

THE EMPIRICAL VARIFICATION OF
HECKSCHER-OHLIN THEOREM
(A SURVEY OF LITERATURE)

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AN EMPIRICAL VERIFICATION OF
HECKSCHER-OHLIN THEOREM
- A Survey of Literature

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MRS . M . D . JOSHI

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INTRODUCTION

The Heckscher-Ohlin (H-O) theorem which was developed by Eli Heckscher (1919) and then by Bertil Ohlin (1933) attempts to give a fundamental cause of variations in relative commodity price among industries. The theory achieved a wide acceptance. Leontief in 1955 tried to test the theorem empirically for America. After this, many attempts were made to verify H-O theorem empirically. The present work is a survey of some important studies in this respect.

In the first chapter the H-O theorem itself is stated with its assumptions. Even though the theorem obtained wide acceptability, it was criticised because of its rigid and unrealistic assumptions.

The other important reason for the decline of the H-O theorem is its failure to receive substantial empirical validity. In 1953, Leontief obtained results in case of America, which were contrary to H-O theorem. This fact is known in literature as 'Leontief's Paradox'. Leontief developed an input-output model to get the labour and capital requirements of different products. The same method has been used by other researchers who tried to verify the H-O theorem.

Chapter two discusses the methodology developed by Leontief.

Leontief in 1956, retested the theorem, in order to take into account various criticisms on his first study. In chapter three, Leontief's second study and the other attempts, especially by Ichimura and Tatemoto (1959), Wahl (1961), Stolper and Roskamp (1961), Bharadwaj (1962), are discussed.

Leontief's results led to a number of criticisms either on theoretical basis or on statistical basis which are discussed in the fourth chapter.

Chapter five is a concluding chapter which also mentions some of the near approaches in international trade which have been developed recently.

CHAPTER 1

THE HECKSCHER-OHLIN THEOREM

1.1 Introduction

The Ricardian or the classical theory of comparative cost, although one of the earliest formulated and longest enduring segments of the international trade theory, never adequately dealt with the question that the pattern of international trade cannot be understood without an explanation of its fundamental immediate determining cause, the variation among industries in relative industrial commodity price. The classical economists largely sidestepped it, in fact, by assigning the cause of comparative cost differences to variations in the 'quality' of each nation's labour-force which in turn were attributed under the one factor classical model, simply to diverse 'conditions of production', themselves qualitative, largely intangible and arbitrary.

In contrast, the so-called 'modern theory of trade', first advanced by Eli Heckscher¹ in 1919 and systematically elaborated by Bertil Ohlin² in 1933, was explicitly based on the attempt to identify the fundamental cause of relative price variation, which it located in the nature of production process itself and in the

1. Eli Heckscher, "The effect of foreign trade on the distribution of income". Translated by Sven Laursen and reprinted in "Readings in the theory of international trade", ed. H.S. Ellis and L.A. Metzler, pp 272-300.
2. Bertil Ohlin, "International trade and interregional trade," Harvard Economic Studies, Vol.39, (Cambridge, Mass, Harvard University Press, 1933).

differing quantitative endowments of productive resources among countries. The Heckscher-Ohlin theory of comparative advantage was intended to achieve perfect generality, treating price determination among economic areas and within each economy in a unified framework of general equilibrium. It attempted to explain not only the underlying determinants of the pattern of trade, but the determination of its equilibrium as well.

The modern theory of trade seemed to possess what might be called 'validation by intuition'. It accorded neatly with the direct perception of a striking and seemingly fundamental element of diversity among national economics³. The central proposition of the theory is strongly plausible and perhaps this fact, rather than the more ambitious aims of the theory, led to its wide acceptance and preferment over the alternative classical doctrine.

1.2 The H-O theorem stated

The basic theorem states that there must be a difference in the relative costs of producing certain commodities in the given member countries. Reason for differences in relative costs is that the two countries do not have the same factor endowment. Trade in essence depends on a relative difference in the factor endowment positions of given countries.

3. Bickel, Factor proportions and relative price under C.E.S. production function : an empirical study of Japanese-U.S. comparative advantage. Stanford University, 1966.

'Each country will export that commodity in whose production a relatively large amount of its relatively abundant factor is required.'

The theory is based on the following assumptions :

- (1) Two countries A and B. Two commodities : X and Y.
Two factors : Capital - C and Labour - L.
- (2) Perfect competition in both countries and in both markets.
- (3) No transport costs, no barriers.
- (4) No mobility of factors between trading countries, but there is complete mobility of factors within the country.
- (5) Production conditions -
 - (a) It is meaningful and possible to measure the physical amounts of productive agents, possessed by each country.
 - (b) Techniques of producing identical goods is the same in both countries.
 - (c) Goods or products can be classified according to their factor intensity. So one good can be said to be relatively capital intensive while the other relatively labour intensive.
 - (d) Each production function is subject to constant returns to scale.
- (6) Once assumption (5a) is postulated, what one of the country's factor endowment ratio is, it can be directly inferred from this - what its relative factor price structure will be. The factor which is abundant will also be cheaper in the given country.

(7) Labour and capital are homogeneous in both the countries.

(8) There is fixed supply of the two factors in the two countries.

In A and B, the costs per unit of output of X and of Y separately are equal to the quantities of capital and of labour valued at their market prices, used in the production of a unit of output of these commodities. In both countries per unit of output X is relatively capital intensive. But in A, capital is relatively cheaper, while in B, labour is relatively cheaper. It must follow by virtue of relative weights given to A's and B's relatively abundant factor that A can, relative to B, produce X relatively cheaper. Thus there must be trade.

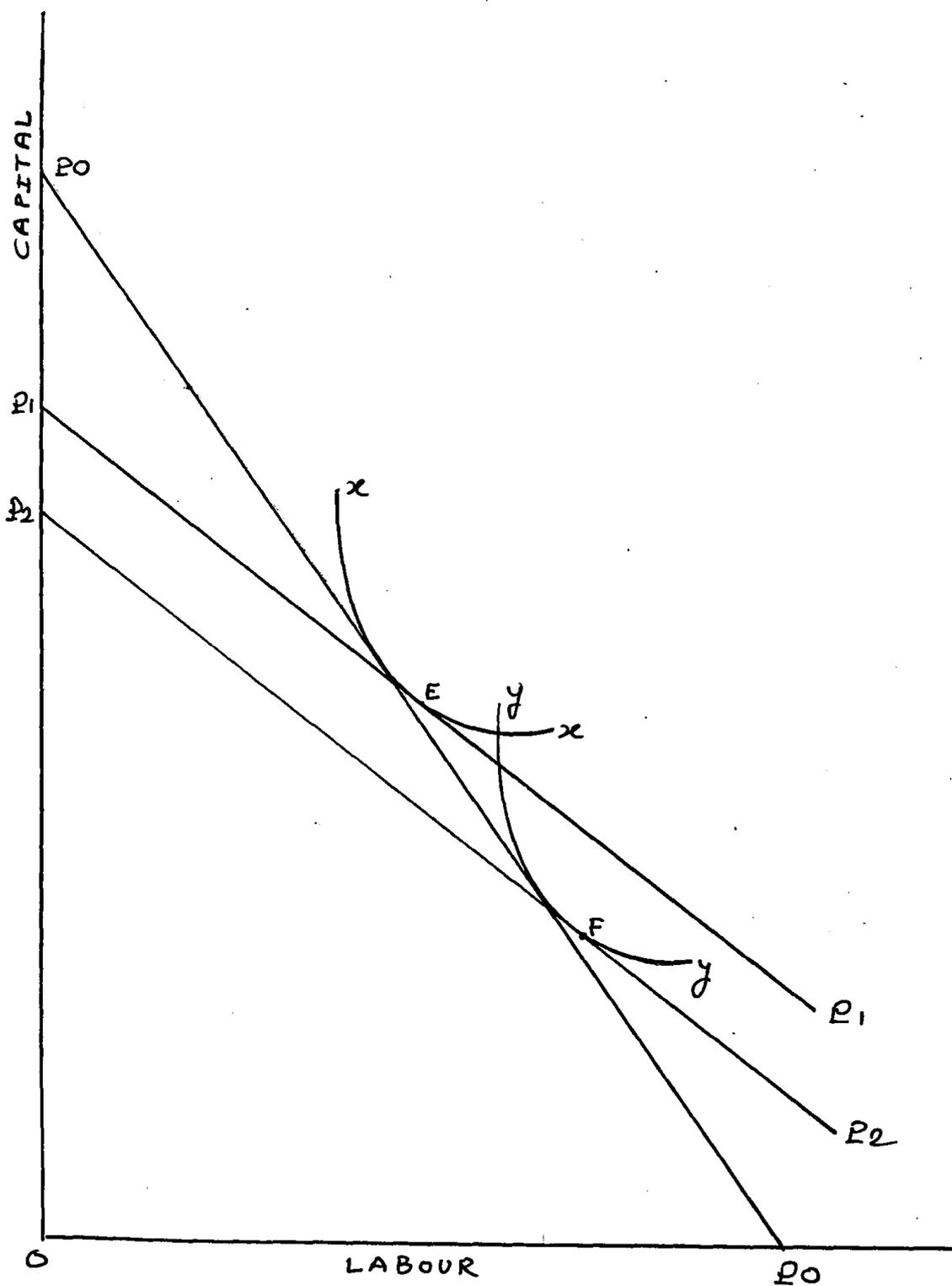
This trade must obey the basic theorem : Each country will export that commodity in whose production a relatively large amount of its relatively abundant factor is required.

