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The Technology Factor in a World Trade Matrix

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One of the external economies that an author can draw upon in a collection of papers such as these is the expository background which the other papers provide. Elsewhere in this collection, the reader will find a number of accounts of the past efforts of economists to find an efficient explanation of international trade—efficient in terms of its ability to describe, predict, and explain the level and composition of such trade. To relate our contribution appropriately to what has gone before, there is no need to make more than the briefest reference to those past efforts.

The mainstream of international trade analysis proceeds, of course,

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from an analytical structure identified with Ricardo, Marshall, Heckscher, and Ohlin, stressing comparative advantage doctrine and factor proportions theory. It hardly needs to be said that analyses in this tradition generally take consumer preferences as given, the market as atomistic, knowledge as free and universal, the production function as invariant, and unit costs as invariant or increasing. The composition of trade is then explained primarily in terms of the differences in factor proportions and consumer preferences between countries.

A number of other lines of analysis have appeared in recent years, however, which have based their search for explanations of international trade on rather different factors. One strand of this aberrant tendency seeks to determine to what extent the leads and lags in technological innovation among countries determine the level and composition of their trade; [1] the departures from the mainstream that are involved in this approach usually include the assumption that technical knowledge or skill is not a costless or universally available good and the assumption that the possession of knowledge or skill creates a transitory advantage for the exporting country. A second theme, not wholly dissociated from the first, has emphasized the relation between the export performance of a nation and a market "horizon"—including both the knowledge and the perception of market risk—of the nation's businessmen; once again, the new emphasis consists mainly of introducing knowledge as a hitherto neglected variable.[2] Still another approach to international trade emphasizes the role of economies of scale, whether internal or external, whether in production or in marketing, as a powerful explanatory variable.[3] Finally, there have been explanations that appeal to systematic institutional factors, such as the parent-subsidiary relation of the buyer and seller or the bilateral trade arrangement of the buying and selling countries. Behind these explanations there usually lies the assumption that buyers and sellers are engaged in a trade-off between risk avoidance and cost, forsaking the freedom to select source or market solely on a price basis, in favor of the advantages of longer run assurances [16].

[1] Williams [21], Kravis [11], Keesing [7], Kindleberger [12], Vernon [18], Hirsch [3], Wells [19], Tsurumi [17], and Stobaugh [15].

[2] H. G. Johnson has pointed out the introduction of skill and knowledge can be readily accommodated within the structure of classical theory [6].

[3] See the sources cited in footnote 1, as well as: Linder [13], Linnemann [14], Hufbauer [5], and Keesing [9].

The purpose of this paper is to provide grist for the mill of theory. The analysis in the paper is based upon a matrix of world trade for manufactured goods relating to one year, 1964. The fact that the data are confined to manufactured goods and the fact that they relate to a single year substantially limit the contribution one can hope to make. Theories that rely on comparative cost concepts to explain international trade generally cannot be tested very rigorously unless all of the trade of the importing and exporting countries is included in the test. And theories that rely on leads and lags for their causation cannot be tested very well unless they are exposed to data over periods of time. Still, there is much that the analysis has to suggest about the relative strength of forces underlying international trade flows.

The central question of the analysis is this: To what extent are the international trade flows of an industry associated with the technological aspects of the industry, and how do these associations vary according to the countries of origin and destination of the trade flow? To explore the question adequately, however, numerous ancillary issues have to be investigated, including the relation between the trade of an industry and its nontechnological characteristics.

TECHNOLOGICAL INPUTS AND WORLD TRADE

Before introducing the world trade matrix that is the *pièce de résistance* of this paper, it will help to summarize some of the findings of earlier studies that have an immediate bearing.

One finding of central relevance to this analysis is that, as far as the United States is concerned, industries associated with a relatively high "research effort" also tend to export a relatively high proportion of their output. It does not matter very much how "research effort" is measured, whether by industry research and development expenditures as a percentage of industry sales, or by technical personnel as a percentage of total industry employment; the results are still very much the same. Various studies done by us and by others have confirmed this relationship [8, 2]. Table 1 extracts some data from one of our earlier studies to illustrate the main point.

In interpreting the results in Table 1, there are a number of difficulties

TABLE 1

Research Effort and World Trade Performance by United States Industries, 1962

	5 Industries with Highest Research Effort	14 Other Industries	All 19 Industries
Research effort			
Total R&D expenditures as percentage of sales	6.3	0.5	2.0
Scientists and engineers in R&D as percentage of total employment	3.2	0.4	1.1
Export performance			
Exports as percentage of sales	7.2	1.8	3.2
Excess of exports over imports, as percentage of sales	5.2	-1.1	0.6

Source: W. H. Gruber, Dileep Mehta, and Raymond Vernon [2], Table 1, p. 23.

to be faced. One of these, as we shall have occasion to point out several times in the course of this paper, is the fact that high R&D activity in U.S. industry is strongly correlated with various other industry characteristics; there is an especially close association, for example, with the comparatively intensive use of high-level manpower in general. Accordingly, one cannot readily determine whether the R&D effort of an industry or its pattern of manpower use in general is the prime factor influencing the export performance of the industry. Yet for some policy purposes, the distinction can be critical.

The statistical tie between strong export performance and skilled manpower use is not limited to U.S. industry alone. The same tie seems to exist in Canadian industry. An illuminating analysis of the performance of sixty-three branches of Canadian industry demonstrates a fairly strong association between (1) male professional and technical workers as a percentage of total employment and (2) exports as a percentage of domestic production [20]. More fragmentary evidence suggests that a similar association may exist for the industries of a number of other countries, but that the tendency weakens and may even be reversed as one moves from developed to less-developed economies.

It is not self-evident why R&D-intensive, skill-intensive industries should characteristically export a relatively high percentage of their output. All that the literature contains at this stage are fragmentary tests of some general hypotheses, linking such behavior to issues of monopoly, scale, and innovational lags [5, 18]. But one cannot yet exclude such mundane explanations as the possibility that the products of such industries are of high value in relation to weight and bulk, or that they are especially free from import impediments such as high tariffs and embargoes.

Having started these hares, it has to be acknowledged at once that the existing data are not good enough to pursue them very far, at least not in terms of the measures presented in Table 1. Figures on the relationship of exports to production, broken down by industrial groupings that can be matched with R&D variables, are available for only a few countries. In order to throw light on the problem from a different direction, therefore, we turn to the analysis of the world trade matrix that constitutes the core of this paper.

AREA EXPORT SHARES IN WORLD MARKETS

One can think of the export trade of any area as being a function of the economic characteristics of the industries that generate the exports. Symbolically, for exporting country *i*:

$$\sum_{j=1}^{n} E_{ijk} = f(a, b, c, \ldots)$$

where: E_{ijk} specifies the volume of exports from area i to area j in product category k; and

$a, b, c, \ldots$ specify various economic characteristics applicable to industries producing manufactured goods.

(The introduction of *j*, the importing area, at this point should not throw the reader off; it does not play an operational part in the discussion until much later and is introduced simply to permit the use of consistent notations throughout the paper.)

When a relationship of this sort is computed separately for each of the exporting areas in the world trade matrix, the basis has been laid for developing two kinds of information.

One type of information is the *similarities* from area to area in the export performance of industries with specified characteristics. Can one say, for instance, that industries in which technological activity or degree of concentration are very marked also generally have large exports, irrespective of the characteristics of the exporting area?

Another kind of information is the *differences* in the export behavior of given kinds of areas. Do capital-rich economies, for instance, systematically exhibit more prominence for capital-intensive industries in their export mix than economies that are relatively less well endowed with capital? More generally, does the export mix seem to be a function of the resource endowment of the exporting country?

So much for prelude. The data developed by us for mounting this phase of the analysis are described in Appendix A. They consist of the 1964 exports of specified manufactured goods, broken down into twenty-four categories, from each of ten exporting areas (United States, United Kingdom, West Germany, France, "Rest of EEC," "Rest of EFTA," Canada, Japan, Mexico, and Brazil) to each of twelve importing areas (the first eight enumerated above plus the white Commonwealth countries, Africa minus South Africa, Latin America, and Asia.)

The choice of areas and industry breakdowns embodied the usual procrustean compromises that research of this sort is bound to require. Given the limitations of resources and data, we adopted a much more highly aggregated classification system of areas and industry than is optimal for work of this sort. As the reader will shortly see, the limitations imposed by the classification of industries proved particularly restrictive. But despite these handicaps, the results provide many insights into the role of the technical factor in international trade.

Table 2 presents the 1964 export data separately for each of twenty-four industries from each of the ten exporting areas. The table also presents summary figures grouping eight "technology-intensive" indus-

TABLE 2

TABLE 2

Exports from Ten Areas by Twenty-Four Industries Normalized by Total Exports of Area, 1964

(exports from each area as per cent of twenty-four-industry total from that area)

Industries (SIC number)	U.S.	U.K.	West Germany	France	Rest of EEC	Rest of EFTA	Canada	Japan	Mexico	Brazil	All 10 Areas
All twenty-four	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
Eight technology-intensive	41.7	31.2	31.0	27.8	29.2	22.4	18.1	23.6	11.8	3.3	29.8
Aircraft (372)	6.7	1.2	.3	1.8	.9	.2	2.2	.2	a	.3	2.1
Office machines (357)	2.4	1.1	1.4	1.1	1.4	1.0	1.1	.3	a	.1	1.4
Drugs (283)	1.6	1.6	1.3	1.6	1.1	2.1	.2	.5	2.6	.1	1.3
Chemicals (minus drugs) (other 28)	13.8	10.0	12.2	10.9	9.2	6.6.	7.7	7.0	5.4	2.2	10.2
Electrical machinery (36)	7.9	8.8	9.1	5.9	8.6	6.0	2.8	11.9	.7	.2	7.8
Instruments (38)	3.1	2.4	3.8	1.9	1.7	4.9	.7	3.3	.4	a	2.8
Agricultural machinery (352)	3.8	3.5	1.4	.9	.6	.8	2.9	.2	.1	a	1.9
Petroleum and coal (29)	2.4	2.6	1.5	3.7	5.6	.8	.6	.4	2.7	.3	2.4
Sixteen other	58.3	68.8	69.0	72.2	70.8	77.6	81.9	76.4	88.2	96.7	70.2
Transport equipment (minus aircraft) (other 37)	6.3	16.6	18.4	10.8	8.2	6.5	3.3	12.3	.6	.5	10.3
Other machinery non-electrical (other 35)	20.6	17.4	20.8	9.0	8.2	12.8	5.1	6.9	1.0	.8	14.0
Nonferrous metals (other 33)	3.3	3.7	2.2	2.2	4.2	4.0	15.5	1.0	15.4	a	4.0
Rubber, and plastics n.e.c. (30)	1.3	1.5	1.4	2.0	1.4	.5	.4	2.1	.1	.6	1.3

