AGENCY FOR INTERNATIONAL DEVELOPMENT
WASHINGTON, D. C. 20523
BIBLIOGRAPHIC INPUT SHEET

FOR AID USE ONLY
Batch 68

1. SUBJECT CLASSIFICATION
A. PRIMARY: Development and economics — DK00-0000-0000
B. SECONDARY: Trade and commerce

2. TITLE AND SUBTITLE
Natural resources, factor mix, and factor reversal in international trade

3. AUTHOR(S)
Naya, Seiji

4. DOCUMENT DATE: 1967
5. NUMBER OF PAGES: 26p.
6. ARC NUMBER: ARC 382.N331

7. REFERENCE ORGANIZATION NAME AND ADDRESS
Wis.

8. SUPPLEMENTARY NOTES (Sponsoring Organization, Publishers, Availability)
(In Economic interdependence in southeast Asia research paper no.17)

9. ABSTRACT

10. CONTROL NUMBER
PN-AAE-395

11. PRICE OF DOCUMENT

12. DESCRIPTORS
Factor analysis
Foreign trade
Resources

13. PROJECT NUMBER

14. CONTRACT NUMBER
CSD-355 Res.

15. TYPE OF DOCUMENT

AID 590-1 (4-74)

III-86

382
N331

NATURAL RESOURCES, FACTOR MIX, AND FACTOR REVERSAL IN INTERNATIONAL TRADE

by

SEIJI NAYA

AID/University of Wisconsin
Research Project on "Economic
Interdependence in South-
east Asia"
Research Paper #17
April, 1967

SUMMARY

The paradoxical finding of Professor Leontief that American exports are, on the average, labor-intensive and imports capital-intensive is known as the Leontief Paradox. Some critics of this controversial finding have pointed to the methodological problem or the seriousness ofomitting factors other than capital and labor, e.g., natural resource factor. Others have argued that the resulting Paradox is due to the invalidity of the factor proportions theory of comparative advantage which Leonteif tested.

That the Paradox is due to the natural resource factor is implied by Leontief himself in one of his computations. Only in this computation, which excludes natural resource sectors, was the Paradox reversed. More recently, Vanek has empirically shown that the U.S. foreign trade pattern reflects a relative scarcity of natural resources. In his attempt to explain away the Paradox, Vanek reasons that capital and natural resources are a pair of complementary factors and, hence, although capital may be an abundant factor, more of it is needed to replace U.S. imports than is needed for exports.

In order to compare the factor structure of U.S. foreign trade with that of Japan, the natural resource products as well as capital and labor structure of Japan's foreign trade have been computed. The result reflects the generally accepted scarcity of natural resources of Japan's economy--the resource content of its imports is more than three times that of its exports. The computation of capital-labor requirements, however, reveals that its exports are capital-intensive

and its imports labor-intensive.

If natural resources and capital are complementary, exclusion of the natural resource sectors should increase the capital-intensity of Japan's exports relative to its imports. But the result of the computation excluding the resource sectors shows that the capital intensity of exports is no longer larger than its import, implying that the complementary argument does not adequately explain the case for Japan as it appears to for the U.S.

Separate studies of India and Canada, both employing Leontief's technique, add to the evidence of the influence of natural resources on the capital-labor structure of trade. Bharadwaj's study shows that Indian exports to the U.S. tend to be capital-intensive relative to its imports from the U.S. A similar result is shown in Wahl's study of Canada. Both writers point out that the relatively large share of primary products in the commodity composition of their country's trade might have influenced the paradoxical finding.

What then is the implication of the above analysis for the C-L structure of the foreign trade of a given country? For a country such as Canada, the C-L requirements of its composite exports tend to be capital-intensive since exports are raw material-oriented and its import requirements labor-intensive because of large imports of manufactured goods. On the other hand, for a country like Japan, exports are also likely to be capital-intensive not simply because the country is capital-rich but because it is land-scarce and imports large amounts of agricultural products which are extremely labor-intensive (in contrast to the capital intensity in the U.S. and Canada). This reasoning can

similarly be applied to explain both the Leontief Paradox and the Indian bilateral trade with the U.S.