1.3 Proof

Ohlin defined richness in factor endowments with the help of factor prices. According to his definition, Country A is abundant in capital if $\frac{P_C^A}{P_L^A} < \frac{P_C^B}{P_L^B}$ where P_C^A is the price of capital in country A and P_C^B is the price of capital in country B and P_L^A is the price of labour in country A and P_L^B is the price of labour in country B.

We have to show that country A will export capital intensive good X and country B will export labour intensive good Y. This

can be easily done as is demonstrated with the help of figure.



We start with two isoquants, xx and yy which characterise the production functions and are the same in both countries. According to these isoquants X is capital intensive good and Y is the labour intensive good. Relative prices in country A , where capital is cheap, are given by the line $PoPo$. In country B , capital is relatively more expensive. The slope of the line representing the ratio of factor prices in country B will be less steep than $PoPo$. $P1P1$ is the factor price line in country B . It is tangential to xx at E . A parallel factor price line is $P2P2$ which is tangential to YY at F .

If we compare the costs in the two countries, we find that it is relatively cheap to produce good X in country A and relatively cheap to produce good Y in country B . From this, it follows that country A will export good X and country B will export good Y . This establishes the H-O theorem.

Mathematically this can be shown as :

$$\text{Given } Cx/Lx > Cy/Ly \quad \text{and} \quad P_A^C/P_A^L < P_B^C/P_B^L ,$$

$$\begin{aligned} P_A^X &= P_C^A \cdot Cx + P_L^A \cdot Lx \\ P_A^Y &= P_C^A \cdot Cy + P_L^A \cdot Ly \\ P_B^X &= P_C^B \cdot Cx + P_L^B \cdot Lx \\ P_B^Y &= P_C^B \cdot Ly + P_L^B \cdot Ly \end{aligned} \quad \left. \begin{array}{l}) \\) \\) \\) \end{array} \right\}$$

Where

$$\begin{aligned} P_A^C &= \text{price of capital in A} \\ P_A^L &= \text{price of labour in A} \\ P_B^C &= \text{Price of capital in B} \\ P_B^L &= \text{Price of labour in B} \\ P_A^X &= \text{Price of x in A} \\ P_A^Y &= \text{Price of y in A} \\ P_B^X &= \text{Price of x in B} \\ P_B^Y &= \text{Price of y in B.} \end{aligned}$$

Therefore,

$$\frac{P_A^X}{P_A^Y} - \frac{P_B^X}{P_B^Y} = \frac{P_C^A \cdot C_x + P_L^A \cdot L_x}{P_C^A \cdot C_y + P_L^A \cdot L_y} - \frac{P_C^B \cdot C_x + P_L^B \cdot L_x}{P_C^B \cdot C_y + P_L^B \cdot L_y}$$

= Some negative quantity
(obtained by the sign of the numerator)

Economic Implication

$\frac{P_x}{P_y}$ in B is greater than $\frac{P_x}{P_y}$ in A., therefore commodity x is costly in B as compared to country A. While commodity y is cheaper in B than in A. Therefore A will export x and B will export y.

1.4 Criticism

This conclusion depends upon all the assumptions of the model. Given that there is such a difference, the fact that trade will occur can easily be seen from a general consideration of the assumptions of the model when they are all considered together.

The basic model is constructed on rigid and very unrealistic assumptions. When the assumptions are altered, we cannot say that factor endowments are the sole basis of trade.

The assumptions regarding identical production functions, comparable productive factors, consideration of only two factors of production are strongly criticised. The suggestions are made regarding inclusion of natural resources as a third factor. The

empirical findings of Minhas (1962)⁴ which show that productive functions are not everywhere the same, the form of generalized production function derived by Arrow⁵ and the implications of the CES production functions for relative commodity prices spelled out by Chenery⁶, taken together appear to constitute powerful evidence that Ohlin's way of conceptualizing the production function process is fundamentally incorrect.

1.4.1 : The important logical consequence of the H.O. model, the so-called 'factor price equalization theorem', which states that trade will even out the absolute as well as relative levels of factor prices across countries, had been subjected to close scrutiny. The theorem is stated forthrightly in Heckscher's 1919 work. Ohlin softened it by positing a "tendency" toward equalization of factor prices through trade. Subsequently Samuelson⁷ demonstrated that with the assumption of 'strong ordering' of factor intensities, essential to unambiguous definition of relative factor intensity, the strong form of the proposition holds. Later he wrote (1951-52) "By convention we assume identical production functions, but adopting such a convention, we are explaining nothing and possibly obscuring a great deal."⁸ However, on the 'strong factor intensity assumption',

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- 4. Minhas; "The homohypallagic production function, factor intensity reversals and H-O theorem." Journal of political economy (April 1962), pp 138-156.
 - 5,5 Arrow, Chenery, Minhas, Solow : "Capital, Labour Substitution and economic efficiency" - The review of Economics and Statistics (August 1961), pp 225-250.
 - 7. P.A. Samuelson; "International trade and equalization of factor prices", Economic Journal (June 1948), pp 163-184.
 - 8. P.A. Samuelson, "A comment on factor price equalization" ; Review of economic studies (1951-52), pp 211.

he wrote, "in connection with the two factor case, I have, the impression that the phenomenon of goods that interchange their role of being more labour intensive is much less important empirically than it is interesting theoretically."

Minhas seriously questions the factual validity of these technological assumptions, which Samuelson regarded as empirically plausible. He proposes (a) that the assumption of a common production function will in fact work, though it may not be true, (b) that if it is true, it permits factor reversals.

In carrying out an international comparative study of production for a large number of industries, Arrow, Chenery, Solow and Minhas introduced a new class of production functions. In one of its forms, the function can be written as -

$$V_i = \left(A_i K^{-\beta_i} + \alpha_i L^{-\beta_i} \right)^{-1/\beta_i}$$

where V_i = Value added by the industry i deflated by the price of commodity i

K and L stand for capital and labour.

A_i , α_i , β_i are the parameters..

$\sigma_i = \frac{1}{1 + \beta_i}$ = the elasticity of substitution between capital and labour which is assumed to be constant. From this property of the function, they called it "the constant elasticity of substitution production function - the CES production function. Its alternative name is

"homohypallagic production function". The CES production function includes both Cobb-Douglas and fixed coefficient production functions as its special cases. (Case 1: $\beta = 0$ - elasticity of substitution = 1 - Cobb-Douglas; Case 2: $\beta = \infty$ elasticity of substitution = 0 - fixed coefficient production function.)

By finding out the ranks based on the total (direct and indirect) capital and labour requirements as well as the direct capital requirements of the corresponding industries, in U.S. and Japan he showed that factor intensity reversals are possible.

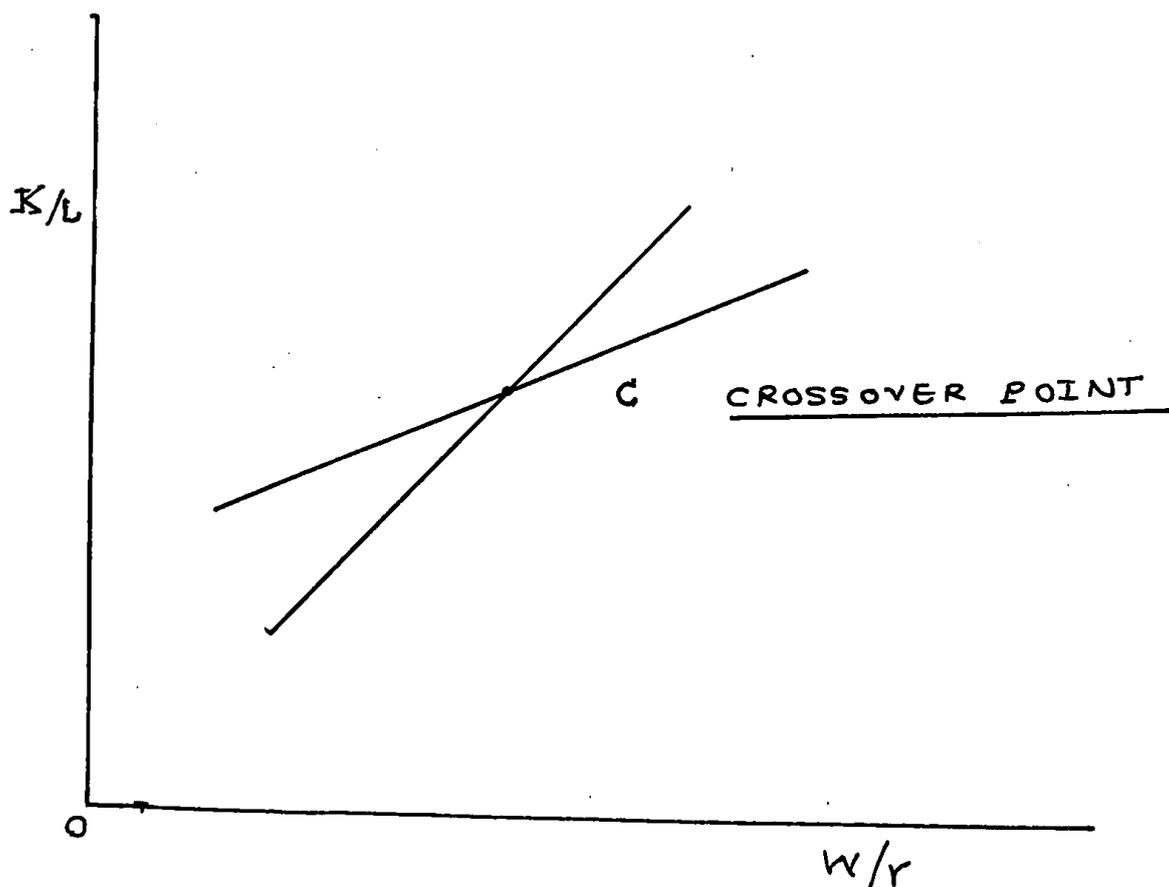
Minhas (1962)⁹ says, "the phenomenon of factor reversals spoils the neatness of the H-O theorem, about the direct relationship between factor endowment and trade patterns. But at the intuitive level, the theorem seems to contain some elements of truth and we can stress the importance of factor endowment in another way."