(continued)

TABLE 2 (concluded)

Industries (SIC number)	U.S	U.K.	West Germany	France	Rest of EEC	Rest of EFTA	Canada	Japan	Mexico	Brazil	All 10 Areas
Ferrous metals (331 & 332)	3.8	5.6	8.3	11.7	10.5	5.6	3.6	15.0	2.8	1.9	7.5
Fabricated metals (34)	2.7	3.8	4.6	2.8	2.9	2.7	1.2	4.0	1.4	a	3.1
Stone, clay, glass (32)	1.3	2.0	2.3	2.1	2.8	1.6	.3	3.2	1.9	a	2.0
Paper (26)	3.3	1.3	1.0	1.6	1.5	11.2	26.1	1.1	.4	.2	4.4
Textiles (22)	2.2	6.2	3.6	7.8	9.2	4.7	.7	15.9	5.3	.7	5.7
Food (20)	9.0	6.0	2.0	13.1	12.3	15.9	13.2	5.6	56.4	85.8	10.4
Tobacco (21)	.6	.5	.1	.1	.4	.4	.1	a	a	a	.3
Furniture and fixtures (25)	.2	.3	.6	.4	.7	1.1	.1	.2	.2	a	.5
Leather products (31)	.4	1.1	1.0	2.3	2.2	.7	.3	1.9	.3	.1	1.2
Printing and publishing (27)	1.3	1.3	.7	1.2	.9	.7	.2	.3	1.2	a	.9
Apparel (23)	1.1	1.4	1.5	3.8	4.7	4.1	.3	4.9	.3	.1	2.6
Lumber and wood (24)	1.0	.1	.5	1.3	.7	4.9	11.6	2.1	.6	5.9	2.0

[a]Less than .05 per cent.

tries and sixteen other industries. As noted earlier, measures of the intensity of research activity and measures of the intensity of use of highly skilled manpower in general are so strongly associated that we cannot hope to avoid the problem of collinearity in any industry classification system.[4] Accordingly, the ambiguity in the phrase "technology-intensive" may have a certain virtue, reminding the reader of the unavoidable ambiguity in the meaning of the classification. In any event, the eight technology-intensive industries are all those which in 1964 employed scientists and engineers in excess of 6 per cent of their total workforce, as measured by U.S. data. To make comparisons somewhat easier for the eye, the export figures for each industry in each area are expressed as a percentage of the total exports of manufactured goods of that area. In the notation system used here, the figures for a given industry in Table 2 are:

$$\frac{\sum_{j=1}^{12} E_{ijk}}{\sum_{j=1}^{12} \sum_{k=1}^{24} E_{ijk}}$$

The eight technology-intensive industries, it is evident, are major contributors to world trade totals in manufactures. As a benchmark to measure that importance, one has only to note that they account for almost 30 per cent of the exports of the ten exporting areas in Table 2, even though the contribution of those industries to world output probably is well below 20 per cent. Apart from the general level of the exports of these industries, however, one is also struck by the faithful way in which the relative importance of the eight technology-intensive industries declines as the eye moves across the table—that is, from the highly developed United States, to the middle range of development represented by Europe and Japan, and finally to the less-developed areas represented by Mexico and Brazil.

A more systematic way of observing the similarities and differences for the industry shares is provided by the figures in Table 3; in that

[4] The Pearsonian coefficient of correlation for the twenty-four industries in Table 2 between (1) scientists and engineers as per cent of total workforce and (2) scientists and engineers in R&D as per cent of total workforce was +.97. Both these measures also were very highly correlated with indirect labor as per cent of total workforce.

table, the logs of the export shares of each of the twenty-four industries for each exporting area are correlated with the logs of the shares of each other exporting area in the matrix.

The figures in Table 3 demonstrate widespread similarities in the forty-five pairs of export profiles. To be sure, the similarities tend to be stronger when the export profiles of advanced countries are paired than when the profiles of such countries are matched with those of less-developed areas; the profiles of the United Kingdom, West Germany, France, Japan, and "Rest of EEC" resemble one another more closely than any of them resemble Mexico or Brazil. In fact, Mexico and Brazil are somewhat less certain matches not only for the advanced countries but even for one another. Still, the data in Table 3 suggest similarity in export profiles more strongly than they suggest difference.

The significance of these similarities, however, must not be exaggerated. A part of the parallelism may be generated by such simple explanations as the existence of universal frictions that prevent the export of some kinds of products from any country. For instance, bulky products, low in value, may be less likely to enter international trade than high-value products, whatever the source. Or the correlations may be simply a reflection of the industry classification system used; large industries are likely to generate more exports than small industries if the industries are not homogeneous in product and cost structure.

In order to distinguish among these possibilities and others, some added analysis on different lines is helpful. By relating each area's exports in a given industry to the exports in that same industry from all ten areas, the variations in export mix among the ten areas are more clearly highlighted. Symbolically, the measure for analysis is:

$$\frac{\sum_{j=1}^{12} E_{ijk}}{\sum_{i=1}^{10} \sum_{j=1}^{12} E_{ijk}}$$

Observe some of the characteristics of this measure. If the industry distribution of a given exporting area is exactly like the industry distribution of world exports, then for that area the measure is identical in value for all twenty-four industries. Stated differently, variations in the measure from industry to industry for any exporting area reflect the

TABLE 3

Exports from Ten Areas by Twenty-Four Industries Normalized by Total Exports of Area, Compared by Pairs of Areas, 1964

(each cell shows Pearsonian coefficient of correlation for logs of export shares of twenty-four industries between indicated areas)

Exporting area	U.S.	U.K.	West Germany	France	Rest of EEC	Rest of EFTA	Canada	Japan	Mexico	Brazil
U.S.	+1.00	+ .79	+ .67	+ .67	+ .61	+ .51	+ .69	+ .43	+ .32*	+ .47
U.K.		+1.00	+ .86	+ .78	+ .81	+ .52	+ .39	+ .61	+ .45	+ .28*
West Germany			+1.00	+ .83	+ .81	+ .68	+ .43	+ .83	+ .44	+ .30*
France				+1.00	+ .92	+ .64	+ .52	+ .88	+ .61	+ .61
Rest of EEC					+1.00	+ .67	+ .43	+ .80	+ .63	+ .50
Rest of EFTA						+1.00	+ .63	+ .73	+ .59	+ .43
Canada							+1.00	+ .43	+ .35	+ .45
Japan								+1.00	+ .56	+ .47
Mexico									+1.00	+ .30
Brazil										+1.00

*Indicates coefficient not significant at the 5 per cent level.

differences in the relative importance of the exports of these industries for the particular area, as compared with the relative importance of these industries in world export totals. The measure therefore captures for each area only the deviations of that area from world export patterns.

Bearing these properties of the measure in mind, Table 4 demonstrates that the areas which are prominent exporters of technology-intensive products, according to our crude twenty-four-industry classification, are also the most prominent exporters of other manufactured products. The exports of the United States, for instance, take first place in both the technology-intensive and the "other" group of industries; West Germany and "Rest of EEC" share second- and third-place honors in both groups, and so on. But Table 4 also affirms what had already begun to be suggested by the figures in earlier tables, namely that the technology-intensive industries occupy an especially prominent place in the export mix of the United States and a less-than-proportionate place in the export mix of most areas toward the lower end of the development spectrum.

There is a good deal more that can be ferreted out, however, regarding the similarities and differences in the industry profiles of the different areas. And as a first step in these added probes, one can repeat the performance of Table 3, cross-correlating the export profiles of all possible pairs of areas. This time, however, export profiles are measured by the data in Table 4, that is, by industry-normalized, not area-normalized, shares.

In Table 5, unlike Table 3, marked similarities in export patterns are no longer in evidence. Quite obviously, the similarities in Table 3 are based in good part on factors that are common to the industries for all the areas rather than to the areas themselves. But some new correlations emerge in Table 5—correlations that are much more telling for analytical purposes.

Although the relations are not very strong and are often not significant in a probability sense, the United States emerges as a distinctive area, its export profile being negatively related to each of the other areas except the United Kingdom and Canada. Canada also offers a maverick profile; it, too, exhibits a negative relation to most other areas. For the rest, there are interesting similarities: the United Kingdom with West Germany; and France, Japan, and "Rest of EEC" with one another.

TABLE 4

Exports from Ten Areas by Twenty-Four Industries Normalized by Total Exports of Industry, 1964

(industry exports from each area as per cent of total industry exports from all ten areas)

Industries (SIC number)	U.S.	U.K.	West Germany	France	Rest of EEC	Rest of EFTA	Canada	Japan	Mexico	Brazil	All 10 Areas
All twenty-four	20.7	11.6	16.2	8.5	16.5	11.3	6.5	7.0	.7	1.1	100.0
Eight technology-intensive	28.9	12.1	16.8	7.9	16.1	8.5	3.9	5.5	.3	.1	100.0
Aircraft (372)	67.5	6.9	2.5	7.5	7.3	.9	6.8	.3	a	.2	100.0
Office machines (357)	36.5	9.0	16.1	6.8	16.7	8.5	5.1	1.3	a	.1	100.0
Drugs (283)	24.8	13.6	15.8	10.0	13.4	17.8	.9	2.4	1.3	.1	100.0
Chemicals (minus drugs; (other 28)	28.0	11.4	19.3	9.0	14.8	7.3	4.8	4.8	.4	.2	100.0
Electrical machinery (36)	21.1	13.2	19.1	6.5	18.3	8.8	2.3	10.7	.1	a	100.0
Instruments (38)	22.7	9.9	21.9	5.6	9.9	19.8	1.7	8.4	.1	a	100.0
Agricultural machinery (352)	41.1	21.5	12.1	4.2	5.6	5.0	9.9	.6	a	a	100.0
Petroleum and coal (29)	19.9	12.2	9.9	12.8	38.0	3.7	1.5	1.1	.7	.1	100.0
Sixteen other industries	17.3	11.4	15.9	8.8	16.6	12.5	7.6	7.6	.8	1.5	100.0
Transport equipment (minus aircraft; other 37)	12.7	18.7	28.9	8.9	13.2	7.2	2.1	8.3	a	.1	100.0
Other machinery non-electrical (other 35)	30.5	14.4	23.9	5.4	9.6	10.3	2.3	3.4	a	.1	100.0

(continued)

TABLE 4 (concluded)

Industries (SIC number)	U.S.	U.K.	West Germany	France	Rest of EEC	Rest of EFTA	Canada	Japan	Mexico	Brazil	All 10 Areas
Nonferrous metals (other 33)	17.2	10.8	8.8	4.8	17.5	11.3	25.2	1.8	2.6	[a]	100.0
Rubber, and plastics n.e.c. (30)	20.1	13.5	17.3	12.8	17.9	4.8	2.0	11.1	[a]	.5	100.0
Ferrous metals (331 & 332)	10.6	8.8	18.0	13.3	23.2	8.5	3.1	14.0	.3	.3	100.0
Fabricated metals (34)	17.9	14.1	23.5	7.7	15.4	9.9	2.4	8.8	.3	.1	100.0
Stone, clay, glass (32)	14.1	12.0	18.7	9.3	23.7	9.2	1.1	11.2	.6	[a]	100.0
Paper (26)	15.6	3.4	3.8	3.0	5.7	28.6	38.0	1.8	.1	[a]	100.0
Textiles (22)	8.1	12.8	10.2	11.7	26.7	9.4	.8	19.5	.6	.1	100.0
Food (20)	18.0	6.7	3.2	10.7	19.5	17.3	8.2	3.8	3.6	9.0	100.0
Tobacco (21)	40.2	17.2	4.6	2.4	18.9	15.3	1.2	[a]	[a]	.1	100.0
Furniture and fixtures (25)	9.7	8.3	20.6	7.9	22.8	26.1	1.6	2.5	.3	[a]	100.0
Leather products (31)	6.8	11.1	13.6	16.8	31.1	7.3	1.8	11.3	.2	.1	100.0
Printing and publishing (27)	29.6	16.6	13.2	11.8	16.1	8.5	1.3	2.1	.9	[a]	100.0
Apparel (23)	8.8	6.5	9.3	12.5	30.3	18.3	.8	13.4	.1	[a]	100.0
Lumber and wood (24)	9.9	.8	4.3	5.3	5.8	26.8	36.7	7.0	.2	3.2	100.0

[a]Less than .05 per cent.