We have so far proceeded within the framework of the factor proportions theory; let us go back now to the question of validity. Are the assumptions of this theory, and consequently its applicability, valid? One of the assumptions that has been criticized is that of "strong factor intensity," i.e., a given product remains relatively capital (or labor) intensive at any relative factor price ratio. If this assumption does not hold true (i.e., a machine product could be more capital-intensive than a textile product in the U.S. and vice-versa in, say, the Philippines), the relative price ratios of products and the pattern of comparative advantage may not be in accordance with the relative factor endowments of the two countries. The possibility of such a phenomenon (called factor reversal) has been theoretically and empirically demonstrated by Minhas.

One of Minhas' tests to show the occurrence of factor reversal is based on the comparison of the rankings of comparable U.S. and Japan industries by capital-labor ratios. The significantly dissimilar rankings of the two countries are given as evidence of factor-reversal. However, this writer finds that the dissimilarity is largely due to the large difference in the capital-intensity of agriculture and agriculture-related sectors. Since efficient production of agricultural products is dictated by a "land" factor and not soley by capital and labor, a ranking comparison excluding these sectors was made. This comparison raises the degree of similarity between the U.S. and Japan

rankings significantly enough to question the generality of the factor-reversal argument as applied to the ranking test.

The outright refutation of the theory on the basis of the two-factor paradoxes of the U.S. and other countries does not appear justified, since the inclusion of natural resources tends to explain these paradoxes. However, more research is needed on such topics as the nature of the production function and complementarity and/or substitutability of different factors as well as the role of the factors nottreated in this paper. Such research would further clarify the real status of the Heckscher-Ohlin theory.

Natural Resources, Factor Mix, and Factor Reversal in International Trade

Seiji Naya*

Most empirical tests of pure trade models are for those employing two factors, capital and labor. An example is the celebrated work of Leontief on the structure of U.S. foreign trade, the results of which are termed "The Leontief Paradox".[1] Many writers have been critical of Leontief's omission of a third group of factors, natural resources.[2] Vanek's empirical study on the role of natural resources in U.S. trade provides the strongest support presently available for the contention

---

*The author is an Assistant Professor of Economics at the University of Wisconsin. This paper has been taken from his unpublished dissertation, The Leontief Paradox and the Factor Structure of Japanese Foreign Trade, submitted to the same University, June, 1965. The author is much indebted to Professors R.E. Baldwin, P.T. Ellsworth, E.D. Hawkins, T. Morgan, H.O. Schmitt, and J.C. Williamson for their comments and to the Agency for International Development for research support.

[1]"The Leontief Paradox" refers to the statistical findings of W.W. Leontief that exports of the U.S. contain relatively less capital but more labor than domestic replacements of its competitive imports (in "Domestic Production and Foreign Trade: The American Capital Position Re-examined," Proceedings of the American Philosophical Society (September 1953), pp. 331-49; and "Factor Proportions and the Structure of American Trade: Further Theoretical and Empirical Analysis," Review of Economics and Statistics (November, 1956), pp. 386-407). In view of the large collection of literature on this subject, especially analytical comments, this paper focuses on recent empirical studies relating to the role of natural resources and factor reversals.

[2]B.C. Swerling, "Capital Shortage and Labor Surplus in the United States?" Review of Economics and Statistics (August, 1954), p. 289; I.B. Kravis, "Availability and Other Influences on the Commodity Composition of Trade," Journal of Political Economy (April, 1956), pp. 143-155; G. Haberler, A Survey of International Trade Theory, International Finance Section (Princeton: Princeton University Press, 1961), pp. 21-23.

that this omission explains the Paradox.[3]

Vanek's study is based only on U.S. data. This paper tests the applicability of his explanation of the Paradox to the trade structure of Japan, India and Canada (Section I). The capital (C), Labor (L) and natural resource product requirements of Japan's foreign trade are computed, but for India and Canada, the findings of R. Bharadwaj and D. Wahl are used.[4] The conclusion of the first section is then used to critically evaluate Minhas' ranking test of C-L intensity reversals, another explanation given for the Paradox (Section II).[5]

I

Although confined to two-factor analysis, Leontief was quite aware of the implication of the omission of the natural resource factor. He observes that the net trade position of such sectors as Sawmill Products, Pottery, Sulphur, and Grain Mill Products deviate from the direction of trade implied in his finding of a comparative capital shortage and labor surplus in the American economy. This deviation is attributed to the relative scarcity or abundance of natural resources required in the productive processes of these products.[6] The stronger possibility that

---

[3] J. Vanek, The Natural Resource Content of United States Foreign Trade, 1870-1955 (Cambridge: 1963).