The empirical observation suggested by the statistical fits is that the labour abundant low wage countries would tend to hold comparative advantage in those industries which have low elasticities of substitution between capital and labour : even though those very industries happen to be relatively capital intensive at the prevailing relative cost of labour and

9. Minhas : "The homohypallagic production function, factor intensity reversals and H-O theorem."
Journal of political economy (April 1962)

capital. The H-O theorem involves the assumption that the facts of technology permit those industries that are characterised by high elasticity of substitution between capital and labour, to use capital (the relatively cheaper factor in capital rich countries) relatively more intensively so that the capital rich countries are able to establish a comparative cost advantage in their production. The validity of this assumption cannot be given unless more detailed and carefully conceived empirical analysis is made.

With an alternative assumption, it can be shown that the labour abundant countries lying to the left of the crossover point, may hold a comparative cost advantage, in production of their relatively labour intensive commodities. Therefore the H-O prognosis will be true only for the range of experience on the side of the crossover point.



1.4.2 : Also in its thoroughly rigorous form, the theory has remained limited to a two country model (although in terms of commodities, it has been extended to the multicommodity case).¹⁰

J. Bhagwati (1974)¹¹ has noted the "serious lacuna" which the failure to extend the theory fully to multi-commodity, multicountry case represents.

1.5 : The other important reason for the recent decline of the H-O theory of trade from its earlier preminence has been its failure to receive substantial empirical verification (with few important exceptions).

1.5.1 : An earlier attempt to verify the comparative cost advantage was made by MacDougall (1952)¹² based on data collected by Rostas in respect of horsepower per worker in some industries in U.K. and U.S.A. Results did not show that U.S.A. was exporting more capital intensive commodities. The study failed to confirm the H-O theorem and supported the classical version.

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10. R.W. Jones; "Factor proportions and H.O. theorem"
- Review of economic studies, 1956-57, pp 1-10.
 11. Jagdish Bhagwati; "The pure theory of international trade : a survey"
Economic Journal, 1974, pp 1-84.
 12. MacDougall G.D.P. : "British and American exports : A study suggested by theory of comparative costs," Part I and II - Economic Journal, December 1951, September 1952.

1.5.2 : Paradoxical findings of Leontief¹³

Leontief (1953) tried to test whether it is true that the U.S. exports commodities the domestic production of which absorbs relatively large amount of capital and little labour and imports foreign goods and services which - if they had produced them at home - would employ a great quantity of indigenous labour but a small amount of domestic capital. The observations show that the average million dollars' worth of U.S. exports embodied considerably less capital and somewhat more labour than would be required to replace from domestic production, an equivalent amount of competitive imports. America's participation in the international division of labour is based on labour intensive rather than capital intensive lines of production - or - U.S. economy is characterized by a relative surplus of capital and relative shortage of labour proves to be wrong.

1.5.3. : Ichimura and Tatemoto (1959)¹⁴

They find in their empirical study that Japan is labour abundant if her trade with U.S.A. alone is considered; but she becomes capital abundant if her trade with all other countries of the world as a whole is considered.

13. W.W. Leontief; Input Output Economics : "Domestic Production and Foreign Trade", pp 67-90

14. Ichimura and Tatemoto; "Factor proportions and foreign trade - the case of Japan". The Review of Economics and Statistics, November 1959.

1.5.4 : Bharadwaj (1962)¹⁵ finds that India is capital abundant if her trade with U.S.A. alone is considered and labour abundant in case of her trade with all the countries of the world as a whole. To test the pattern of trade, according to him, one can examine trade 1) with rest of the world. 2) with rest of the world directly in trade, with it. 3) with the rest of the world directly in trade with it. 4) one country's trade with each of the countries in direct trade with it.

1.5.5. : Wahl (1961)¹⁶ : His study for Canada is based on the calculation of direct capital coefficient for only 22 sectors in the year 1949. Canada appears to be more capital endowed as against U.S.A.

1.5.6 : Stolper and Roskamp (1961)¹⁷ He collected data for 1956. The physical coefficients were valued at 1950 West German prices. They obtained results opposing to H-O theorem.

1.5.7 : Prasad (1978)¹⁸ : He included natural resources as third factor of production. His results show that the exports from India are natural resource oriented.

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15. Bharadwaj R.; "Structural basis of India's foreign trade" University of Bombay, 1962.
 16. Wahl; "Capital and labour requirements for Canada's foreign trade" - The Canadian Journal of Economics and Political Science, August, 1961.
 17. Stolper and Roskamp; "An input-output table for East Germany with applications to foreign trade". Bulletin of Oxform University Institute of Statistics, November 1961.
 18. Prasad; "Empirical varification of H-O therem " 1978

CHAPTER 2

LEONTIEF'S METHODOLOGY

THE INPUT-OUTPUT ANALYSIS

2.1.1. : Leontief's Procedure¹⁹ to test H-O Theorem

Leontief (1953) tried to test whether it is true that the U.S. exports commodities the domestic production of which absorbs relatively large amounts of capital and little amount of labour and imports foreign goods and services which, if they had produced them at home - would employ a great quantity of indigenous labour but a small amount of domestic capital.

He imagined a situation in which the U.S. for some reason wanted to reduce its dependence on foreign countries and to achieve this end, decided to decline both its imports and exports by one million dollars each. He examined a particular case in which the reduction of exports is to be achieved by an equal proportional cut in each export commodity, so that after the reduction the percentage composition of exports remains unchanged. The same procedure is applied to competitive imports, i.e. the imports of commodities which can be and are, at least in part, actually produced by domestic industries. The level of noncompetitive imports is assumed to remain unchanged. Therefore the labour and capital requirements for the domestic production of these commodities (e.g. coffee) cannot be realistically assessed.

19. Leontief and others; The studies in the structure of American economy, New York, Oxford University Press, 1953.

To replace a million dollars' worth of imports, he raised the output of the corresponding U.S. industries. If competitive imports were cut proportionally, the domestic production of specific goods involved would have to expand by the amounts equal to the reduction in the corresponding imports i.e. by the same proportional amounts.

Such domestic production for replacing imports would mean additional direct and indirect capital and labour requirements. To determine these, he used the large 200 industries input-output table of American economy for the year 1947²⁰, showing the competitive imports for that year by the commodity groups into which they would fall if they had been produced by the domestic industries. Dividing each one of these figures by the aggregate dollar value of all competitive imports gives us the amounts by which the domestic outputs of these goods and services would have to be increased if the economy proceeded to replace commodity by commodity on aggregate million dollars worth of competitive imports. To compute total amount of capital which would be required to produce domestically this particular collection of commodities, he multiplied each of these figures by the corresponding capital requirements and then added the resulting products. Similarly labour requirements were found out.

20. Leontief W.W.; Input-Output Economics, Domestic Production and foreign trade.
New York, Oxford University Press, 1966, pp 68-99.

The quantities of capital and labour absorbed by the American economy per million dollars of its 1947 exports were determined exactly in the same way.

2.1.2 : The principal findings

The principal findings of the quantitative factual analysis are :

	Exports	Import Replacements
Capital (dollars in 1947 prices)	25,50,780	30,91,339
Labour (man years)	1,82,313	1,70,004

i.e. in case of exports, the capital labour ratio is 14 : 1 whereas in case of import replacements, it is 18 : 1 approximately. These figures show that the average million dollars worth of U.S. exports embodied considerably less capital and somewhat more labour than would be required to replace from domestic production, an equivalent amount of competitive imports. America's participation in the international division of labour is based on its specialization on labour intensive rather than capital intensive lines of production i.e. this country resorts to foreign trade in order to economize its capital and dispose off its surplus labour. The widely held opinion - that as compared to the rest of the world - U.S. economy is characterised by a relative surplus of capital and relative shortage of labour proves to be wrong.

2.1.3 : The Explanation of this unexpected result was given by Leontief himself as : "The observation is that the U.S. possesses more productive capital per worker than any other country." If we maintain the implicit assumption of H.O. theorem that the relative productivity of capital and labour is same here and abroad and if the techniques are identical in two countries or inputs differing in both industries in the same proportion in one country - the comparative costs argument necessarily leads to the conclusion that a country possessing a large stock of capital and relatively small number of workers will find it advantageous to specialize in industries which in terms of its own productive possibilities require much capital and relatively little labour.

