of the conclusions of the Heckscher-Ohlin theorem with the following recommended adjustments:

1. A re-definition of the variables used by Oster, as well as the possible exclusion or inclusion of other variables, if needed for adaptation to a different situation.
2. The substitution of the method of maximum likelihood for the principal factor method in the factor analytic phase of the technique for the following reasons:
 - a. The distribution of industry scores on the dual economy factor F_Q is implicitly assumed to be of the form

$$n(z_1 \mu_1 + z_2 \mu_2, z_1^2 \sigma_1^2 + z_2^2 \sigma_2^2)$$

as a consequence of the form of the probability density function of F_Q mentioned in (3.2) if the industry scores on F_Q in the core and those in the periphery sectors are stochastically independent.

The probability density function of F_Q , like those of the other common factors, is not specified in the principal factor method of factor analysis. The common factors are assumed to be normally distributed in the

maximum likelihood method.

- b. The goodness of fit may be tested rigorously in the maximum likelihood method of factor analysis.

Referring to the different methods of factor analysis, which include the principal factor method, Morrison¹⁶ says:

"The various approaches are discussed by Harman [16] in his scholarly and comprehensive text and in summary form by Solomon [38]. While many of the models included 'error' terms reflecting the sampling variation of the observed correlations, none actually used the results of the new discipline of statistical inference. It was not until 1940 that D.M. Lawley reduced the extraction of factor parameters to a problem in maximum likelihood estimation and by so doing eliminated the indeterminacies of the centroid method. Furthermore, the goodness of fit of a solution with just m factors could now be tested rigorously by the generalized likelihood-ratio principle."

Having classified the goods in the model into core and periphery sectors, we can then determine the critical value of the capital-labor ratio which partitions these sectors. It would then be possible to test the validity of the conclusions of the Heckscher-Ohlin theorem. That is, to determine whether or not countries which have an abundant supply of capital export capital-intensive goods and countries which have an abundant supply of labor export labor intensive goods.

¹⁶ Ronald Morrison, Multivariate Statistical Methods, (New York: McGraw-Hill Book Co., 1967), p. 260.

Appendix

List of Variables Used in Oster's Test of the
Theory of the Dual Economy*

1. Depreciable assets/production worker (1965)
2. Percentage unemployment in industry (1960)
3. Median years schooling, female (1960)
4. Median years schooling, male (1960)
5. Percentage black male employment (1960)
6. Percentage white female employment (1960)
7. Percentage black female employment (1960)
8. Layoffs/100 workers, average (1961, 1965, 1967)
9. Percentage of total industry receipts accounted for by
firms with total assets greater than \$100 million,
average (1958, 1961, 1965)
10. Government purchases/total industry receipts (1958)
11. Government purchases plus exports/total industry
receipts (1958)
12. After-tax income/total assets, average (1953-1966)
13. Percentage black employment (1960)
14. Percentage female employment (1960)
15. Percentage total minority employment (1960)
16. Percentage industry unionization (1960)
17. Industry total assets, average (1953-1966)
18. Industry total receipts, average (1953-1966)
19. 1963/1953 value added per worker-hour

20. Capital expenditure/production worker (1963)
21. 4-firm concentration ratio (1963)
22. Index of establishment size (1960)
23. 1960/1950 industry employment
24. Percentage self-employment income (1960)
25. Annual hours/male production worker (1960)

*Source: Gerry Oster, "A Factor Analytic Test of the Theory of the Dual Economy," Review of Economics and Statistics (1979), 35.