[4] R. Bharadwaj, "Factor Proportions and the Structure of Indo-U.S. Trade," The Indian Economic Journal (October, 1962), pp. 105-16, and Structural Basis of India's Foreign Trade, Series in Monetary and International Economics, No. 6 (Bombay: University of Bombay, 1962); Donald F. Wahl, "Capital and Labor Requirements for Canada's Foreign Trade," Canadian Journal of Economics and Political Science (August, 1961), pp. 349-58.

[5] Bagicha Singh Minhas, An International Comparison of Factor Costs and Factor Use (Amsterdam: 1963), pp. 39-42.

[6] Leontief, W.W., op. cit., Proceedings of the American Philosophical Society.

Paradox itself is largely due to the natural resource factor is implied in one of the computations (in his second article) excluding 19 natural resource industries. Only in this computation do we get the expected result: U.S. exports contain a relatively greater amount of capital in comparison with its imports. Although Leontief refrains from pursuing this line further, the significance of natural resources seems evident. Vanek's recent work, however, deals specifically with the role of natural resources in U.S. production and trade. He attempts to show that the importance of natural resources in relation to capital and labor has declined over time and that the present pattern of trade shows a relative scarcity of natural resources, which is then extended to explain the Paradox.

In undertaking the difficult task of measuring natural resources, an indirect method is employed by Vanek--the natural resource products embodied in a unit value of a given commodity are substituted for the natural resource factor requirement under the assumption that the former is proportional to the latter.[7] Twenty-one sectors (various agricultural and mining sectors and logging sector) out of 192 intermediate sectors are selected and their outputs are used to determine the role of the natural resource factor in production and trade.

---

[7]Despite Vanek's indirect method, which employs a proxy variable, his approach is operationally reasonable in view of the lack of an ideal statistical method to identify the natural resource factor of production. In considering the factor combinations of the productive processes, it may be argued that the necessary requirements of natural resources as the direct input will be relatively larger for the production of primary goods than for manufacturing. Or, on the average, the nearer a commodity is to its initial or primary stage of production, the larger is the proportion of natural resources required as direct inputs.

The natural resource product requirements per million dollars of American exports (R^x) and competitive import replacements (R^m) computed by Vanek are defined as follows:[8] $R^x = BX$ and $R^m = BM$ where B refers to the 21 by 192 portion of the inverse matrix while X and M refer to the proportionate distribution of a million dollars, each, of U.S. exports and competitive imports, respectively. R^x and R^m show the summed values of the direct and indirect outputs of the 21 natural resource sectors required for American exports and competitive import replacements.

Vanek's finding on R^x and R^m are given in Table 1 along with Leontief's capital and labor requirements. As can be seen from the Table, import replacements contain a considerably larger natural resource output than do exports. Since resource products are assumed, on the average to be more natural resource factor-intensive than non-resource products, this difference in R^m and R^x implies that the U.S. engages in trade to economize her scarce factor, natural resources.

Vanek's finding on R^m and R^x does not directly explain the Paradox. To do this, he relies on the hypothesis that natural resources and capital are a pair of complementary factors while natural resources and labor are not. That is, the use of natural resources would jointly require a relatively large amount of capital. Since the U.S. is scarce in resources in relation to capital and labor, a relatively greater amount

---

[8] Vanek, op. cit., pp. 82-83.