But Leontief then rejects these assumptions and makes a plausible alternative assumption that in any combination with a given quantity of capital, one man-year of American labour is equivalent to three man-years of foreign labour. Then in comparing the relative amounts of capital and labour possessed by U.S. and the rest of the world - a comparison used for the explanation of their respective specialization in capital or labour intensive industries respectively - the total number of American workers must be multiplied by three. Therefore American capital supply per "equivalent worker" turns out to be comparatively smaller rather than larger, than that of many other countries. So according to Leontief, trade pattern follows

H-O path, but the assumptions of (1) production functions for the same commodity and (2) the quality of factors being the same in both the countries are inappropriate.

2.2 : The Input-Output System²¹

The input-output analysis is concerned with studying the interdependence of the producing and consuming units in an economy and with showing the interrelations among different sectors which purchase goods and services from other sectors and which in turn produce goods and services which are sold to other sectors. There are two types of input-output models.

1. Closed model,
2. Open model.

It was always recognised that the object of economic activity was satisfaction of final demand and Leontief exploited this fact in his design of "open static model". In this system final demand i.e. exports, government services, household consumption and capital formation is assumed to be related to other sectors but is autonomously determined by factors outside the system. Labour is considered as an input but not as a functionally related produce of households.

In doing input-output study, it is necessary to produce three main tables. 1. a transactions table, 2. a table of technical coefficients, 3. a table of interdependence coefficients.

21. Chiou-Shuang Yan : Introduction to Input-Output Economics, Principles of Economic Series, Edited by Edward Ames.

2.2.1 : Transactions Table

The basic table of input-output system is known as the transactions table. In this table, various economic flows within the economy during some particular base year are entered in value terms. In order to prepare this table, the economy is divided into a number of sectors. Output of each sector is distributed along a row of the table while the corresponding column records the inputs of this sector.

The transactions table can be divided in four quarters as :

I n x n	II n x m
III p x n	IV p x m

The first quadrant shows the flows of goods and services which are both produced and consumed in the process of current production. These are usually referred to as interindustry flows or intermediate demand.

The second quadrant shows the various elements of final demand for the output of each producing sector. It consists of final demand of household and government consumption, capital formation and exports.

The third quadrant shows what are called primary inputs, to the productive sectors. These inputs are not part of the output of current production.

The fourth quadrant shows the primary inputs which go directly to the final demand sectors.

In an input-output table, the total value of output of each productive sector i.e. the row total is always equal to its total expenditure on inputs i.e. the column total. The equality of inputs and outputs in a transactions table is an accounting identity.

2.2.2. : Technical Coefficients

After preparing the transactions table, the next operation is to calculate the unit cost structure or the technical coefficients. These coefficients are calculated by dividing every item in quadrants I and III by total of column in which the item is recorded.

2.2.3 : Interdependence coefficients

Because of the interrelationship between different sectors of an economy, a change in the final demand for the products of one sector causes changes throughout the system which change not only the outputs of the sector concerned but also those of most or perhaps all of the other sectors of the economy. To study these changes, we must consider the direct as well as the indirect effects of changes in final demand. The technical coefficients show only the direct effects of the changes in the final

demand. Therefore the matrix of technical coefficients shows only the direct effects of the changes in the final demand. Therefore the matrix of technical coefficients is not able to give us the total effects. So we have to prepare a special kind of matrix which gives the direct as well as indirect effects of the changes in the final demand. This matrix can be prepared as follows :

The transactions table can be written as :

	Agriculture	Industry	Services	Total Final demand	Total output
Agriculture	X11	X12	X13	Y1	X1
Industry	X21	X22	X23	Y2	X2
Services	X31	X32	X33	Y3	X3
All Primary inputs	Z1	Z2	Z3		
Total Inputs	X1	X2	X3		

$$\begin{aligned}
 \text{Therefore, } X1 &= X11 + X12 + X13 + Y1 &) \\
 X2 &= X21 + X22 + X23 + Y2 &) \\
 X3 &= X31 + X32 + X33 + Y3 &)
 \end{aligned}
 \quad (1)$$

The interindustry technical coefficients are given as A matrix.

Sector	Agriculture	Industry	Services
Agriculture	a11	a12	a13
Industry	a21	a22	a23
Services	a31	a32	a33

Where $a_{11} = \frac{X_{11}}{X_1}$, $a_{21} = \frac{X_{21}}{X_1}$, $a_{12} = \frac{X_{12}}{X_2}$, $a_{13} = \frac{X_{13}}{X_3}$ etc.

So $X_{11} = a_{11} X_1$ $X_{12} = a_{12} X_2$ and so on.

Substituting these values in the above equations,

$$\begin{aligned} X_1 &= a_{11} X_1 + a_{12} X_2 + a_{13} X_3 + Y_1 \\ X_2 &= a_{21} X_1 + a_{22} X_2 + a_{23} X_3 + Y_2 \\ X_3 &= a_{31} X_1 + a_{32} X_2 + a_{33} X_3 + Y_3 \end{aligned} \quad (2)$$

$$\begin{aligned} \text{Therefore } (1-a_{11}) X_1 - a_{12} X_2 - a_{13} X_3 &= Y_1 \\ - a_{21} X_1 + (1-a_{22}) X_2 - a_{23} X_3 &= Y_2 \\ - a_{31} X_1 - a_{32} X_2 + (1-a_{33}) X_3 &= Y_3 \end{aligned} \quad (3)$$

This can be written in matrix form as -

$$\begin{vmatrix} (1-a_{11}) & -a_{12} & -a_{13} \\ -a_{21} & (1-a_{22}) & -a_{23} \\ -a_{31} & -a_{32} & (1-a_{33}) \end{vmatrix} \begin{vmatrix} X_1 \\ X_2 \\ X_3 \end{vmatrix} = \begin{vmatrix} Y_1 \\ Y_2 \\ Y_3 \end{vmatrix}$$

or

$$\begin{aligned} (I - A) X &= Y \\ X &= (I - A)^{-1} Y \dots \dots (4) \end{aligned}$$

The interdependence coefficients given by the matrix $(I - A)^{-1}$ show both direct and indirect effects of increasing final demand for any sector by one unit of value.

Though the total effects of demand changes are given by the interdependence coefficients, it is sometimes useful to break down these effects into their different components so as to isolate the first order, second order, third order etc. effects.

If the final demand for agriculture produce increase by one unit with no change in the final demand for other sectors,

the direct or the first order effect on the total outputs in direct sectors will be -

$$\begin{array}{c}
 \begin{array}{ccc}
 & A & \\
 \left| \begin{array}{ccc}
 a_{11} & a_{12} & a_{13} \\
 a_{21} & a_{22} & a_{23} \\
 a_{31} & a_{32} & a_{33}
 \end{array} \right| & & \begin{array}{c} Y \\ \left| \begin{array}{c} 1 \\ 0 \\ 0 \end{array} \right|
 \end{array} \\
 & & = \\
 & & \begin{array}{c} X^{(1)} \\ \left| \begin{array}{c} a_{11} \\ a_{21} \\ a_{31} \end{array} \right|
 \end{array}
 \end{array}
 \end{array}$$

These first order effects give rise to second and higher order effects ~~because the first order effects~~ because the first order increases in output require further inputs to generate them, and these in turn generate increase in outputs further and so on.

The second order effects will be therefore :

$$\begin{array}{c}
 \begin{array}{ccc}
 & A & \\
 \left| \begin{array}{ccc}
 a_{11} & a_{12} & a_{13} \\
 a_{21} & a_{22} & a_{23} \\
 a_{31} & a_{32} & a_{33}
 \end{array} \right| & & \begin{array}{c} X^{(1)} \\ \left| \begin{array}{c} a_{11} \\ a_{21} \\ a_{31} \end{array} \right|
 \end{array} \\
 & & = \\
 & & \begin{array}{c} X^{(2)} \\ \left| \begin{array}{c} a_{11}^2 + a_{12} a_{21} + a_{31} a_{13} \\
 a_{21} a_{11} + a_{22} a_{21} + a_{23} a_{31} \\
 a_{31} a_{11} + a_{32} a_{21} + a_{33} a_{31}
 \end{array} \right|
 \end{array}
 \end{array}
 \end{array}$$

Similarly the third order, fourth order effects can be obtained as :

$$\begin{array}{l}
 X^{(1)} = AY \\
 X^{(2)} = AX^{(1)} = A^2Y \\
 X^{(3)} = AX^{(2)} = A^3Y \\
 X^{(n)} = AX^{(n-1)} = A^nY
 \end{array}$$

These effects can be calculated until a point is reached when no further increase of any significance whatsoever is obtained for the sum of effects of all further orders.

$$\begin{aligned} \text{Thus : } X^n &= Y + AY + A^2Y + \dots + A^nY \\ &= (I + A + A^2 + \dots + A^n) Y \end{aligned}$$

The vectors of outputs obtained for a sufficiently large value of n is effectively the same as that obtained by multiplying the vector of final demand by the interdependent coefficients. This "iterative" approach²² is another way of obtaining the total effect of demand increase upon the outputs of the different sectors.

From equations (4) and (5) we get -

$$\begin{aligned} X^n &= (I - A)^{-1} Y = (I + A + A^2 + \dots + A^n) Y \\ \text{Therefore } (I - A)^{-1} &= (I + A + A^2 + \dots + A^n) \end{aligned}$$

Where n is sufficiently large. This method of obtaining the inverse is known as "expansion of powers" method but it is suitable only for the matrices whose elements form a convergent series when expanded.