TABLE 5

Exports from Ten Areas by Twenty-four Industries Normalized by Total Exports of Industry, Compared by Pairs of Areas, 1964

(each cell shows Pearsonian coefficient of correlation for logs of export shares of twenty-four industries between indicated areas)

Exporting area	U.S.	U.K.	West Germany	France	Rest of EEC	Rest of EFTA	Canada	Japan	Mexico	Brazil
U.S.	+1.00	+ .31*	- .18*	- .43	- .45	- .47	+ .13*	- .71	- .41	- .05*
U.K.		+1.00	+ .54	+ .15*	+ .35	- .38	- .60	- .13*	- .03*	- .42
West Germany			+1.00	+ .31*	+ .27*	+ .04*	- .51	+ .50	- .05*	- .42
France				+1.00	+ .64	- .29*	- .50	+ .60	+ .33*	+ .26*
Rest of EEC					+1.00	- .03*	- .65	+ .28*	+ .35	- .04*
Rest of EFTA						+1.00	+ .09*	+ .21*	+ .29*	- .09*
Canada							+1.00	- .19*	- .08*	+ .15*
Japan								+1.00	+ .27*	+ .12*
Mexico									+1.00	+ .04*
Brazil										+1.00

*Indicates coefficient not significant at the 5 per cent level.

Brazil and Mexico bear little similarity to the advanced countries, and no similarity to one another.

With these broad impressions as an introduction, we are ready for the next question: Area by area, are the industry-normalized export measures related in some systematic way to the economic characteristics of the industries that generate the exports?

The selection of appropriate industry characteristics is, of course, critical to the exercise. The characteristics used in this analysis were intended to reflect, with fine impartiality, both the kinds of factors that are relevant to a comparative-cost approach and those that might be surrogates for monopoly effects and scale effects. They were:

L, a raw-labor intensity measure—employees per dollar of value added, as reported for U.S. industry

T, a technology-intensity measure—scientists and engineers as percentage of total employment, as reported for U.S. industry

K, a capital-intensity measure—fixed assets as percentage of sales, as reported for U.S. industry

S, an intermediate-good specializing measure—output delivered to other business as percentage of total output, as reported for U.S. industry

C, an industry-concentration measure—a measure based on the relative importance of the largest firms, as reported for U.S. industry

M, a crude materials input measure—inputs of crude materials as percentage of total output, as reported for U.S. industry.

The first three measures are intended to correspond respectively to three factors: labor in a raw or unimproved state; human skills embodied in labor (sometimes referred to as human capital); and fixed capital.

Although the measures are defined and discussed in more detail in Appendix A, one should be aware at once that they suffer from numerous inadequacies and inelegancies. First of all, although some of the measures purport to reflect the intensity of different inputs in the product of the industry to which they are related, these measures are actually based on the characteristics of the industry responsible for only the final fabricating stage of the product; they are not the sum of the direct and indirect inputs to the product, such as might be derived from an inversion of the national input-output matrix. Second, the measures purporting to gauge inputs are inconsistent in the sense that some of them are related to sales (S and M), while others are related to value added or to a conceptual equivalent (T and L). The analysis is relying—perhaps too heavily—upon the fact that measures of this sort usually display considerable insensitivity to greater refinement, especially at the gross levels of industry aggregation that we have been obliged to use here. The refinement of the industry-characteristic measures is quite clearly an area in which more work needs to be done.

Another point to be emphasized is that the "industry characteristics" used in these tests and others are characteristics based on U.S. industry data. Just how damaging that fact may be for the analysis is not clear; the debate over the existence and strength of factor inversions as an element in international trade is still going on and the results are not all in. Our use of U.S. characteristics commits us to the assumption that the relative factor position of given industries is similar in different countries. If this should prove to be the case, then the use of U.S. data is not overwhelmingly disconcerting [5, App. B, pp. 115–120; 12; 4]. But some pitfalls are opened up by this limitation, a fact that requires special care in the interpretation of the results.

On the other hand, the independent variables used in this analysis enjoy certain elements of strength that are not immediately apparent. The selection of these variables was the result of a tedious weeding-out process—a process that involved as many as a dozen different industry measures at various stages in the analysis. As a result of this process, the interrelations among various industry characteristics were well explored, adding somewhat to our sense of confidence both in the selection of variables and the interpretation of the results.

To what extent does intercorrelation exist between the measures that are to serve as the descriptive variables for our twenty-four industries? In responding to this question, one has to recognize that some of the measures—those relating to factor intensity—cannot fail to be intercorrelated, simply because of what they purport to represent. Factor-intensity measures purport to reflect the relative use of different inputs; if some are used relatively heavily, others must have been used relatively lightly. If, for instance, the product of a given industry is represented as highly capital-intensive, then the combined use of other factors in that product should be of lower than average intensity. If not, some major input is being wholly missed by the measures, or else there is something wrong with the measures used.

The results of the tests for intercorrelation between the industry variables are presented in Table 6. On the whole, the relationships in the table show a gratifying tendency toward rationality. There is a modest correlation between the technology-intensity measure, *T*, and the capital-intensity measure, *K*. But none of the factor-intensity measures—*L*, *T*, or *K*—shows a very strong positive correlation with any other. On the other hand, there are some strong negative correlations: both the technology-intensity measure and the capital-intensity measure are negatively correlated with the raw-labor measure.

There are other signs of rationality and consistency in the various measures descriptive of the twenty-four industries. The index purporting to measure technology intensity proves to be positively correlated with the measure representing industry concentration—a relationship frequently observed in other studies. And where a high use of raw labor exists, the industries involved tend to exhibit a low degree of concentration. The measure for industries specializing in intermediate goods output is positively correlated with the index of capital intensity, conjuring up an image of steel mills and aluminum smelters; and the measure for crude material use shows a similar tie to capital intensity, fortifying the image. Finally, consistent with earlier studies, the capital-intensity measure shows no significant relation with the measure of industry concentration; evidently capital-intensive processes afford no sure road to oligopoly power, at least when measured by the structure of U.S. industry [2].

Although the various industry measures offer a certain satisfying internal consistency, the reader will already have noted that they suggest special difficulties in the clarification of a major issue. If high technology inputs go hand in hand with high concentration, this fact is bound to imperil any statistical effort to discern what part of the export advantage of any given country in such industries may be due to the abundance and low cost of the technology inputs and what part to the exploitation of monopoly advantage. If technology intensity goes hand in hand with industry concentration, which is cause and which effect? And which is the necessary and sufficient condition to successful exports?

TABLE 6

Relations Between Descriptive Measures of Twenty-Four Industries

(each cell shows Pearsonian coefficient of correlation between indicated measures for twenty-four industries)

	Industry Measure[a]	*L* Raw Labor Intensity	*T* Technology Intensity	*K* Capital Intensity	*C* Industry Concen- tration	*S* Intermediate Goods Specialization	*M* Crude Material Intensity
L	Raw labor intensity	+1.00	- .65	+ .46	- .60	+ .05*	- .19*
T	Technology intensity		+1.00	+ .41	+ .66	- .01*	- .09*
K	Capital intensity			+1.00	+ .24*	+ .67	+ .43*
C	Industry concentration				+1.00	- .08*	+ .13*
S	Intermediate goods specialization					+1.00	+ .11*
M	Crude material intensity						+1.00

Source: Based on U.S. industry data.

*Indicates coefficient not significant at 5 per cent level.

[a]Correlations are based upon logarithms of the underlying measures.

Even with that particular analytical objective in peril, however, there is still much to be learned by comparing the export measures on which Tables 4 and 5 are based with the characteristics of the industries to which they are related. Table 7 presents some of the results of such an analysis. In computing the net regressions and other data shown in Table 7, the dependent variable subjected to analysis was, of course, the same as that used in Tables 4 and 5, converted to log form. At the same time, all the independent variables were also expressed in log form. The purposes of this conversion are the usual ones. Because of the statistical skew that is found in most of the series, the conversion generates a distribution that is more in accord with the normal-distribution assumption of the statistical significance tests applied here. At the same time, the conversion permits the analyst to compare the apparent influence on exports of the various industry characteristics in each of the different exporting areas, expressing that influence in a common unit—the unit of the elasticity concept.

One hardly needs to be reminded that as a model purporting to explain the comparative performance of various exporting areas in different products the structure in Table 7 is incomplete. Some of the lacunae are self-evident. For instance, each exporting area confronts a different array of markets, remote or proximate, protected or otherwise. Moreover, each exporting area has a different propensity for serving its foreign markets by way of direct investment in overseas subsidiaries. Failure to deal with these variables affects any product category differently for the various exporting areas. The indications provided by a model such as that in Table 7 are predictably incomplete.

As it turns out, the statistical relationships shown in Table 7 prove to have appreciable "explanatory" power for only three of the exporting areas—the United States, Japan and Mexico—as indicated by the value of the coefficient of multiple correlation. For all the other areas, systematic deviations from the world export profile are feeble.