Table 1. Domestic Capital, Labor, and Natural Resource Product Requirements per Million Dollars of American Exports and Competitive Import Replacements, 1947

	Exports (X)	Imports (M)	X/M
1. Capital (dollars)	2,550,780	3,091,339	0.83
2. Labor (man-years)	182.313	170.004	1.07
3. Natural Resource Products (dollars)	340,000	630,000	0.54

Source: J. Vanek, op. cit., p. 132.

of production services of this scarce factor is imported than exported. Consequently, the replacement of imports by domestic production would require more natural resources than would exports. With respect to the relative position of capital and labor, the former may be the relatively abundant factor, but being complementary with natural resources, more of it is also needed to replace U.S. imports than for exports.

Although Vanek's explanation of the Leontief Paradox is based on the critical "complementarity" between natural resources and capital, the only test provided for this proposition is his general observation that the resource content and capital requirements of commodities are positively related while the natural resource content and labor requirements are not.[9] His finding then implies that the C-L ratio of resource products tend to be relatively high in comparison with non-resource

[9] Ibid., p. 133.

products as is generally shown in Leontief's C-L figures of U.S. industries.

One way to test the generality of Vanek's analysis of the Paradox is to examine its applicability to the trade structure of foreign countries. One of Vanek's assumptions is that production functions are identical in all countries. If capital and natural resources are complementary in the U.S., they must also be complementary in other countries. It is further implied that each of the remaining pairs of factors, natural resources and labor, and capital and labor, cannot be complementary but are competitive. The C-L structure of foreign trade of a country such as Japan, which is considered to be even more characterized by scarcity of natural resources than the U.S., should, under this assumption, conform to the Leontief Paradox while the reverse should hold true for a country such as Canada.

In order to compare the factor structure of U.S. foreign trade with that of Japan, the natural resource product requirement for 1955 and 1959 (Table 2) is computed according to Vanek's approach. The data required for this computation are from Inter-Industry Analysis of the Japanese Economy.[10] The inverse matrix (as well as direct capital and labor coefficients used later) is based on 35 intermediate sectors. In computing the natural resource product requirements, the four sectors treated as natural resource sectors are: Agriculture, Forestry, and Fishery; Coal and Lignite: Crude Petroleum and Natural Gas; and Metals

[10]Japan, Ministry of International Trade and Industry, Minister's Secretariat, Div. of Research and Statistics, Inter-Industry Analysis of the Japanese Economy (Based on the 19 5 inter-industry table), Tokyo, 1962.

and Non-metallic Minerals.

The results in Table 2 clearly reflect the generally accepted scarcity of natural resources in Japan's economy. The ratio of resource product requirements of exports to imports is 0.263 and 0.298 in 1955 and 1959, respectively. Although the American and Japanese inter-industry classification are not strictly comparable, the figures for Japan are still strikingly lower than the 0.54 for 1947 computed by Vanek for the U.S.

Table 2. The Natural Resource Product Requirement per Million Yen of Japanese Exports and Competitive Import Replacements, 1955 and 1959

Year	Exports (yen)	Imports (yen)	Exports / Imports
1955	238,990	910,043	0.263
1959	221,051	742,085	0.298

If natural resources and capital, but not natural resources and labor, are complementary, then the relative requirements of capital for Japan's import replacements should be larger than for her exports. Even without the complementarity proposition, such a result for Japan would not be surprising since her comparative advantage is generally assumed to lie in relatively labor-intensive products. But the computations on the C-L requirements of Japanese foreign trade for 1955 and 1959 (which are in line with Leontief's) do not support the above contentions (see Table 3, Row A). For both years tested, Japanese exports require relatively more capital and less labor in comparison with import replacements. Similar findings for 1951 are shown in a

joint study by Takemoto and Ichimura.[11]

Natural resources being scarce for Japan ($R^m > R^x$), if natural resources and capital are complementary, then the exclusion of the natural resource sectors should increase the C-L ratio for Japanese exports relative to that for import replacements. For, if natural resource industries were relatively capital-intensive, the exclusion of these industries would tend to exert a larger downward influence on the C-L ratio of import replacements than on exports. But the result of the computation excluding the natural resource sectors for 1955 (Table 3, Row B) shows that the C-L ratio of both import replacements and exports has gone up. More significantly, a result contrary to that implied by the complementarity proposition is revealed in this computation. The C-L intensity of the import replacements has risen sufficiently more