22. Hatanka : "The workability of Input-Output analysis."

2.2.4 : Testing the validity of input-output assumptions²³

(1) The constancy of input ratios :

Controversy about input-output analysis has ranged most intensely over the original Leontief assumption of constant input ratios or coefficients. If held strictly, this assumption has four implications which appear contradictory by general observation. First, it implies that all inputs are uniformly affected by a change in the scale of production, thus ignoring the time honoured distinction between fixed and variable inputs and between short and long run. Second, it assumes that industries can be classified sufficiently finely to eliminate multiproduct industries whose input structures would be affected by changes in product mix of their outputs. Third, it means that economizing substitutions among inputs due to changes in relative prices or availabilities are of negligible importance. Finally, it implies that technological changes in input structures are sufficiently rare and slow that they can be either disregarded or adjusted for in simple fashion.

Yet the assumption of constant input-output ratios can only be a first approximation to the more complex production functions of the real world. Nonproportional inputs, changes in the product mix, input substitutions and technological changes all do occur, beyond any question. The really important question,

23. Hatanka : "The workability of Input-output analysis".

therefore, is an empirical one : 'are the errors involved in using this simplifying assumption satisfactorily small?'

There are two main kinds of tests of the empirical usefulness of the assumption of constant input coefficients. One kind consists in direct comparisons of individual input ratios at different points in time. The other kinds involves comparing the computed results of an input-output projection with the actual operation of the economy.

The tests by applying direct method were taken for U.S. and Japan. The main inference drawn from these direct tests of the input ratios is that this assumption of constancy of input coefficients, for the bulk of coefficients in an input-output matrix is not likely to cause great difficulty, but for a relatively small number of coefficients it should be treated systematically.

Several tests were taken by applying the second method. The overall tests do indicate that, in certain parts of the economic structure modifications of strict input-output assumptions are clearly desirable.

(2) The input-output table cannot be written in physical units. It must be written in value terms. For this, the physical units are multiplied by the price of the corresponding commodity. Whether to use the purchaser's price or the producer's price is the problem. The purchasers of inputs buy the commodities at producers prices. The purchasers of final commodities purchase them at purchaser's prices and so the problem arises. Most of the input-output tables use producer's prices for getting the value

2.2.5 : Dynamic Aspects of Input-Output Analysis²⁴

The input-output model discussed so far, neglected entirely the effect of time element. First of all, when a given change occurs, we are interested in finding the new equilibrium level of output rather than the processes of adjustment in production and the time required in reaching the new equilibrium. Due to the fact that technical coefficients in value terms are less than one, the indirect input requirements converge and eventually the input-output system is expected to reach the new equilibrium. However, it is also important to know the speed of adjustments. If the adjustments are slow in pace, the gap between demand and supply is difficult to be filled and before the equilibrium is reached, final demand may divert its course that the expected effect will never be materialized.

There are some theoretical explanations on the dynamic adjustment processes in both micro and macroeconomics. But there is practically no empirical investigation on the speed adjustments. "Time" is crucial in many economic problems, e.g. when final demand increases, we need not be worried about inflation if the adjustments of production to the new level of final demand are rapid. However, if the adjustments are slow, some measures may be required to prevent the possible inflation. It is desirable then to conduct empirical as well as theoretical research on the adjustments process of input-output system.

24. Chenery H.B. and Clark P.G.; "Interindustry Economics", New York, John Wiley and Sons, 1959.

Another dynamic aspect of production is the attention on the input of capital stock. Capital stock in contrast with the current inputs, used this year can be reused next year except for the part which wears out. Therefore there is no need to produce new capital goods unless some existing stock has to be replaced or additional capital goods are required due to increase in output levels. For simplicity, we shall disregard the replacement needs. Then, the amount of new capital goods needed by sector j (ΔK_j) depends on the change in the output level (ΔY_j) of that sector.

$$\Delta K_j = f_j (\Delta Y_j)$$

By applying the assumption of fixed proportions, let us denote the capital coefficient for the sector.

Then the additional capital goods needed by sector j are :

$$\Delta K_j = K_j \Delta Y_j$$

The production of ΔK_j by the capital good industry requires inputs of various kinds, suppose that m_{ij} units of product i are required to produce one unit of capital good used in sector j . Then to acquire the additional capital goods, sector j has to indirectly purchase $m_{ij} K_j \Delta Y_j$ units of output from sector i . This is in addition to its purchase from current uses from sector i ; Therefore total output produced by sector i is now the sum of the output sold as

current inputs ($\sum_{j=1}^n b_{ij} Y_j$) the output sold to form capital goods ($\sum_{j=1}^n m_{ij} K_j \Delta Y_j$) and the output sold to final demand (F_i).

$$\text{Therefore } Y_i = \sum_{j=1}^n b_{ij} Y_j + \sum_{j=1}^n m_{ij} K_j \Delta Y_j + F_i$$

Since the change in output is the difference of output in one period and the period before, the output of sector i in the time period t is

$$Y_i(t) = \sum_{j=1}^n b_{ij} Y_j(t) + \sum_{j=1}^n m_{ij} K_j (Y_j(t) - Y_j(t-1)) + F_i(t)$$

Thus we find that in addition to final demand, output in one period is actually affected by the output in previous period.

2.2.6 : The Leontief Paradox : Mathematical Form²⁵

Given the set of one million exported goods and that of imported goods, Leontief calculated total labour and capital requirements for producing them domestically by applying the matrix which indicates the requirements of fixed resources per unit of final demand. Let us denote this matrix as F matrix. The exports and imports here are both in money terms and the F matrix is in physical units. It is thus necessary to derive another F matrix in terms of money.

25. Chiou-Shuang Yan - Introduction to Input-Output Economics: Principles of Economics Series, Ed. Edward Ames.

Let vectors \bar{l} and \bar{k} denote the direct labour and capital requirement per unit of output in money units.

$$\bar{l} = (\bar{l}_1, \bar{l}_2 \dots \dots \dots, \bar{l}_n)$$

$$\bar{k} = (\bar{k}_1, \bar{k}_2 \dots \dots \dots, \bar{k}_n)$$

and s be the matrix consisting of vectors l and k

$$\text{Therefore } s = \begin{vmatrix} \bar{l}_1 & \bar{l}_2 & \dots & \bar{l}_n \\ \bar{k}_1 & \bar{k}_2 & \dots & \bar{k}_n \end{vmatrix}$$

Multiply the inverse matrix in value terms $(I - A)^{-1}$ to the S matrix, where $(I - A)^{-1}$ matrix indicates the direct and indirect requirements per dollar of final demand.

$$\begin{aligned} S (I - A)^{-1} &= \begin{vmatrix} \bar{l}_1 & \bar{l}_2 & \dots & \bar{l}_n \\ \bar{k}_1 & \bar{k}_2 & \dots & \bar{k}_n \end{vmatrix} \begin{vmatrix} e_{11} & e_{12} & \dots & e_{1n} \\ e_{21} & e_{22} & \dots & e_{2n} \\ e_{n1} & e_{n2} & \dots & e_{nn} \end{vmatrix} \\ &= \begin{vmatrix} l_{ie11} & l_{ie12} & \dots & l_{iein} \\ k_{ie11} & k_{ie12} & \dots & k_{iein} \end{vmatrix} \\ &= \begin{vmatrix} f_{11} & f_{12} & \dots & f_{1n} \\ f_{21} & f_{22} & \dots & f_{2n} \end{vmatrix} \\ &= F \end{aligned}$$

Since the economy is divided into 200 sectors, the matrix used by Leontief has 200 columns and two rows (the first row indicates the labour requirements and the second, the capital requirements).

$$\text{Therefore, } F = \begin{vmatrix} f_{11} & f_{12} & \dots & f_{1 \ 200} \\ f_{21} & f_{22} & \dots & f_{2 \ 200} \end{vmatrix}$$

The set of exported goods E and that of imported goods M to be reduced are -

$$E = (E_1 \ E_2 \ \dots \ E_{200})$$

$$M = (M_1 \ M_2 \ \dots \ M_{200})$$

The total direct and indirect labour and capital requirements for production of this set of exported goods are,

$$\begin{aligned} \overline{F E} &= \begin{vmatrix} f_{11} & f_{12} & \dots & f_{1 \ 200} \\ f_{21} & f_{22} & \dots & f_{2 \ 200} \end{vmatrix} \begin{vmatrix} E_1 \\ E_2 \\ \cdot \\ \cdot \\ E_{200} \end{vmatrix} \\ &= \begin{vmatrix} \sum_{i=1}^{200} \overline{f_{1i}} & E_i \\ \sum_{i=1}^{200} \overline{f_{2i}} & E_i \end{vmatrix} \dots \dots \dots (1) \end{aligned}$$

The total direct and indirect labour and capital requirements for the production of this set of imported goods are,

$$\begin{aligned} \overline{F M} &= \begin{vmatrix} \overline{f_{11}} & \overline{f_{12}} & \dots & \overline{f_{1 \ 200}} \\ \overline{f_{21}} & \overline{f_{22}} & \dots & \overline{f_{2 \ 200}} \end{vmatrix} \begin{vmatrix} M_1 \\ M_2 \\ \cdot \\ \cdot \\ M_{200} \end{vmatrix} \\ &= \begin{vmatrix} \sum_{i=1}^{200} \overline{f_{1i}} & M_i \\ \sum_{i=1}^{200} \overline{f_{2i}} & M_i \end{vmatrix} \dots \dots \dots (2) \end{aligned}$$

Comparing the results of (1) and (2), Leontief found that,

$$\sum_{i=1}^{200} f_{1i} E_i > \sum_{i=1}^{200} f_{1i} M_i$$

$$\sum_{i=1}^{200} f_{2i} E_i < \sum_{i=1}^{200} f_{2i} M_i$$

Namely, the total labour required for the production of the set of exported goods is greater than that for the production of the set of imported goods.