The fact that there is not much to be inferred from the table regarding the export patterns of the areas just below the United States in development, from the United Kingdom to "Rest of EFTA," is reassuring in one sense. This result means that the industry export profiles of these areas exhibit few tendencies that distinguish them from the world pattern as a whole, at least as gauged by the industry measures used

TABLE 7

Net Regressions Derived from Relating Industry-Normalized Exports of Twenty-Four Industries to Selected Industry Characteristics, 1964

(Figures in parentheses under net regressions are t values; those under correlation coefficients, F values)

$$\log \frac{\sum_{j=1}^{12} E_{ijk}}{\sum_{i=1}^{10} \sum_{j=1}^{12} E_{ijk}} = a + b_1 \log L + b_2 \log T + b_3 \log K + b_4 \log C + b_5 \log S + b_6 \log M$$

Exporting area	Net regressions for: L Raw labor	T Technology	K Capital	C Industry concentration	S Intermediate goods	M Crude material	R Multiple correlation
U.S.	− .804	+ .169	− .641	+ .296	+ .456	− .017	.85
	(2.75)	(1.73)	(2.59)	(1.07)	(1.76)	(.89)	(7.27)
U.K.	− .611	+ .009	− .360	+ .522	− .077	− .013	.58
	(1.17)	(.05)	(.81)	(1.06)	(.17)	(.38)	(1.40)
West Germany	+.029	+ .119	+ .206	− .342	− .056	− .032	.36
	(.05)	(.58)	(.40)	(.59)	(.10)	(.80)	(.43)
France	+ .100	+ .062	+ .028	− .507	+ .021	+ .004	.36
	(.23)	(.43)	(.07)	(1.23)	(.05)	(.15)	(.42)
Rest of EEC	− .030	− .210	+ .278	+.250	− .342	− .004	.37
	(.06)	(1.31)	(.68)	(.55)	(.81)	(.14)	(.44)
Rest of EFTA	− .329	− .196	+ .228	− .701	− .354	+ .024	.58
	(.57)	(1.02)	(.47)	(1.29)	(.70)	(.63)	(1.46)
Canada	+1.065	− .058	+ .706	+ .398	− .002	− .010	.41
	(1.07)	(.17)	(.84)	(.42)	(.01)	(.15)	(.56)
Japan	+1.983	+ .414	+ .254	−1.554	+ .717	+ .072	.73
	(2.09)	(1.30)	(.32)	(1.73)	(.85)	(1.16)	(3.18)
Mexico	−2.06	− .420	+ .997	−2.54	− .153	+ .062	.74
	(1.74)	(1.05)	(.99)	(2.53)	(.15)	(.79)	(3.33)
Brazil	− .505	+ .233	− .945	− .643	+.910	+ .210	.44
	(.28)	(.39)	(.62)	(.38)	(.57)	(1.77)	(.68)

here. That is what one should expect of some major group of exporters; in this case, the fact that the exporters occupy the conceptual middle ground in the analysis adds a little to the credibility of the interpretation with regard to the United States and Japan.

For the United States, according to the figures, relatively high shares of world exports are associated with a trilogy of factors: with high technology-intensity, with low raw-labor intensity, and with low capital-intensity. Since these intensities are not independent, there is a certain artificiality involved in commenting on them one at a time; one should, perhaps, confine his observations to industries incorporating the whole syndrome. Still, it is worth noting that the labor result is consistent with expectations. The capital result would probably have been resisted before the Leontief paradox was exposed; but perhaps, by now, it is part of conventional wisdom. The strength of the technology factor is consistent with other studies and with Leontief's solution of his paradox; on the other hand, it is also consistent with the possibility that "technology" is a surrogate for "oligopoly," given the existence of collinearity between the variables.

In the case of Japan, the industry characteristics conducive to high export shares in world markets prove to be raw-labor intensity and capital intensity—once again, a pair of intercorrelated characteristics. The results with respect to the raw-labor measure are as expected. Those with regard to capital are no doubt influenced by her strong position in "ferrous metals"—iron and steel—and by her weak position in many of the industries with low capital intensity. The explanation for Japan's strength in the capital-intensive industries may well be the converse of the explanation for U.S. weakness: either a classical explanation of the type proposed by Leontief, or a national capability for paying labor at less than its marginal productivity.

The Mexican figures defy easy explanation. Without more investigation, it is not very fruitful to speculate over their meaning.

To sum up: The analysis to this point tends to confirm much of what had generally been suspected. It supports once again the right of the technology factor (or, since the two are not statistically separable, the human skill factor) to be regarded as one type of factor endowment that may contribute to an explanation of international trade flows. It suggests, if further corroboration were needed, that the factual observations underlying both the U.S. and the Japanese versions of the Leontief paradox were not mere statistical aberrations. But it does not resolve the tension between the classical and eclectic "explanations" of these phenomena; and it offers the seeds for some new disputes over the critical factors determining the patterns of trade.

TRADE BETWEEN AREAS

The search for an explanation of the trade performance of the technology-intensive industries is pursued here in still another direction. Up to this point, the export figures used for analysis were for given industries from given areas, totaled for all destinations. In attempting to understand the forces behind the trade in technology-intensive industries, however, the characteristics of the importing areas may impart as much information as those of the exporting areas. In short, the world trade matrix for any given industry can be viewed as a network of bilateral trade flows whose structure is determined by various economic characteristics of the exporting and importing areas concerned.

The approach in this section is to analyze the bilateral trade networks of each of our twenty-four industries in terms of selected variables that are based on the exporting and importing areas. The object is not only to identify the variables that help to explain the trade flows but also to detect systematic variations in the value and direction of those variables from one kind of industry to the next.

For any k:

$$\log E_{ijk} = f(PC_i, PC_j, GNP_i, GNP_j, D_{ij}, P_{ij}, |\Delta PC_{ij}|, \text{and } |\Delta H_{ij}|)$$

where:

PC_i = log of per capita income of exporting area

PC_j = log of per capita income of importing area

GNP_i = log of gross national product of exporting area

GNP_j = log of gross national product of importing area

D_{ij} = a function of the distance between i and j

P_{ij} = a dummy variable representing the presence (1) or absence (0) of a preferential trade arrangement between i and i

$|\Delta PC_{ij}|$ = log of the absolute difference between PC_i and PC_j

$|\Delta H_{ij}|$ = log of the absolute difference between "index of human resource development" in the exporting area (H_i) and such an index in the importing area (H_j); the index, which is based on educational attainment patterns, is known as the Harbison-Myers index.

A more detailed description of these measures appears in Appendix A.

The first six independent variables are fairly familiar in this sort of analysis; they are measures which have been employed by others, with varying success, to "explain" international trade flows.[5] These variables bear a close affinity to standard gravity models, where distance and mass are the key "explanatory" variables.

The other two variables, $|\Delta PC_{ij}|$ and $|\Delta H_{ij}|$, are more novel. These variables are introduced in order to test a family of hypotheses which hold that countries whose national environments differ considerably will have a different pattern of trade relations than those whose national environments are very much alike; and, further, that these differences will vary systematically by the nature of the product. The difference between the per capita incomes of any two areas, $|\Delta PC_{ij}|$, may be taken as a crude index of the difference in consumption patterns. The difference in human resource development, $|\Delta H_{ij}|$, to the extent that its descriptive power differs from $|\Delta PC_{ij}|$, is thought of as stressing the side of production. In short, the human resource level is thought of as the measure of an input, generated by investments in education and knowledge, whereas per capita income is related to the structure of the economy's demands.

Despite the ambitious coverage of the independent variables, some of the limitations previously encountered in Table 7 remain painfully evident. The role of import barriers, including the effective tariff rates, import licensing regimes, and other such impediments, is not explicitly accounted for. Nor is the influence of the existence of direct investments abroad by the industries of the various exporting countries. Our limited resources did not permit us to try to fill these gaps, and the reader will

[5] Linnemann [14] uses a very similar form of equation. However, he confines his analysis principally to aggregate trade flows and only ventures tentatively into the question of the differences in trade flows among different types of commodities.

have to be on his guard to detect where these omissions may have led us astray.

Before exploring the aggregate explanatory power of the variables that were included, there is the usual indispensable threshold question: To what extent are the independent variables intercorrelated? Table 8 sets out a matrix of correlation values for all possible pairs of the independent variables.

One can see at once that the variables are intercorrelated in a web of relations, complicating somewhat the interpretation of everything that is to follow. Not surprisingly, the logs of per capita income are positively associated with the logs of the gross national product to which they relate; any other result would be somewhat suspect. Distance, D_{ij}, is related to per capita income differences, $|\Delta PC_{ij}|$; where small distances exist between countries, the per capita income differences are also small, while larger distances are associated with larger per capita income differences. But this relation may have no causal significance and may simply be a reminder of the fact that seven of the eight rich exporting areas and seven of the nine rich importing areas in our trade matrix are relatively close together, in Europe and North America, while the poor areas of our trade matrix are far away from most of their trading partners.

The two measures of area differences, $|\Delta PC_{ij}|$ and $|\Delta H_{ij}|$, also exhibit some relationship to one another. But it is apparent that they are far from being carbon copies. While there is, of course, an intimate relation between the per capita income and the human resource development index of any area, the correlation of the absolute differences in these measures for pairs of areas is weak. This reflects the aberrant behavior of several areas including Canada, Japan, and "Rest of EFTA." Canada is on the low side as measured by the human resource development index in view of its per capita income, while Japan and "Rest of EFTA" project the opposite picture.

Regressing the logs of the trade flows on the eight variables presented in Table 8, industry by industry, a set of twenty-four industry equations are derived. The net regressions in these twenty-four equations for 1964 data are shown in Table 9, below, together with the value for the multiple correlation coefficients.

One of the striking aspects of Table 9 is the remarkable consistency

TABLE 8

Relations Between Descriptive Measures Relating to Exporting and Importing Areas, 1964
(each cell shows Pearsonian coefficient of correlation between indicated measures)

Measure	PC_i	PC_j	GNP_i	GNP_j	D_{ij}	P_{ij}	$\lvert\Delta PC_{ij}\rvert$	$\lvert\Delta H_{ij}\rvert$
PC_i log per cap income, export area	+1.00	a	+.79	a	− .17	+ .08*	+ .10*	+ .06*
PC_j log per cap inoome, import area		+1.00	a	+ .50	− .35	+ .09*	− .11*	− .06*
GNP_i log GNP export area			a	− .07*	− .02*	+ .02*	+ .17	+ .21
GNP_j log GNP import area				+1.00	− .22	− .06*	+ .10*	+ .22
D_{ij} function of distance between areas					+1.00	− .43	+ .54	+ .18
P_{ij} trade preference dummy variable						+1.00	− .32	− .35
$\lvert\Delta PC_{ij}\rvert$ log difference between PC_i and PC_j							+1.00	+ .46
$\lvert\Delta H_{ij}\rvert$ log difference between human resource development indexes								+1.00

*Indicates coefficient not significant at 5 per cent level. Although n = 114 for most correlations in the table, n = 10 for the PC_i, GNP_i correlation and n = 12 for the PC_j, GNP_j correlation.