Table 3. Results of Capital and Labor Requirements per Million Yen of Japanese Exports and Competitive Import Replacements, 1955 and 1959

Coverage of Sectors	Years		Capital Y1,000	Labor (man-years)	C/L	Export Ratio / Import Ratio
A. All Sectors	1955	Competitive Imports	1,206	5.119	236	1.678
		Exports	1,289	3.258	395	
	1959	Competitive Imports	1,265	3.164	400	1.315
		Exports	1,504	2.859	526	
B. Excl. Natural Resource Sectors	1955	Competitive Imports	703	1.352	520	0.985
		Exports	1,125	2.197	512	

[11] Masahiro Tatemoto and Shinichi Ichimura, Factor Proportions and Foreign Trade: The Case of Japan, Discussion Paper No. 8 (Osaka University: The Institute of Social and Economic Research, 1958). Reprinted in The Review of Economics and Statistics (November, 1959), pp. 442-46.

than that of exports to make the former ratio slightly greater than the latter.

It is interesting to note that for both the U.S. and Japan, which are assumed to be scarce in natural resources, the paradoxical findings on the C-L structure of trade are reversed and the expected results from the Heckscher-Ohlin hypothesis are derived when natural resource sectors are excluded in the C-L computation. However, there is a sharp difference in the direction of this change in the C-L requirements of the two countries. The C-L ratio of exports has gone up in comparison to import replacements for the U.S. by excluding natural resource sectors (Leontief's study), while the reverse is true for Japan. If natural resources and capital are complementary factors everywhere, exclusion of natural resource sectors should have reduced the complementary factor, capital, more from import replacements than exports for both countries. Although the U.S. data appear to support the complementarity proposition, the Japanese results are clearly inconsistent with it.

The C-L ranking of Japanese industries (Table 4) shows that three out of four resource sectors have relatively low C-L ratios. The agricultural sector has the lowest ratio of all industries both in 1955 and 1959. In contrast, crude petroleum is relatively capital-intensive, 6th and 7th in the C-L ranking in 1955 and 1959 respectively. This sharp difference in the ranking of Agriculture and Crude Petroleum does not by itself justify complete rejection of the complementarity proposition, but it certainly provides additional evidence that Vanek's observations on the relationship between natural resources and capital

Table 4. Capital-Labor Ratios for Japanese Industries and Their Rankings, 1955 and 1959

Industry	Ranking*	
	1955	1959
1. Agriculture, forestry, and fishery	35	35
2. Coal and lignite	25	28
3. Crude petroleum and natural gas	6	7
4. Metals and non-metallic minerals	18	23
5. Processed food	30	30
6. Natural textile mill products	26	26
7. Synthetic textile mill products	9	6
8. Textile and fabric products	27	24
9. Paper and pulp	22	18
10. Lumber and wood products	33	34
11. Miscellaneous manufacturing	28	25
12. Coal products	14	21
13. Petroleum products	3	3
14. Chemical fertilizers	11	11
15. Basic and intermediate chemical products	8	9
16. Final chemical products	19	15
17. Non-metallic mineral products	16	16
18. Primary iron and steel products	4	4
19. Steel casting, forging, and rolling	5	5
20. Finished metal products	13	27
21. Non-ferrous metals	7	8
22. General industrial machinery	23	22
23. Precision machinery	29	33
24. Industrial electrical machinery	17	20
25. Non-industrial light electrical machinery	21	17
26. Automobiles	15	14
27. Ships and locomotives	20	19
28. Construction	31	31
29. Engineering	34	32
30. Trade	32	29
31. Transportation	2	2
32. Electricity	1	1
33. Other services	12	12
34. Scraps	10	10
35. Unclassified	24	13

*Rankings based on total factor requirements.

cannot be generalized without qualification. The imports of the four resource sectors are very large while the exports are extremely small. But, among the sectors, the net imports of Agriculture are by far the largest and hence the result that Japan exports relatively capital-intensive products and imports labor-intensive goods (Table 3, Row A) must have been strongly influenced by the large net imports of the agricultural sector and its low C-L ratio.