Alternatively, the set of exported goods requires more labour input and less capital input than the set of imported goods. This conclusion tells us that the U.S. exported labour intensive goods and imported capital intensive goods, which is contrary to conventional thinking.

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CHAPTER 3

LEONTIEF'S SECOND STUDY AND OTHER ATTEMPTS OF VERIFICATION

3.1 : Leontief's second study (and its appraisal)

Leontief (1956)²⁶ tried to incorporate a number of points in his second study; which were raised against his first study. In order to take account of various criticisms, the second study gives a number of alternative computations regarding capital and labour requirements per million dollar worth of U.S.A.'s competitive imports and exports both for 1947 and 1951 as 1947 was alleged to be a typical year. The assumption here is that the physical input coefficients for 1947 are the same for 1951 also.

Computation A covers capital and labour employment in all the 192 sectors, input coefficients here include capital replacement and the capital and labour requirements are for per million dollar worth of competitive imports and exports of all sectors.

Computation D is similar to A in all other respects except that capital and labour employment in 19 sectors comprising of raw and semi-fabricated imports are not covered. They are treated as non-competitive since they are taken to

26. Leontief W.W., 'Factor proportions and the structure of American trade - further theoretical and empirical analysis' :Review of Economics and Statistics, November 1956, pp 386-407.

be natural resource based and as such their corresponding rows and columns are excluded from matrix A.

In computations B and C1 to C4, capital replacement and service sectors are not considered at all. In computation B, capital and labour employment for 50 aggregated sectors is considered. Computations C1 and C2 cover 1-164 sectors for capital and labour employment, whereas C3 and C4 cover only 10-164. None of C1 to C4 covers services sector.

Then, he calculates the ratio of capital labour ratio of competitive imports / capital labour ratio of exports which he calls α . If $\alpha > 1$, it shows competitive imports as compared to exports are capital intensive. In all the computations right from A to C4, the value of α is greater than one which supports the results of his first study. But in computation D, $\alpha < 1$, which supports the general notion.

3.2 : Other attempts

3.2.1 : Japan : Ichimura and Tatemoto (1959)²⁷ have calculated capital and labour (man-years) requirements of Japan's exports and competitive imports for 1951 on the basis of

$$\begin{aligned} & \bar{K}_1 (I - A)^{-1} (b) \quad \text{and} \quad \bar{n}_1 (I - A)^{-1} (b) \quad \text{and} \\ & \bar{K}_1 (I - A)^{-1} (c) \quad \text{and} \quad \bar{n}_1 (I - A)^{-1} (c) \end{aligned}$$

27. Ichimura and Tatemoto; "Factor proportions and foreign trade - the case of Japan", The Review of Economics and Statistics, November 1959.

where (K1) and (n1) are capital and labour coefficients vectors. A is 29 x 29 I-O table and (b) and (c) are respectively column vectors of exports and competitive imports coefficients when total exports and competitive imports are taken as equivalent to one million yen. They have calculated -

$$r = \frac{\text{Cap. Lab. ratio for competitive imports}}{\text{Cap. Lab. ratio for exports}}$$

which is .644. Japan's exports are capital intensive as compared to her competitive imports. This is a paradox as Japan is taken to be a labour abundant country. But when they compare capital/labour ratio for Japan's exports to U.S.A. with that of Japan's total exports, the ratio is comparatively low i.e. Japan is exporting less capital to U.S.A. as compared to all the countries taken together. They also have found that r for U.S.A's exports to Japan is greater than that of r for U.S.A.'s exports to rest of the world, i.e. U.S.A.'s exports to Japan are more capital intensive as compared to U.S.A.'s exports to rest of the world.

3.2.2 : Canada : Wahl's (1961)²⁸ study for Canada for 1949 is based on the calculation of direct capital coefficient for only twenty-two sectors of the 42 x 42 I.O table. The table is

28. Wahl, "Capital and Labour requirements for Canada's foreign trade" : The Canadian Journal of Economics and Political Science - August 1961.

reduced to 23 x 23. 23rd sector being unallocated sector. Labour coefficients are taken from wages and salaries row of I-O table, which is a break from the similar studies where man-years are considered. Capital coefficients are based on accumulated investments for thirty years with the assumption that service life of investment expenditure is constant. He calculates total capital and labour coefficients and uses them to derive total capital and labour requirements per million dollars worth of Canadian total trade, trade with U. K. and trade with U.S.A. He has presented his results with exclusion of non-competitive imports. His results show that Canadian exports are capital intensive as compared to its imports - this is true of Canada's total Canada-UKL and Canada-U.S.A.'s trade. This is true also for the year 1970. From this, Canada appears to be more capital endowed as against U.S.A. This further strengthens Leontief's paradox.

*has been
at 2.12.61*

3.2.3 : East Germany

Stolper and Roskamp (1961)²⁹ have used a variety of methods to calculate 14 x 14 I.O. table, exports, imports and capital and labour coefficients for East Germany for 1956. Physical coefficients, if available, are valued at 1950 West German prices and some of the sectors of I.O. table are based on West German relationships. Exports of particular industry are

29. Stolper and Roskamp, "An Input-Output table for East Germany with applications to foreign trade"; Bulletin of Oxford University Institute of Statistics : November 1961.

estimated on the basis of the ratio of Export of major comm.s
their output. Capital output ratios are based on

$$\frac{\text{Total investment for 1950-57}}{\text{Total output for 1950-57}}$$

However, capital output coefficients for agriculture are
somehow high. The calculations for this study show that to
produce imports indirectly via exports requires both less
capital and less labour than to produce the goods directly.

$$\text{If } r = \frac{\text{Capital labour ratio for competitive imports}}{\text{Capital labour ratio for exports}}$$

is calculated, it comes out to be greater than one i.e. East
German competitive imports are capital intensive rather than
her exports. Still they remark that the capital requirements
per man-year of labour for exports in 1956 were of the order
of DM 28-30,000. East German exports are thus relatively
capital intensive. Calculations for 1959 show similar results.

*all
very
exp
countries*

3.2.4 : India

Bharadwaj (1962)³⁰ in his study with respect to Indo-US
trade, initially calculates direct and indirect capital labour
requirements per unit delivery to final demand from each of
the sectors. After that by multiplying them with composite

30. Bharadwaj R., "Structural basis of India's foreign
trade", University of Bombay 1962.

commodity exports and competitive imports worth (i) one crore of rupees in case of India, (ii) a million dollars in case of U.S.A. he gets total capital and labour required for one crore rupees worth of exports and competitive imports. This he calls 'Input approach'. This he calculates for U.S. exports and competitive imports to and from India in 1951 at 1947 prices and similarly for Indian exports and competitive imports to and from U.S.A. in 1951 at 1953-54 prices.

Though the study is essentially Leontief's type, it is the first study which uses I.O. tables of different countries. The results in the case of U.S.A. as far as its trade with India is concerned are in conformity with the generally held views about U.S.A.'s overall trade i.e. U.S.A.'s exports are capital intensive and imports labour intensive. In case of India's as far as trade with U.S.A. is concerned, it presents a paradox i.e. India's exports are capital intensive and imports labour intensive. This is at variance with Bharadwaj's other study with respect to India's total trade.

In his first study, Bharadwaj has made an attempt to identify the presence of a third factor with respect to U.S.A.'s exports and imports to and from India in 1951 (at 1947 prices) by seeing whether total payments to capital and labour (direct and indirect) come upto one million dollar worth of exports and competitive imports. This is done by taking into account rate of return on labour and rate of return

on capital per dollar for 1949. The presence of third factor is more important in case of U.S.A.'s imports from India.

In his second study, Bharadwaj finds out factor requirements on the basis of both Input approach and deliveries approach. In deliveries approach, the production requirements are found first and then they are multiplied with respective direct capital and labour coefficients. All this is done for a crore of rupees worth of Indian exports and competitive imports with the rest of the world for the year 1953-54. The results are non-paradoxical in the H.O. context in this case as Indian exports like labour intensive and competitive imports capital intensive.

What are these approaches that he is talking about?

Where is Prasanna's study?

.....

Year	Study by	Country	Method used	Observed Results
1959	Ichimura and Tatemoto	Japan : Trade with all Trade with USA	Same as Leontief's	Paradoxical to H-O. Exports were capital intensive as compared to competitive imports.
1962	Bharadwaj	India : Trade with all Trade with USA	Same as Leontief's But used I-O tables of different countries	India : Capital abundant - if her trade with USA is considered. India is labour abundant if her trade with rest of the world is considered.
1961	Wahl	Canada : Trade with all Trade with U.K. Trade with USA	Same as Leontief's Calculated labour requirement from wages and salaries in I.O. table, instead of mandays	Exports were capital intensive as compared to competitive imports : Paradoxical to H-O.
1961	Stolper and Roskamp	East Germany	Same as Leontief's	Exports are relatively capital intensive : Paradoxical to H.O.
1978	Prasad	India	Considered three factors instead of only two 1.labour 2.Capital 3.Natural resources	India's exports are natural resources oriented.

CHAPTER 4

CRITICISM

Leontief's results have drawn a stream of criticisms which may be grouped as (1) theoretical and methodological and (2) statistical and factual. Those who attacked, from a theoretical angle are P.T. Ellsworth, Jones R.W. and S. Valvanis-Vail. Those who have questioned Leontief on the statistical side are Swerling, Diab and Buchanan.