[a]not calculated.

TABLE 9

Net Regressions and Multiple Correlations Reflecting Relations Between

TABLE 9

Net Regressions and Multiple Correlations Reflecting Relations Between Bilateral Trade Flows and Characteristics of Trading Areas, 1964

$$\log E_{ijk} = a + b_1 \log PC_i + b_2 \log PC_j + b_3 \log GNP_i + b_4 \log GNP_j + b_5 \log D_{ij} + b_6 P_{ij} + b_7 \log|\Delta PC_{ij}| + b_8 \log|\Delta H_{ij}|$$

Industries (SIC number)	Net Regressions for: PC_i	PC_j	GNP_i	GNP_j	D_{ij}	P_{ij}	$\|\Delta PC_{ij}\|$	$\|\Delta H_{ij}\|$	R Multiple Correlation
Eight technology-intensive									
Aircraft (372)	- .111*	-.154*	+1.194	-.006*	- .364*	+.412	+.318*	-.055*	.69
Office machines (357)	+ .506	-.019*	+ .652	+.350	- .430	+.206*	-.103*	+.106*	.79
Drugs (283)	- .005*	-.590	+ .796	-.161*	- .794	+.226*	+.265*	-.088*	.70
Chemicals (minus drugs) (other 28)	+ .929	-.513	+1.079	+.686	- .735	+.332	+.013*	-.124*	.92
Electrical machinery (36)	+ .396*	-.408	+1.156	+.294*	- .712	+.366	+.119*	-.012*	.83
Instruments (38)	+ .024*	-.123*	+1.197	+.370	- .394	+.232*	-.064*	+.015*	.76
Agricultural machinery (352)	+ .119*	-.162*	+ .854	-.203*	- .986	+.349	+.132*	+.281	.74
Petroleum and coal (29)	- .629	-.363	+1.330	-.168*	-1.463	+.255*	+.241*	+.165*	.76
Sixteen other									
Transport equipment (minus aircraft) (other 37)	+ .684	-.455	+ .854	+.134*	- .855	+.524	+.182*	+.111*	.75
Other machinery non-electrical (other 35)	+1.098	-.457	+1.056	+.298	- .724	+.392	-.015*	+.055*	.90
Nonferrous metals (other 33)	+1.293	-.121	- .043*	+.582	- .927	+.503	+.253*	+.156*	.85
Rubber, and plastics n.e.c. (30)	- .482*	-.385	+1.126	+.233*	- .716	+.430	-.100*	+.297	.74
Ferrous metals (331 & 332)	+ .172*	-.467	+ .971	+.468	-1.000	+.618	+.034*	+.126*	.77
Fabricated metals (34)	+ .250*	-.372	+ .819	+.251*	- .761	+.416	+.151*	+.133*	.78
Stone, clay, glass (32)	- .567	-.185*	+1.224	+.274*	- .896	+.344	+.154*	+.033*	.76
Paper (26)	+1.296	-.355	- .051*	+.152*	-1.057	+.470	+.324	+.263	.79
Textiles (22)	- .294*	-.406	+1.382	+.419	- .802	+.475	-.018*	-.058*	.73
Food (20)	- .467*	-.382	+ .861	+.602	-1.238	+.427	+.500	+.167*	.76
Tobacco (21)	- .754	-.107*	+ .922	+.076*	- .089*	+.180*	+.308	-.143*	.46
Furniture and fixtures (25)	- .372*	-.399	+ .222*	+.108*	-1.311	+.334	+.395	+.207	.72
Leather products (31)	- .406*	-.108*	+ .864	+.331*	- .725	+.505	+.139*	+.023*	.67
Printing and publishing (27)	- .189*	-.085*	+ .736	-.070*	-1.050	+.139*	+.287	+.077*	.70
Apparel (23)	- .500*	-.161*	+1.152	+.216*	- .825	+.462	+.125*	+.068*	.69
Lumber and wood (24)	+ .406*	+.001*	+ .124*	+.240*	- .886	+.488	+.324*	+.096*	.65

*Indicates not significant. For net regressions, based on *t*-test at 5 per cent level; for multiple correlations, based on *F*-test at 5 per cent level.

in the trade behavior of the different products, almost irrespective of product type. The only seeming difference between the behavior of the eight technology-intensive industries and the sixteen other industries—and that difference feeble at best—is the explanatory power of PC_i, the per capita income of the exporting country. In this variable, consistent with conventional wisdom, one detects the prevalence of a positive relation to trade levels in the technology-intensive industries and of a negative relation in the industries at the other end of the technology spectrum. But the relations are weak and wavering.

The fact that there are so few consistent differences between the two groups of industries is a finding that generates very mixed reactions. As will shortly be evident, the seeming consistency may be due in part to the relative grossness of our industry classifications, a grossness that may have the effect of grouping a broad band of industrial activities within each of the twenty-four industry groups in Table 9. We shall return to that issue later in the discussion. For the present, the consistencies themselves are worth noting.

As indicated by many earlier studies, the distance factor, D_{ij}, has strong explanatory power for most product classes, large distances being associated with low trade. There is a temptation to equate the distance factor with some simple economic equivalent, such as transport cost. But the pervasive strength of that factor, including its appearance in such industrial categories as "drugs" and "agricultural machinery," suggests that more may be involved in this measure than mere transport cost. Perhaps what one sees here is a measure that captures not only the effect of transport cost but also the effect of other frictions associated with distance, such as limitations on businessmen's knowledge about sources and markets.

According to Table 9, the preference factor, P_{ij}, like the distance factor, significantly affects the trade flows in most of the twenty-four industry groups, conducive to higher trade levels. Here, one cannot be sure whether the tariff treatment is the moving force, or whether the market familiarity and market knowledge that go with the existence of a preferential trade relation are the causal factors of the higher levels of trade.

Table 9 also shows that irrespective of industry the size of the gross national product of the exporting country, GNP_i, is strongly correlated with the level of trade flows; but the size of the gross national product of the importing country is much more feebly and uncertainly related. Hypotheses that stress the internal and external scale economies of large countries as a source of export strength in manufactured products seem supported by this finding.

The per capita income figures for importing countries throw added light on the sources of trading strength. On the whole, the higher the per capita income of the importing country, PC_j, the lower its imports of the products covered by this matrix; this is a relation, of course, that is purportedly net of the GNP effects. One has to be cautious about interpreting the meaning of the partial relationships between per capita levels and trade flows in view of the positive correlation of the per capita figures with the GNP data. If the relationship is not a mere quirk of the data, it reflects either a perverse consumption pattern for manufactured goods in high-income countries or the ability of such countries to engage in import substitution more effectively than others. On sheer plausibility grounds, the second possibility is more appealing than the first. If import substitution in manufactured goods is more extensive in high-income countries, is this a phenomenon other than that of mere scale? Does it perhaps reflect a greater capacity for high-income countries to assemble the ingredients of technology, capital, and entrepreneurship, whenever the existence of a domestic market is evident?

The likelihood that scale alone may not be the critical variable in explaining the results is indicated by the consistent direction in the regression values generated by $| \Delta PC_{ij} |$ and $| \Delta H_{ij} |$. In both these cases, as Table 9 indicates, large differences between importing and exporting countries are associated with high trade levels. The tendency is not very strong, but it is stubbornly persistent; nineteen of the twenty-four industry groups exhibit positive net regressions both for $| \Delta PC_{ij} |$ and for $| \Delta H_{ij} |$. If gaps in per capita income and human-resource development between importer and exporter have any effect on the level of world trade, that effect is to augment such trade, not to reduce it.

How seriously is one to take the results of an analysis of this sort?

At a minimum, with an analysis so complex and a set of independent variables so intimately interrelated, one wants to be sure of the sensitivity of the results to different structures of the model. Two features of the model are especially bothersome: the pervasive role of per capita income in the specification of the independent variables; and the unweighted character of the observations, which gives each bilateral flow as much weight as any other in the statistical generalizations.

Troubled by these aspects of the model, we sought to test the persistence of the principal results by altering the model in numerous ways. In one series of variants, one or more independent variables were dropped. In another series, geographical areas that appeared at the upper or lower end of the range—the United States in one variant, Mexico and Brazil in another—were dropped from the analysis. Through all of these, the major findings continued to appear: Distance and preference played their usual roles. Countries with a large GNP were stronger exporters of manufactured goods than countries with small, but a large GNP was no sure indicator of large imports. And finally $|\Delta PC_{ij}|$ and $|\Delta H_{ij}|$ persisted in exhibiting a mildly positive relation with trade levels for practically every type of product.

Among the variants in the model that were tried was one that separated out the bilateral trade flows affected by preference from those in which no preference existed. There were 17 preference-related bilateral flows out of the 114 flows of the 12 x 10 matrix, resulting principally from the existence of the EEC, EFTA, and the British Commonwealth preferences. Having in mind the complexity of the forces at work in these preference situations, the question was whether the tendencies manifested in the 114-pair matrix would continue to appear in the 17-pair and 97-pair matrices.

The answer is yes and no; no, in general for the 17 pairs of preference relations, and yes with undiminished strength in the 97 no-preference pairs. In the 17-pair preference group, only one or two of the explanatory variables show much strength. GNP_i, measuring the size of the exporting area, continued to be an important explanatory factor. But the distance variable, D_{ij}, lost its explanatory power as did the human resource development index. Preferential areas, it appears, have their own *modus vivendi.* In the 97-pair no-preference group, however, all of the explanatory variables took on added strength and pervasiveness among the industry groups.

Still another decomposition of the 114 bilateral flows was suggested by the strong hints of significance of $|\Delta H_{ij}|$ as an explanatory variable.

That variable, it will be recalled, seemed to bear a slight positive relation to trade flows, even for technology-intensive products. The possibility that differences in human resource development levels might encourage exports from the more highly developed to the less developed areas seems plausible enough. One might also entertain the possibility that, at least for certain kinds of products, human resource differences encourage trade to flow from the less developed to the more highly developed areas. But it seems improbable a priori that the trade stimulus would be similar in intensity and direction for all types of products.

In order to sort out the influence of the human resource measure with somewhat greater clarity, export flows were separated into two groups: those that represented an "upward" flow, from areas with low human resource indexes to areas with higher indexes; and those that moved in the opposite direction. There were 61 flows of the first sort, and 53 of the second, making up the usual 114-flow total.

From other compilations of the underlying data—compilations derived as by-products of the first main part of this study—a good deal was already known or easily inferred regarding the differences in the industrial mix of exports. High-income areas, as Table 2 had demonstrated, had a heavier representation of technology-intensive goods in their total export mix than lower-income areas. Beyond that, if one subjected the measures in Table 4 to systematic analysis, one could demonstrate that the high-income areas showed a positive tie between the prominence of a given industry in their export profile and the technology intensity of the industry, whereas that tie was absent or even negative for the low-income areas.