Two separate studies of India and Canada add to the evidence on the influence of natural resources on the C-L structure of trade. Bharadwaj's study of India shows that the composite C-L ratio of Indian total exports is less than that of the replacements of its total competitive imports.[12] However, when the C-L requirements of the country's bilateral trade with the U.S. are considered, the results are inverted: Indian exports to the U.S. are shown to be relatively capital-intensive and imports from the U.S., labor-intensive.[13]

Wahl's study on the C-L structure of Canadian trade also gives an apparently contradictory result: capital-intensive exports but labor-intensive imports.[14] His finding may not necessarily be inconsistent with the Heckscher-Ohlin hypothesis since Canada may well be relatively capital-abundant *vis-a-vis* the rest of its trading partners. But even in Canada's bilateral trade position with the U.S. and England, he still gets a result similar to that for total trade.

---

[12] Bharadwaj, Structural Basis of India's Foreign Trade, pp. 56-7.

[13] Bharadwaj, "Factor Proportions and the Structure of Indo-U.S. Trade," p. 109.

[14] Wahl, Op. Cit., p. 353.

Each writer appropriately points out that the relatively large share of primary products in the commodity composition of his country's trade might have influenced the paradoxical findings on the bilateral trade positions. Bharadwaj reasons that the normally large Indian imports of agricultural products from the U.S., which were even larger in 1951 (the year tested) due to a crop failure, tended to lower the C-L ratio of imports from the U.S. while relatively large exports of minerals and ores tended to raise the C-L ratio of Indian exports to the U.S. Wahl similarly qualifies his result in terms of a large share of primary products in Canadian exports and a predominance of manufactured goods in its imports. Raw material-oriented exports of Canada, which are capital intensive, tend to raise the C-L structure of exports but imports, oriented toward manufactured goods which are labor-intensive, tend to lower the C-L ratio of competitive imports.

The somewhat paradoxical results shown for the U.S., Japan, India, and Canada all point to one common feature: the significant influence of primary products in the C-L structure of each of their trade patterns. More importantly, however, the influence seems to emerge in two distinctive patterns associated with different kinds of natural resource products originating from agricultural and extractive industries. As explained below, the influence of extractive industries is somewhat in line with the complementarity proposition while that of agricultural industries directly contradicts the proposition in explaining the paradoxical results of the four countries considered.

Agricultural and extractive products, such as crude petroleum and mining products, have thus far been allocated to the natural resource-

intensive group, but the specific type of natural resource factors embodied in these two would vary. The C-L ranking of industries in each of these countries indicates that extractive industries have comparatively high C-L ratios in all countries. The ratios of agriculture vary widely, from the highest in the U.S. and Canada to the lowest in Japan and India. The extreme variation of the C-L ratio of Agriculture between the two pairs of countries is clearly shown in the studies on each of these four countries. But the case of extractive industries is less clear partly because of different industrial classifications in these countries. In both Canada and India, a considerable amount of processed items is included in raw extractive products. (Crude as well as processed petroleum are grouped together in these countries while they are specifically differentiated in the U.S. and Japan.)

What are the implications of the above analysis? For a country such as Canada, the C-L requirements of its composite exports tend to be capital-intensive since exports are raw material-oriented and her import requirements labor-intensive because of large imports of manufactured goods. On the other hand, for a country like Japan, exports are also likely to be capital-intensive not simply because the country is capital-rich but because it is land-scarce and imports large amounts of agricultural products which are extremely labor-intensive (in contrast to the capital intensity in the U.S. and Canada). Similar reasoning can be applied to explain both the Leontief Paradox and the Indian bilateral trade with the U.S.

Vanek's complementarity explanation may apply to the U.S. and Canada as both agricultural and extractive natural resources are

capital-intensive in these countries, but it does not apply to countries such as Japan and India because of the contrasting C-L structure of their agricultural sectors. The specific natural resource required in agricultural processes, i.e., land, may very well not be complementary with capital.