4.1 : P.T. Ellsworth (1954)³¹ : Since there are possibilities of different technical production functions in U.S. and abroad conditioned by differential factor supplies and hence factor prices, the correct comparison in his view would be to compare the capital and labour requirements for production of U.S. imports in the respective producing countries and not the requirements for producing the U.S. import replacements using the American production functions. He is of the opinion that when such a comparison is made, the so-called Leontief paradox will not be there.

How do you think the Leontief paradox is explained?

It is not the Leontief paradox, it is the Leontief paradox.

While examining Leontief's explanation of his findings, Ellsworth says that the superiority of American labour is to be examined "in terms of more abundant supplies of co-operating factors - entrepreneurship, natural resources and capital". This, together with the prevailing factor prices (high wages



31. P.T. Ellsworth; "The structure of American foreign trade a new view examined": The Review of Economics and Statistics, August 1954, pp 279-285.

and low rate of interest) supports, says Ellsworth, the common
senser presumption that the U.S. exports capital intensive
goods and imports labour intensive goods. Leontief could arrive
at the paradoxical conclusion, by sticking to a narrow approach
which does not take into account factor supplies and prices
abroad and by assuming that producers of import substitutes
use the same method as do the foreigners.

4.2 : Valvanis Vail (1954)³² : Tried to show (a) Input output
models are logically incompatible with international trade :
Leontief's way of getting his estimates is likely to be invalid.
(b) A country does not have to export the products of its most
abundant factor. Therefore, although American labour may, in
fact be superior to foreign labour, this is not a sufficient
explanation of the pattern of trade that Leontief observes.
(c) A country does not have to produce relatively more of the
product of its abundant factor, (d) If we know domestic and
foreign factor endowments and the extent to which America's
labour is superior, we can sometimes infer the pattern of
world production but not the pattern of trade.

why?

*Does it not
mean something
to them?*

Leontief obtained the estimates from his dynamic input-
output mode. In this model an industry may respond to external
shocks both by acquiring and disposing of fixed equipment and
by readjusting its scale of operations. The theoretical argu-
ment however, seems to run solely in terms of the static model.

32. S. Valvanis Vail, "Leontief's scarce factor paradox"
Journal of Political Economy, December 1954, pp 111-113.

But Valvanis Vail believes that fixed coefficients of production are generally incompatible with international trade, whether static or the dynamic model is used.

He criticizes that if the two countries have identical technology, they will in time become scale models of each other, their sizes depending on the rarest unalterable factor in each; such countries, if they also have identical tastes, cannot profitably engage in trade. Even if technologies and tastes both differ, but it happens that each country has a strong preference for the products of its own relatively abundant factor-home production may fall short of home demand and we may find each country exporting the product of its scarce, and not of its abundant factor.

Factor abundance and factor scarcity are ambiguous terms according to Valvanis-Vail, "Physical abundance and scarcity, though easy to detect are theoretically useless "Economic" abundance and scarcity, though useful, are difficult to detect operationally.

He suggests : "Beware of input-output models in international trade". So he believes that input-output model technology is incompatible with the study of problems of international trade. His argument is based on the fact that the assumption of full employment of factors does not always go together with fixed proportion of factor uses.

4.3 : There are several possible ways of explaining away Leontief's paradox. Leontief's study was an attempt at giving some empirical validity to the Ohlin-Heckscher theorem, in fact,

so far we have seen the opposite to be true, far from ramifying it, it has actually refuted it. America is capital rich. Yet she exports labour intensive products.

From the point of view of H-O theorem, there is on criticism that can be made of Leontief study which vitiates its conclusion and hence the H-O theorem remains undamaged.

Ford's (1965)³³ criticism is concerned directly with the methodological approach employed by Leontief. According to him, the Leontief procedure is not in fact a logically valid method of empirically testing the theorem. Leontief relates his figures for capital and labour inputs to export industries and competitive import replacements. What he should have done is to compare the input coefficients for exports and for non-competitive or actual imports. The O-H theorem only holds true when we compare actual imports with actual exports. In order for us to be able to conclude, in accordance with the O-H theorem, we would have to know the production functions for each product in America and in all other countries with which it traded. Ford says - "When one looks more carefully at the structure of American imports, one can well imagine it to be the case that if we were able to compile an input-output matrix for even some of these countries which trade with America one should find that the products that are imported from these

why?

33. Ford, "The O-H theorem of commodity trade" (1965) p.p. 58-59.

countries are labour intensive ones or require factors and conditions that are just not available in America".³⁴

1/4 America & 3/4 Europe

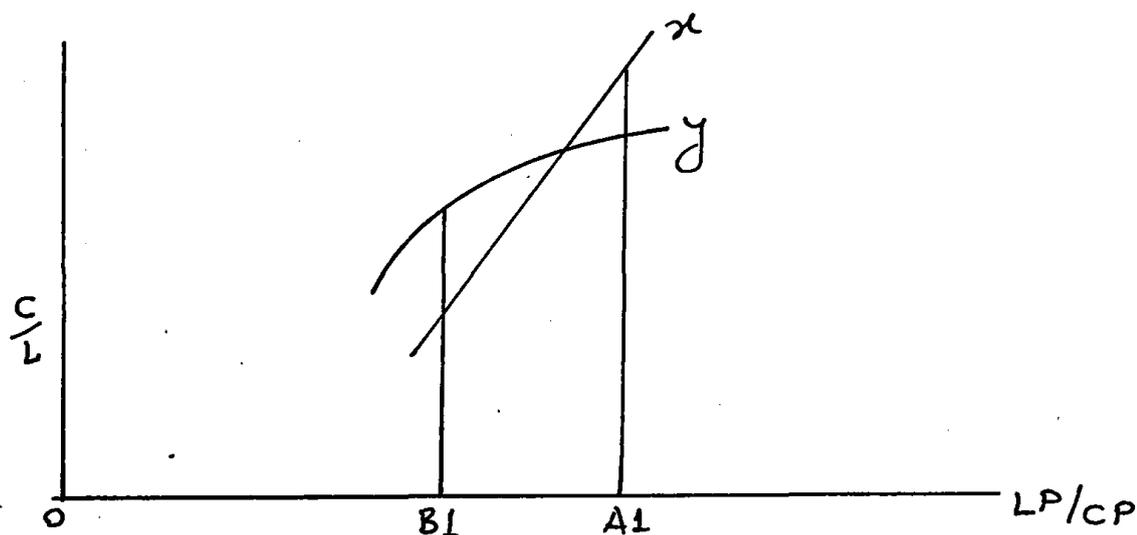
Since Leontief only considered import-replacements in terms of American productive practice, we would imagine that given the relatively favourable endowment of America with capital, that its overall productive process, including entrepreneurial experience and knowledge, was geared to being what one ought to call : 'Capital intensive' in the sense of using more capital than labour, or at least being inclined to substitute capital for land more readily than most other countries. Some of the products that are classified under import replacements may require for their efficient production materials or conditions which are not available in America. So Ford gave a restatement that : "America exports capital intensive products and import products which, if it were to produce them, would require relatively more of its abundant factor".

did he check with the

One explanation of Leontief paradox is related to the likelihood of completely different factor intensities for the same products between America and any country that exports to America where we have a situation in which we have "factor reversals" in the production coefficients for any given product in both countries, i.e. when 'a' product is capital intensive in one country and labour intensive in the other, then we cannot say directly from the factor endowment position which

34. Ford; "The O-H theorem of commodity trade" (1965)

country will export which product. The capital-rich country may have the advantage in producing the capital intensive commodity or commodities or the labour intensive ones.³⁵