On the basis of various exploratory compilations done in connection with the first section, it also had been learned that any exporting area when selling down the income ladder to lower-income areas displayed a larger stress on technology-intensive goods in its export mix than when selling to areas of similar or higher income. In the case of the middle range of developed countries from the United Kingdom to Japan, for instance, it is known that the eight technology-intensive industries accounted for 19.8 per cent of their total exports to the United States, but for 27.8 per cent of their total exports to each other, and 30.7 per cent of their total exports to the less developed areas. Could one add to an understanding of the forces affecting upstream and downstream trade by reference to the variables in Table 9? The data in Table 10 provide some glimmerings of an answer.

The first impression to be drawn from Table 10 is the marked similarity in the results between the 61 "downstream" trade flows and the 53 "upstream" flows.

Observe the contribution of GNP_i, the gross national product of the exporter, in the two groups of cases. In both instances, a large GNP is strongly related to a high level of exports; for most industries, whether or not they are technology-intensive, the size of the exporting economy is important in determining the level of exports.

Note, too, the persistence in the tendency for per capita income in the importing country, PC_j, to be associated negatively with trade flows, both for upstream and for downstream trade flows. There is a suggestion in the table that this tendency is stronger in the eight technology-intensive industries than in the sixteen others; if that is so, the hypothesis that the negative correlation may reflect a greater capability of high-income countries for import substitution gains a bit more credence.

Finally, Table 10 tells us that the size of the income gap and the size of the human resource gap between exporter and importer continue mildly but persistently to be related to the level of bilateral trade flows. These tendencies seem somewhat weaker in the downstream trade of the technology-intensive industries than in the upstream trade in those industries; but there are no other clear differences in relative impact.

In terms of classical theory, there is no great surprise in the fact that exporting countries should find an especial affinity with markets most different from themselves in per capita income and human resource characteristics. What is difficult to accept is that this tendency should exist even for upstream exports in technology-intensive products. In this case, no doubt, we are the victims of the grossness in the system of industry classification on which the analysis is based. One strongly suspects that if the data could be broken down adequately, the products being exported upstream under the "technology-intensive" label would be a fairly standardized, relatively uncomplicated type of product, demanding little in the way of skill or technology from the exporting country.

TABLE 10

TABLE 10

Net Regressions and Multiple Correlations Derived from Analysis of Sixty-One Trade Flows ($H_i > H_j$) and Fifty-Three Trade Flows ($H_j > H_i$), 1964

$\log E_{ijk} = a + b_1 \log PC_i + b_2 \log PC_j + b_3 GNP_i + b_4 \log GNP_j + b_5 \log D_{ij} + b_6 P_{ij} + b_7 \log |\Delta PC_{ij}| + b_8 \log |\Delta H_{ij}|$

	Sixty-One Case Group, $H_i > H_j$			Fifty-Three Case Group, $H_j > H_i$		
Net Regressions for:	Mean Value	Number with Same Sign as Mean	Number Statistically Significant[a]	Mean Value	Number with Same Sign as Mean	Number Statistically Significant[a]
Eight Technology-Intensive Industries						
log PC_i	+ .030	5	1	+ .199	6	2
log PC_j	− .431	8	4	− .507	7	2
log GNP_i	+1.113	8	8	+1.466	7	7
log GNP_j	+ .364	7	4	− .173	5	1
log D_{ij}	− .918	8	7	− .724	8	6
P_{ij}	+ .442	8	4	+ .110	6	0
log $\|\Delta PC_{ij}\|$	+ .167	6	1	+ .240	8	1
log $\|\Delta H_{ij}\|$	+ .043	4	0	+ .322	7	5
Multiple correlation, R	.79	–	8	.78	–	8
Sixteen Other Industries						
log PC_i	− .472	12	4	+ .024	6	4
log PC_j	− .281	14	6	− .055	8	1
log GNP_i	+ .751	16	11	+1.259	13	10
log GNP_j	+ .123	10	1	+ .172	11	3
log D_{ij}	−1.106	15	15	− .705	16	11
P_{ij}	+ .512	16	13	+ .348	14	4
log $\|\Delta PC_{ij}\|$	+ .379	15	7	+ .142	13	0
log $\|\Delta H_{ij}\|$	+ .168	13	3	+ .241	14	5
Multiple correlation, R	.75	–	16	.78	–	16

[a] For net regressions, based on t-test at 5 per cent level; cases with sign different from mean are not included. For multiple correlation coefficients, based on F-test at 5 per cent level.

On looking back at the various provocative indications afforded by the models, two generalizations stand out. One is the explanatory power of some of the forces that are implicit in the gravity model; large exporters (but not necessarily large importers) generate large trade flows, but the frictions associated with distance dampen down such flows. The other conclusion relates to the explanatory power of the quality of labor. To plagiarize and modify Ricardo, the data may be displaying the dominance of an exchange of brain-created goods for brawn-created goods. As suggested by the analysis presented earlier, differences in capital and resource availability may be of less importance. Perhaps nations inadequately endowed with capital and natural resources can substitute for these to some extent or import them if necessary, without much loss of competitive position [cf. 1]; but it may be more difficult to substitute for a lack of highly skilled manpower and more uneconomic to substitute for a lack of unskilled labor.

STATIC AND DYNAMIC FACTORS

In interpreting the findings in this paper, one has constantly to recall that the findings have nothing to say about the temporal sequence of events—that they represent simply and unabashedly a cross-sectional analysis of world trade relationships. Sometimes the researcher has no choice but to try to infer what may happen over time by exploiting the indications provided from cross-sectional data. In international trade, however, that kind of exercise seems especially hazardous.

One major difficulty with moving from static to dynamic concepts in international trade has to do, as usual, with the temporal interdependence of critical variables.

The patterns of trade in an early time period may have a great deal to do with the strength of the independent variables in the period that follows. Because trade has expanded in the past, the frictional effects of distance upon future trade may decline and the lubricating effects of preferences may increase.

Moreover, although trade may be thought of as a substitute for the movement of the factors in any given time period, it may also be a stimulant for the movement of those factors in the periods that follow; investment may follow the market, and human resources may follow the investment. Trade in one period, therefore, may be the instrument for the displacement of trade in the periods that follow.

Although one has to proceed with caution in applying static observations to dynamic concepts, it is possible to reconcile the temporal sequences suggested by dynamic product-cycle or market-cycle theories with the static cross-sectional snapshot presented here.

As various dynamic models suggest, it may well be that when manufactured products first enter international trade, they tend to find their initial export markets in areas very like that of the exporter, rather than in areas that differ markedly from the exporter in human resource development terms. Our results suggest, however, that this is no more than a transitional stage; eventually, imports are cut back by domestic production and the exporter moves on to other more remote markets. What endures in international trade seems to be the commodity flows that are based on gross differences in factor endowments, differences not readily bridged by the regroupment of local factors in new combinations or the import of foreign factors to supplement those that are in local short supply.

One can speculate that the factors relating to human resource development are especially hard to replace or supplement where they are inadequate. The capabilities that go with a high level of human resource development, whether applied through cost and price or through monopoly power, may be difficult to match; and the capabilities that accrue from an adequate supply of raw labor may also be among the more enduring advantages of a trading nation. If that is so, then, the static cross-sectional pattern of world trade may well be dominated by these relatively intractable factors.

APPENDIX A

This appendix deals with the sources and methods of compilation of the trade data, the industry data, and the area data used in the study.

Trade data

Trade data were taken from OECD, *Statistical Bulletins,* Series D, Numbers 1 to 6 for January to December 1964; and the United Nations, Statistical Papers, *Commodity Trade Statistics,* January to December 1964. The following conversion of SITC to SIC categories was used:

Industry	SIC	SITC
Food and kindred products	20	Total food shipments (0) minus nonmanufactured food (041, 043, 044, 045, 051) plus beverages (111, 112)
Tobacco products	21	122
Textile mill products	22	651 minus 651.6, synthetic fibers, 652, 653, 654, 655, 657
Apparel and related products	23	841, 842, 656
Lumber and wood products	24	631, 632, 633, 243
Furniture and fixtures	25	82
Paper and allied products	26	641, 642, 251
Printing and publishing	27	892
Chemicals and allied products	28	5, 231, 651.6
Drugs	283	541
Chemicals minus drugs	28 minus 283	5, 231, 65.6, minus 541
Petroleum and coal products	29	332
Rubber and plastic products n.e.c.	30	621, 629, 893
Leather and leather products	31	611, 612, 831, 85
Stone, clay, and glass	32	661, 662, 663, 664, 665, 666
Ferrous metals	331, 332	671, 672, 673, 674, 675, 676, 677, 678, 679
Nonferrous metals	33 minus (331 + 332)	681, 682, 683, 684, 685, 686, 687, 688, 689
Fabricated metal products	34	691, 692, 693, 694, 695, 696, 697, 698
Machinery, except electrical	35	711, 712, 714, 715, 717, 718, 719
Office machines	357	714
Agricultural machinery and implements	352	712
Other machines except electrical	35 minus (357 + 352)	711, 715, 717, 718, 719
Electrical machinery	36	722, 723, 724, 725, 726, 729, 891.1, 891.2
Transport equipment	37	731, 732, 733, 734, 735
Aircraft	372	734
Other transport	37 minus 372	731, 732, 733, 735
Instruments and related products	38	86, 891 minus (891.1 + 891.2)

Country groupings provided by the OECD were used in those cases where it was possible. A number of difficulties were encountered in the raw data, e.g., different figures in the English and French texts. In a few cases, subtraction of figures for West Germany and France from the EEC total left a negative value for the rest of EEC. Similar difficulty occasionally appeared in the subtraction of U.K. data from EFTA totals. Such cases, however, were infrequent and involved small volumes of trade. When this occurred, a value of 0 was assumed. Some U.S. exports in industries 36 and 372 were unspecified as to destination; it was assumed that these were exports of defense products and that they were distributed to Asia, 60 per cent, Latin America, 30 per cent, and Africa, 10 per cent. In some cases, data were available on an exporter basis and in other cases on an importer basis. Where observations were separately available both for the exporter and for the importer, the differences were not always consistent in an obvious sense. Some of the unexplained variance in the statistical analysis must be attributed to the poor quality of the data.

"Africa" includes all of Africa except South Africa. "Latin America" includes Spanish-speaking and Portuguese-speaking areas of South and Central America, and of the Caribbean and Mexico; it does not include non-Spanish-speaking or non-Portuguese-speaking Caribbean, Central and South American territories. "Asia" includes all of Asia and the Near East, except the U.S.S.R. and mainland China.

Industry data

The number of scientists and engineers, by industry, is from: Bureau of Labor Statistics Bulletin No. 1418, *Employment of Scientific and Technical Personnel in Industry,* Washington, 1964, Table A-14.