II

The main purpose of the last section was to point out that consideration of capital and labor alone is inadequate to explain trade patterns since the exchange of natural resource products may be dictated more by the natural resource factor. Such reasoning can also be directed to the testing of the C-L intensity reversal when the natural resource sectors are among the industries compared, as in one of the two tests employed by Minhas.

In fitting the CES production function, Minhas uses inter-country cross-sectional data for 24 industries. But, in demonstrating factor reversal or cross-over points, he selects only 6 of the 24. In so doing, he finds five out a possible 15 cross-over points, which are the only real evidence of factor-reversal provided by this test.[15]

---

[15]In evaluating Minhas' work, Leontief made computations for 21 of the same industries, basically using the data furnished in Minhas' work, in "International Factor Cost and Factor Use," American Economic Review, June 1964-Part I, 54, 335-45. Interestingly, Leontief's result hardly supports the generality of factor reversal claimed by Minhas. Out of 210 possible cross-over points, only 17 occur in Leontief's computation. Further, Leontief states: "...most of these cross-overs occur between industries whose curves run so close together throughout the entire range that for all practical purposes, their capital-labor intensities would be considered identical." (p. 343)

Because of the small number of industries tested, Minhas extends his work to include a relative ranking comparison of the C-L ratio of 20 industries of the U.S. (1947) and Japan (1951). The C-L ranking for these 20 industries are reproduced in Table 5.

The underlying assumption of the C-L ranking comparison is that the existence of factor reversals will be associated with changes in the relative ranking of the C-L ratios of the same industries in two economies which reflect different configurations of relative factor prices. One way to test this assumption is to examine the similarity or dissimilarity of the orderings of the comparable industries in terms of the capital intensities in the two countries using the Spearman rank coefficient of correlation.

Minhas compares the relative ranking of capital intensities based on total (direct and indirect) factor requirements and also on just the direct requirements. The Spearman rank coefficient of correlation between the two orderings (U.S. and Japan) based on total factor requirements is only 0.328.[16] Such a low value definitely implies a large dissimilarity of relative capital intensities, supporting the factor reversal argument. However, in comparing the two orderings in terms of direct factor requirements only, Minhas finds a greater similarity in the relative rankings with a value of the coefficient of 0.73.

Before identifying the source of this low coefficient, a few qualifications should be raised. First, the industries compared are too broadly aggregated to provide a conclusive result for the purpose of

---

[16] Minhas, Op. Cit., pp. 39-40.

Table 5. Ranking of Industries by Capital Intensity For the U.S. (1947) and Japan (1951)

Industry	Ranks Based on Total Capital and Labor Requirements			Ranks Based on Direct Capital and Labor Requirements		
	U.S.	Japan	Difference	U.S.	Japan	Difference
Petroleum products	1	1	0	1	1	0
Coal products	2	2	0	2	2	0
Agriculture	3	20	-17	3	14	-11
Grain mill products	4	19	-15	9	6	3
Processed foods	5	13	- 8	10	7	3
Chemicals	6	5	1	6	4	2
Non-ferrous metals	7	4	3	4	3	1
Iron and steel	8	3	5	5	5	0
Paper and products	9	11	- 2	7	15	- 8
Non-metallic mineral products	10	9	1	8	11	- 3
Textiles	11	15	- 4	18	12	6
Transport equipment	12	10	2	11	9	2
Machinery	13	6	7	12	10	2
Rubber and products	14	12	2	14	16	- 2
Ship building	15	7	8	13	8	5
Lumber and wood	16	17	- 1	15	17	- 2
Industry-not-elsewhere-classified	17	16	1	17	20	- 3
Printing, publishing	18	8	10	16	18	- 2
Leather	19	18	1	19	19	0
Apparel	20	14	6	20	13	7

Source: Minhas, Op. Cit., Table V, p. 40.

inter-country comparison. It seems there exists a large difference in the classification of industries.[17] For example, the food processing sector in the Japanese input-output table includes tobacco and cigarette manufacturing while it does not in the U.S. input-output table. Questions of comparability also arise in the case of apparel and machinery. In view of these likely differences in the commodity mix for the industries treated as identical, it seems more realistic to evaluate the over-all similarity or dissimilarity than a one-to-one correspondence of the factor intensity ranking.