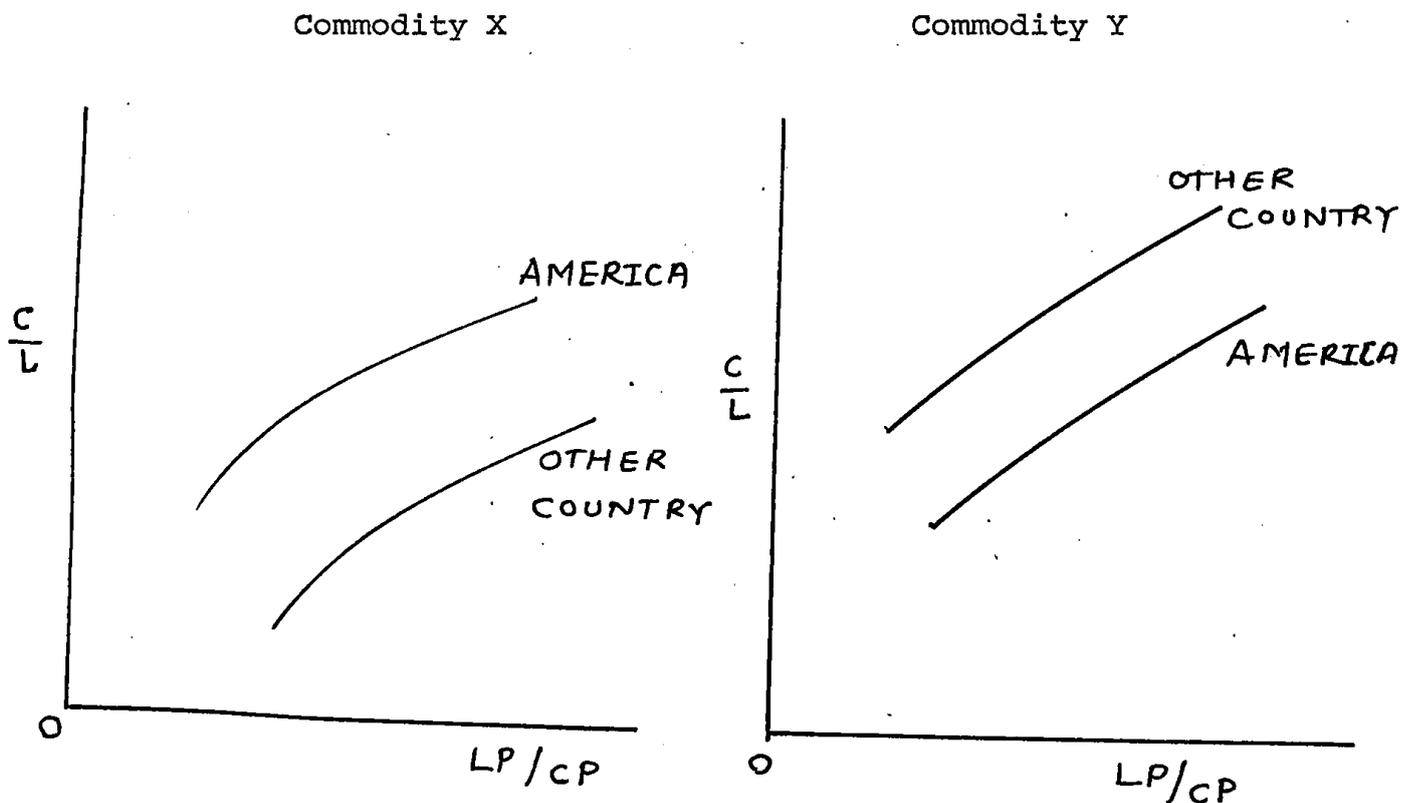


In the figure, if we suppose that the overall capital labour ratio is higher in America, we may expect that there the factor price ratio will be higher than in the given country with which it is about to trade. Therefore its relative price of labour will be OA^1 and that in other country OB^1 . Given demand conditions we observe that America exports Y, the labour intensive commodity there but the capital intensive one in the other country, while it imports X which is capital intensive in America but labour intensive in the other country. From this, it can be appreciated that if America was to begin production of X to replace imports, then it would be necessary to employ more capital per unit of output than

35. R.W. Jones, "Factor proportions and H.O. model" :
Review of economic studies, Volume 24, No.1, 1956-57,
pp 1-10.

for the export commodity Y. Thus it is possible owing to the enormous discrepancy between the American Capital labour ratio and that in other countries, given a situation of factor reversals as depicted in the figure for America to have an export import pattern as given by the Leontief study.

Ford has given a more interesting and possibly more empirically significant explanation of the Leontief paradox which employs a line of reasoning almost identical with that given above. According to him, it is more probable that the production techniques for any given commodity or group of commodities will be different in America from those employed elsewhere. Given two commodities X and Y and their different production processes in 2 countries -



the figure shows that in America for all factor price ratios X is relatively capital intensive. In the other country, Y is relatively capital intensive. Here America will export Y; the other country exports X. Thus, America is exporting the commodity that is in its own productive practice labour intensive (but which in the other countries is capital intensive) and is importing the commodity which in its own productive practice is capital intensive.

Two further explanations of Leontief paradox can be given. (1) It is quite possible that demand conditions might be such in America to force that country to import capital intensive commodities, home demand might be of such a nature that there is excessive pressure on the home market for all products that require a large amount of capital intensive production. This demand will, ceteris paribus cause the price of capital to rise to such proportions that on the one hand, America is forced out of export markets and on the other, home demand has to be satisfied by importing such commodities.

To test this hypothesis, we would have to demonstrate that American consumer demand was of such a form that it was biased towards capital intensive commodities. It has been maintained, however, that it does not bear this characteristic.³⁶ However, due to rapid economic and social development in

36. Brown A.J., "Prof. Leontief and the pattern of world trade", Yorkshire bulletin of Economic and Social Research, November 1957, p 71.

America, demand there is now concentrated on services which require an extremely large capital outlay and on highly finished manufactured products in whose production a large amount of expensive and intricate capital equipment is required.

4.4 : It is said that the peculiar conclusion reached by Leontief arises out of his failure to deal adequately with "natural resources". If commodities are excluded from the computation of capital labour ratios which rely heavily on natural resources, as Leontief's own computations show (Leontief 1956, pp.395-398), his conclusions would be reversed. If they are excluded, we obtain 0.88 instead of 1.06 when dividing the capital labour ratio in imports by the ratio in exports. This gives us the normally expected picture of America exporting capital intensive goods and importing labour intensive goods. As natural resources are an important element in the actual imports of America, it seems that as Leontief only considered import competing industries. It would be advisable to leave them out of account altogether in any study of American trade.

4.5 : There are also some statistical reasons for not accepting his study as having any useful purpose in accounting for the foreign trade structure of America and for maintaining that there is no paradox to explain away.

It had been maintained that 1947 was not a particularly proper year to select as the base year.³⁷ This Leontief has in part counteracted by using data for 1951 and reaching the same conclusions that he reached on the 1947 basis.

The one problem liable to cause most uneasiness is that of the calculation of the capital coefficients.³⁸ Diab challenged on this score. He has halved the capital coefficients for agriculture but has arrived at almost exactly the same conclusion as Leontief did. But Ford (1965)³⁹ says that one must have serious doubts about accepting the Leontief conclusion because it relies on his strict interpretation of capital requirements. Leontief maintains that no matter what level of output a given industry is producing at that when it has to increase its output by one million dollars' worth, it will always require the same capital input. But in reality an industry could be labour intensive for most increases in output and yet when it has to increase its output by one million dollars' worth, it could easily be capital intensive. There is obviously a danger in the Leontief definition of C/L intensive and he should have tried to account for the effects of levels of output on capital coefficients.

37. Swerling B., "Capital shortage and labour surplus in U.S." Review of Economics and Statistics, August 1954, p. 288.

38. Diab, "The United States capital position and the structure of its foreign trade" : pp 33-34.

39. Ford J.L., "The H-O theory of the basis and effects of commodity trade", Asia Publishing House, 1965, p 67.

CHAPTER 5

CONCLUSION

Leontief's study and the other studies made on his line have given rise to a number of critical reviews and reappraisals of both H-O theorem and Leontief paradox, the problem has remained inconclusive. Leontief's study and H-O theorem still continues to be subjected to a number of searching criticisms. In his recent study, Ford has said, "It is really impossible to test the basic theorem".⁴⁰ He concludes that Leontief study could never be an adequate test of H-O theorem, since the conditions under which the theorem is constructed are not present in reality.

Minhas⁴¹ challenged strong factor intensity assumption of H-O theorem. He discovers a new production function - SMAC or CES which permits reversibility of factor intensity between industries. Travis contends that factor endowments and protection combined can explain actual trade flows and not factor endowments alone.

Bickel⁴² concludes that relative factor proportions account

40. Ford, "The O-H theorem of commodity trade" (1965)

42. Bickel, "Factor proportions and relative price under C.E.S. production function" (1966)

41. Minhas, "The homohypallagic production function, factor intensity reversals and H-O theorem", (1962)

for 2/3rd of the observed variation in weighted average international commodity price ratios. But variation among industries in technical efficiency levels derived from CES accounts for 20% of the observed variation in relative commodity prices.

Hence, H-O theorem can be taken as an empirical generalisation where tests of the proposition have to be viewed as attempts to measure the comparative importance of factor endowments as opposed to the other influences which must be recognised as contributing to the determination of relative prices.

However, new grounds have been opened in this field which doubt the validity of the factor endowment being the sole explanation of trade pattern.

The inadequacy of factor endowments being the sole explanation of trade pattern and the fact that trade pattern in underdeveloped countries has been quite at variance with the predictions of H-O theorem have led to the search for new explanations.

For Kravis (1956)⁴³ it is 'availability' which explains trade pattern between industrial and primary producing countries. It is so because differences in natural resources in relation to population make primary commodities available for exports in underdeveloped countries, whereas technological change in industrial

43. Kravis, "Availability and other influence on commodity of trade", Journal of Political Economy, April 1956, pp 143-155.

countries make their products available (demonstration effect ensuring their demand) for exports to underdeveloped countries. National product differentiation (specific product of a specific country) and government policy make trade possible for specific commodities only. However, he himself realises the need for further research to find out how far these factors influence trade among underdeveloped countries or among industrialised countries themselves.

Linder (1961)⁴⁴ on the other hand distinguishes trade in primary and manufacturing commodities. Though factor endowments determine trade for primary commodities, it is similarity in the demand pattern of the trading countries which determine trade pattern for manufacturing commodities. It is so because then only internal expansion of the industry is sufficient enough to make it competitive in the world market.

Posner (1961)⁴⁵ explains trade on the basis of technical change and development provided they are occurring in one country but not simultaneously in the other or if there is some time lag involved.

Still, we can say that none of these views gives us full explanation of the whole trade pattern that is observed and so it calls for still further research in this field.

44. Linder, "An Essay on Trade and Transformation", New York, John Wiley and Sons (1961).

45. Posner M.V., "International trade and technical change", Oxford Economic Papers (October 1961), pp 323-41.

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