Total employment by industry is from U.S. Bureau of Labor Statistics Bulletin No. 1312–4, *Employment and Earnings Statistics for the United States, 1909–1966,* Washington, 1964.

Value added by industry is from U.S. Bureau of the Census, *Census of Manufactures: 1963,* Washington, 1968.

The capital/output ratio was calculated from data in FTC-SEC *Quarterly Financial Reports.* Capital was defined as net property, plant and equipment; output as sales. The data for two industries was not available from the FTC-SEC reports. Office machines were calculated from the annual reports of Control Data and SCM; agricultural equipment from the annual reports of International Harvester and John Deere & Co.

The industry concentration measure was calculated from *Census of Manufactures: 1963*. Each industry value was based upon the share of total industry shipments held by the largest eight firms. Four-digit SIC data were weighted by shipments and summed to create the variables at the two-digit and three-digit level used in the study.

Intermediate output, crude materials input, and the output by industry used in the intermediate goods specialization and crude materials input measures were calculated from: "The Transactions Table of the 1958 Input-Output Study and Revised Direct and Total Requirements Data," *Survey of Current Business*, September 1965, pp. 33ff. Definitions of crude materials input and intermediate goods output were taken as given, with one exception: Although the output of SIC 241 appears in the original source as an intermediate output, it was reclassified as a crude material input for the paper industry.

Country data

GNP and population figures were taken from Table 3 of *Gross National Product; Growth Rates and Trend Data*, Washington, AID, 1967, pp. 8–14. For this purpose, "Latin America" is: Costa Rica, El Salvador, Guatemala, Honduras, Nicaragua, Argentina, Bolivia, Brazil, Chile, Colombia, Dominican Republic, Ecuador, Mexico, Panama, Paraguay, Peru, Uruguay, Venezuela, Jamaica, Trinidad and Tobago. "Africa" includes: Ethiopia, Ghana, Kenya, Morocco, Nigeria, Rhodesia, Sudan, Tanganyika, Tunisia, Uganda, Zambia; note the omission of a few important countries including Egypt and Algeria. "Asia" includes: Cyprus, Greece, Iraq, Israel, Jordan, Turkey, Ceylon, India, Pakistan, Burma, China (Taiwan), Korea, Malaysia, Philippines, Thailand; note that Indonesia is omitted.

The human resource development index is defined by its authors as the "arithmetic total of (1) enrollment at second level of education as a percentage of the age group fifteen to nineteen, adjusted for years of schooling, and (2) enrollment at the third level of education as a percentage of the age group, multiplied by a weight of 5." See F.

Harbison and C. A. Myers, *Education, Manpower and Economic Growth,* New York, 1964, pp. 31–48, for a more detailed definition of the index and some correlations between the index and other measures of economic development.

EFTA, EEC, LAFTA, the British Commonwealth preference, and the French Union preference determined the preference classification.

Distance in miles was used to create a distance-from-exporter-to-importer index. Where possible, the midpoints of regions were used as terminal points. Distances were measured in one-thousand-mile units. Land distances were weighted by a factor of 2. Values less than 1 were assigned a value of 1, and those over 10 a value of 10.

REFERENCES

1. Cooper, R. W., *The Economics of Interdependence,* New York, 1968, Chap. 3.

2. Gruber, W. H., Mehta, D., and Vernon, R., "The R&D Factor in International Trade and International Investment of United States Industries," *Journal of Political Economy,* February 1967, pp. 20–37.

3. Hirsch, S., *Location of Industry and International Competitiveness,* Oxford, 1967.

4. Horowitz, M. A., Zymelman, M., and Herrnstadt, I. L., *Manpower Requirements for Planning, An International Comparison Approach* (2 vols.), Boston, 1966.

5. Hufbauer, G. C., *Synthetic Materials and the Theory of International Trade,* Cambridge, 1966.

6. Johnson, H. G., "Comparative Cost and Commercial Policy Theory for a Developing World Economy," Wicksell Lectures of 1968, mimeographed.

7. Keesing, D. B., "Labor Skills and Comparative Advantage," *American Economic Review: Papers and Proceedings,* May 1966, pp. 249–58.

8. ———, "The Impact of Research and Development on United States Trade," *Journal of Political Economy,* February 1967, pp. 38–45.

9. ———, "Population and Industrial Development," *American Economic Review,* June 1968, p. 448.

10. Kindleberger, C. P., *Foreign Trade and the National Interest,* New Haven, 1962.

11. Kravis, I. B., " 'Availability' and Other Influences on the Commodity Composition of Trade," *Journal of Political Economy,* April 1956, pp. 143–55.

12. Lary, H. B., *Imports of Manufactures from Less Developed Countries,* New York, NBER, 1968, Chaps. 2 and 3.

13. Linder, S. B., *An Essay on Trade and Transformation,* New York, 1961.

14. Linnemann, H., *An Economic Study of International Trade Flows,* Amsterdam, 1966.

15. Stobaugh, R. B., Jr., "The Product Life Cycle, U.S. Exports, and International Investment," Ph.D. dissertation, Harvard Business School, 1968.

16. Tilton, J. E., "The Choice of Trading Partners: An Analysis of International Trade in Aluminum, Bauxite, Copper, Lead, Manganese, Tin and Zinc," *Yale Economic Essays,* Fall 1966.

17. Tsurumi, Y., "Technology Transfer and Foreign Trade: The Case of Japan 1950–1966," Ph.D. dissertation, Harvard Business School, 1968.

18. Vernon, R., "International Investment and International Trade in the Product Cycle," *Quarterly Journal of Economics,* May 1966, pp. 190–207.

19. Wells, L. T., Jr., "Product Innovation and Directions of International Trade," Ph.D. dissertation, Harvard Business School, 1966.

20. Wilkinson, B. W., *Canada's International Trade: An Analysis of Recent Trends and Patterns,* Montreal, 1967.

21. Williams, J. H., "The Theory of International Trade Reconsidered," *Economic Journal,* June 1929, pp. 195–209.

COMMENTS

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I should like to make a few comments on Mr. Hufbauer's excellent paper.

(1) The attempt at running comprehensive tests, using a common set of data, for a variety of competing "theories" of trade patterns is welcome. However, I find Hufbauer's use of U.S. coefficients for *other* countries quite difficult to accept. While it is true that we have to work with the "best" data that are available, it is not true that we do not have the kinds of coefficients required by Hufbauer for his many countries. For example, we do have data (even if not fully comparable with U.S.) on skills in different activities for countries such as India. It would be worthwhile for Mr. Hufbauer to work through his exercises by actually using the coefficients of at least one other country and examining how far the use of U.S. coefficients everywhere biases his results. Ultimately, we can develop confidence in his results only if the coefficients used are those actually obtained from these other countries.

(2) Further checking of his other statistical indices would also be useful. For example, his estimate of the scale factor in different industries (for the United States) is admittedly open to extremely serious, and in my judgment overriding, objections. But here also, I suspect that Hufbauer could try to improve his results by comparing his statistical results, at the least, with the results derived with superior techniques by economists such as Stigler (who uses the "survival" technique), Haldi, and Manne.

(3) It should also be noted that Hufbauer uses only "direct" coefficients in his tests.

(4) The work on "human capital" in international trade has been carried out by Bharadwaj and Bhagwati for India's pattern of trade and by Roskamp and McMeekin for West Germany, in addition to Peter Kenen and Elinor Yudin for the United States. Merle (Yahr) Weiss' introduction of "human capital" in the estimation of C. E. S. production functions, yielding elasticities of substitution close to unity and hence reversing the conclusions of Minhas, is also relevant.

(5) Finally, while Hufbauer is to be congratulated for bringing Leontief's exercise up to date, I would like to record my student B. R. Hazari's comment that a full test of the Heckscher-Ohlin theorem in a multicommodity system requires that *each* exportable commodity from the United States should have a higher capital/labor ratio than each importable commodity. Working with aggregate capital/labor ratios for exports and imports as groups would not be an adequate test. Thus, even if the latter test were passed, the stricter test may not hold at a significant level; but if the former test were failed (as in the paradox), clearly the latter will also have failed.

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The studies by Hufbauer and by Gruber and Vernon, for all the dissimilarities in their methods and approaches, complement each other very effectively. Together they mention and attempt to test, explicitly or implicitly, virtually the whole bewildering array of explanations that are now competing in trying to account for international trade in manufactures. The main results of each paper help, it seems to me, to confirm the same general picture of the causes of trade; yet the differences in interpretation and emphasis leave us free to describe this picture in many alternative ways. Indeed, it is striking that the authors often manage to give the same strands of contemporary thinking decidedly different conceptual and empirical twists.

I think the most striking joint implication of the two papers is that, at least at an operation level, we can no longer go back to any single, simple explanation of trade. Our new findings have been pushed to the point where we are now irreversibly aware of several basic, real-life causes operating in combination.

The strong roles in trade of natural resources, distance and preferences, which the Gruber-Vernon study helps to confirm, would seem almost trivially obvious in terms of microeconomics, except for the role of distance in products for which transport costs are minor. To explain this, as others have suggested, may require an information or communication approach to the subject.

The most obvious challenges for theory, and ultimately for policy, are the other apparent causes of trade. These are not only all highly interrelated, but, perhaps even more significant, they are all intimately related to the growth and development process. I am tentatively inclined to think of these would-be explanations in three clusters: the first group has to do with human resources, skills, and education; a second group relates to scale economies, external economies, total national income, and the dimensions (including the demand characteristics) of national markets; and the third group, elusive to formulate in parallel with the others, relates to R&D, innovation, new products, standardization, and levels of technological development. I suspect that the information and communication side of trade, if we were to investigate it further, would also prove to be related in none-too-simple ways with development, skills, scale, and technology.

I am not optimistic about our ability (1) to sort out these causes of trade or (2) to unify them into an operationally meaningful theory, on the basis of empirical and theoretical work focused on trade itself. Indeed, I expect that within a few years we will have largely exhausted what can be done to map the causes of trade which are based on trade patterns together with commodity characteristics. The main outlines are already becoming clear from the two papers we are considering and their empirical predecessors.

Rather, I would like to suggest that the challenge must ultimately be resolved through the unifying effect of advances in growth and development theory, which will probably take a long time to be realized. So that the really central challenge for empiricists is to build up a detailed knowledge of the technical interrelationships underlying growth and development. Trade theory is foredoomed to become an extension of growth and development theory; but the latter is still struggling toward its first successful synthesis. Until we possess adequate models of the growth and development process, trade theory will remain a temporary patchwork spread over a void and the sense of crisis and general dissatisfaction that now pervades the field will continue.

Turning to the individual papers, Professor Hufbauer has done a remarkably ingenious job of devising new quantitative proxies for economies of scale, first trade date, and standardization. There are obvious shortcomings in each of his novel measures; but these measures can probably be combined with others, derived from other countries and approaches, to quantify these concepts better in the future.