Even if one refrains from comparison of a one-to-one correspondence, the orderings based on the total factor-intensity cannot be regarded as similar. It is clear from Table 5 and from our previous discussion that the largest difference in the capital intensity is found in Agriculture. While the total capital intensity is ranked third in the US., it is ranked 20th (lowest) in Japan, or a difference of 17. Therefore, the ranking of Agriculture, which is highly capital-intensive in the U.S. but labor-intensive in Japan, exerts the most dominant downward influence on the value of the Spearman coefficient.

Notice further that the other land-intensive sectors, e.g. Grain Mill and Processed Food, are also far apart in the C-L ranking in terms of total factor requirements (a difference of 15 and 8 respectively). But such large differences are not shown in the C-L ranking of the

---

[17]The original source of Japanese data is not specifically given. But it is reasonable to assume that the factor requirements are based on a finer breakdown of industries for the U.S. than for Japan, judging from the Japanese inverse matrix, and capital and labor coefficients published and available (probably no more than 35 producing sectors).

direct factor requirements for these two sectors (a difference of only 3 for each). This is to be expected, however, since these two sectors tend to require relatively large inputs of agricultural products in their production processes. On the one hand, the use of labor-intensive agricultural inputs in Japan for the production of grain mill products and processed food would tend to lower their total capital intensity ranking in comparison with the ranking of their direct factor requirements. On the other hand, the capital-intensive agricultural inputs required for these sectors in the U.S. raises the total factor ranking in comparison to the direct factor ranking. As shown in the Table, rankings for Grain Mill Products and Processed Food in Japan are 6th and 7th respectively based on the direct requirements but are lowered to 19th and 13th based on the total requirements, while they are raised in the U.S. from 9th and 10th to 4th and 5th in rank. Therefore, the wide difference in the orderings based on the total factor requirements obtained by Minhas, implying the strong possibility of factor reversal, is largely due to the direct influence of Agriculture and the indirect influence of Agriculture and Grain Mill Products and Processed Food.

In order to minimize the likely bias from the land factor, a C-L ranking comparison excluding these three sectors has been made.[18] The result indicates a significant improvement in the similarity of the rankings. The value of the Spearman coefficient is now 0.826 for the direct C-L requirements and 0.765 for the total factor requirements

---

[18] A recent article also evaluates Minhas' ranking test by exclusion of such sectors (D.S. Ball, "Factor-Intensity Reversals in International Comparison of Factor Costs and Factor Use," The Journal of Political Economy (February, 1966), pp. 77-80.)

(compared to 0.73 and 0.328 respectively when the three sectors are included). The rankings for both direct and total factor requirements still do not match exactly, but the degree of similarity between them is sufficient to make one question the empirical generality of the factor reversal argument.

III

Emphasis in this paper on the influence that natural resources exert on the C-L structure of trade leads to a final conclusion that empirical applications of the factor proportions theory will be more meaningful when factors in addition to capital and labor are explicitly incorporated. The outright refutation of the theory on the basis of the two-factor paradoxes of the U.S. and other countries is unjustified since the inclusion of natural resources tends to explain these paradoxes as well as the C-L intensity reversals. However, more research is needed on such topics as the nature of the production function and complementarity and/or substitutability of different factors as well as the role of the factors not treated in this paper. Such results would further clarify the real status of the Heckscher-Ohlin theory. Some efforts in this direction are already being made. For example, a recent empirical work of D. B. Keesing attempts to show that the U.S. exports are "research" intensive.[19] A more comprehensive study which tests not only the "research" factor (incorporating direct and indirect research requirements) but also "education" requirements is being

[19]Donald B. Keesing, "The Impact of Research and Development on United States Trade," (unpublished), Feb. 10, 1966.

prepared by Baldwin, a preliminary result of which agrees with Keesing's.[20]

[20] R. Baldwin, "Economic Characteristics of U.S. Exports and Import-Competing Industries," (research in progress), Univ. of Wisconsin, Dept. of Economics.