Hufbauer's biggest problems arise out of the underlying associations among the various commodity characteristics which he tries to measure, and the overlaps in the theories and the proxies he uses for them. Three-digit rank correlations between his characteristics, which he used originally on an unweighted basis, fail to show the real degree of multicollinearity among the explanations themselves. The bulk of world trade in manufactures consists of machinery, electrical machinery, certain types of transport equipment, and complex chemicals—a few trade categories in all—in which the industries at one and the same time are very skill-intensive, involve substantial scale economies, produce a large proportion of new, unstandardized products, and conduct much R&D. The pattern of trade in these products, both absolutely and compared to other manufactures, reflects quite consistently the trading countries' levels of development and their economic size.

I write these comments before seeing Hufbauer's revisions; but I trust that he will have explored further both the underlying associations I have just mentioned and the very high correlations in the relative standings of countries when his various commodity characteristics are applied to the same trade flows. These patterns of association, to judge by my own experiments with his data, turn out to be rather different according to whether rank or linear correlations are used. On a linear basis, for example, capital per man performs substantially worse than the other explanations; wages per man cease to be the "best" performer; and the ratio of consumer to intermediate goods does quite a fair job, despite the weakness of the underlying "theory." In either sort of correlation, at any rate, there are some intriguing mysteries. For example, when applying his measure of scale economies to exports, why should the results correlate very closely with GDP per capita? Why, for that matter, do his results for scale economies correlate so well with his results for standardization?

It must also be seriously questioned whether some of his proxies, borrowed from other people's studies, correspond to the theories to which he relates them. It is certainly conspicuous that Hufbauer regards professional and technical workers in an industry as a measure of a skill theory of trade, while Gruber and Vernon consider the same proxy to be a measure of their "R&D factor."[1] Again, the high, unweighted Spearman rank correlation of .920 (not shown in the Hufbauer article), between Hufbauer's export results with U.S. wages per man and a country's GDP per capita, does not necessarily confirm a skill theory of trade; for, in practice, U.S. wages per man in an industry reflect not only the skills and education of the labor force, but also the industry's success in terms of R&D and new products, economies of scale, and even trade itself. After all, U.S. labor is not averse to raising wages when profits permit.

I for one cannot get excited about Hufbauer's new evidence on capital and the Leontief paradox. It seems to me that the physical capital version of the Heckscher-Ohlin-Samuelson theory is almost irrelevant to observed trade patterns, probably because both financial capital and capital goods are far more mobile internationally than other key inputs such as skills, technical knowledge, organizational know-how, and externalities from the surrounding economy. Hufbauer's capital measure is easily the worst of his seven "explanations" of trade, at least on a linear-quantitative basis. That he got a positive result at all is at least partly because he used capital per man, which is positively associated with skills, R&D, and the like, rather than capital relative to output, for which this association is blurred because of the productivity effects of the other factors.

One last point on this paper: although Hufbauer has done an ingenious job of trying to test Linder's hypothesis with countries' aggregate trade data, the job really calls for data on bilateral trade flows, along the lines of Gruber and Vernon's matrix. It seems to me

[1] Editor's note: The final version of the Gruber-Vernon paper adopts the Hufbauer concept.

that their Tables 8, 9, and 10 shed a good deal of light on the underlying question. As I read this evidence, Linder's explanation will scarcely survive as a single or separate theory of trade; but his hypothesis has helped to call attention to distance, scale, and market size effects that are extremely important in practice.

Gruber and Vernon's paper really reports two different empirical studies, the first climaxing with Table 7 and the second with Tables 9 and 10. The paper is ingenious and well written, and the findings are very suggestive, especially those of the second empirical study. The empirical tests and findings are not linked to theory with the same explicitness and rigor as in Hufbauer's study; but an even wider range of theories are implicitly tested, and the results present intriguing further challenges for theory, while complementing Hufbauer's in many ways.

I have a number of qualms about their first empirical study as it was originally presented. I am not clear, much less convinced, of the theoretical basis for selecting advertising intensity, intermediate good specialization, and industry concentration as characteristics to be tested in Tables 6 and 7. I would rather see these characteristics dropped and a proxy for scale economies included instead.[2]

I am even more bothered by methodological aspects of the regressions shown in Table 7, where the dependent variable is the country's share of the ten areas' total exports. Since each country's share is negatively related to the other countries' shares, the regression results for one country are not independent of those for the next one; and the result is that for any characteristic one or two countries tend to be on each opposing side, while most wind up with inconclusive results in the middle. Moreover, since export characteristics turn out to be a function of levels of industrial development, it is hardly surprising that for several areas that fall into the weighted middle of the Gruber-Vernon sample in terms of income, namely the United Kingdom, the rest of EFTA, and Canada, no independent variable significantly explained their trade-share patterns. Surely there are ways around this problem. At the very least, regressions such as these should be attempted on other measures of trade shares, such as a country's share of an industry's exports when U.S. exports are excluded and more poor countries are

[2] Editor's note: The final version of the Gruber-Vernon paper is partially responsive to this criticism.

included; or, perhaps even better, a country's exports of the product relative to the exports of countries with higher and lower per capita incomes.

Their second study yields extremely interesting results. My only serious reservations relate to the implicit nature of much of their theoretical framework and to the presence in Tables 9 and 10 of so many separate independent variables related to income. This is especially serious in that income is a good proxy for not only demand but many supply conditions associated with development. I consider it a forceful testimonial to the strength of the many trade effects linked with development that so many significant coefficients appeared for these variables, despite all the underlying multicollinearity.

Let me add that, against the background of the existing literature, I find quite exciting Hufbauer's effects with scale economies and the Gruber-Vernon effects with total national income, as well as their results using differences in the Harbison-Myers index.

This large-scale testing of theories has many of us wondering which important explanations of trade might have been overlooked up to now. Let me therefore call attention here to the case of Israel, as discussed by Seev Hirsch in a later paper in this volume. In that country—in which rather impressive human resources have been thrown together recently and are now being combined into new organizations—export success in complex, skill-intensive products seems to be taking much longer than in simple, standardized products. This helps to suggest that we might build a useful line of theory around organization-building and the theme that the capabilities of a productive organization can be much more than the sum of the factors it employs. In such an explanation one would want to combine somehow Arrow's learning by doing, Leibenstein's X-efficiency, and Gabriel's corporate skills. Organization-building and learning effects would seem to me to be most important in technologically complex, R&D-intensive, fast-changing, skill-intensive industries. Unfortunately, however, it may prove impossible to define such an approach so as to be operational and measurable.

Together the Hufbauer and Gruber-Vernon papers should stand as a landmark in our empirical research; but there is still room for considerable further research along similar lines. In view of the identification problems implied by their results, the point will soon be reached where we will need to test such relationships by applying advanced econometric methods to explicit alternative systems of equations.

I have already suggested, however, that, by their nature, studies of the relationships among trade patterns and commodity characteristics cannot give us anything like a unifying explanation of trade patterns. Success in achieving such an explanation will only come, I expect, through empirical and theoretical advances in our understanding of the basic technical interrelationships underlying development. Given the difficulty of this task, it will probably be a long time and a lot of work before we can put the Humpty Dumpty of trade theory together again.

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The papers before us are in the new but distinguished tradition of using the capacity of the computer for massive manipulation of numbers to verify the theory of international trade, and in particular to see which of a variety of competing theories dominates the explanation of trade in manufactures. The authors think the time is past for the identification of possible theories or taxonomy. As Hufbauer says of the new theories: "They often perform very well when applied to a single group of commodities or a limited range of countries." But some theories must be better than others, and some one theory must be best. So our authors pile up the numbers for selected countries and areas, arranged overall in one case and in matrix form in the other, and we are off.

There is no faulting the ambition or the technical virtuosity of our authors. I admire the first and envy the second, even though I am not always clear what some of the manipulations imply in detail. It is useful to test our theories empirically, even though it seems impossible at this stage of our knowledge and data to establish any one theory as dominant, or even to disprove much.

My scepticism about proving a great deal about the theory of trade from manufacturing data goes back a long way to the "proofs" of comparative advantage put forward by MacDougall, Balassa, and Stern, and based on the Ricardian labor theory of value. In these cases, a discarded theory was proved by empirical demonstration, using bilateral trade and trade of two similar countries with third countries. The proofs seemed to satisfy few observers, neglecting as they did the contribution of capital to comparative advantage and omitting such industries as chemicals. The Leontief paradox moved the discussion back to the Heckscher-Ohlin-Samuelson model with variable factor proportions.

The Leontief paradoxical results showing that United States exports were labor-intensive and imports capital-intensive, produced an explosion in the theory of trade, despite little agreement on the explanation of the untoward results. Agreement is lacking between the Hufbauer and the Gruber-Vernon papers on this point, since Hufbauer's results confirm the Leontief findings only for the United States and restore the Heckscher-Ohlin-Samuelson findings with respect to capital and wages for other countries (How reconcile with Ichimura and Tatemoto for Japan, and with Roskamp for Germany?), while Gruber and Vernon seem to find capital out of line throughout their world trade matrix.

Hufbauer classifies seven explanations of trade, six orthodox and converging, and one, that of Linder, heretical. The orthodox explanations are grouped into a neofactor proportions account, combining human and physical capital, and a neotechnological account relying mainly on economies of scale, product innovation, and product differentiation; Linder's is a preference-similarity theory. It is not clear, however, that the neofactor and the neotechnological theories converge analytically. Neofactor proportions theories assume that there is a standard world technology and that factor endowments determine the direction of trade. Neotechnological theories assume that technology is continuously changing unevenly, and that these changes alter the trade pattern. Innovations lead to exports; the spread of technology to the world establishes a pattern based on factor proportions, which may or may not differ from that induced by the initial gap. To the extent that the pattern based on factors differs from that based on innovation, the neofactor and neotechnological explanations differ rather than harmonize.

The papers, it should be noted, discuss only one sort of technological theory, when there are in fact two. Innovation can take place in product or in process. The authors here identify technical change with new products rather than with producing old products in new and lower-cost ways. The widespread disdain among empiricists today for factor reversals is based on the same view. There is strong evidence to support the position, as Lary has shown in his work, but it cannot be ruled out by assumption. We know that factor reversals exist in some fields, as in rice which is produced in labor-intensive ways in the Far East, but the United States, using capital-intensive methods of sowing and fertilizing from aircraft and harvesting by outboard motorboat, is today its leading world exporter. And it is well to remember the work of Tyzynski who corrected the results of the German Enquête Ausschuss of the 1920's which emphasized new goods with high income elasticity as a source of trade growth, by pointing to the Japanese case which the earlier data had overlooked. In addition to the commodity and country effects taken to be high for "new products," based on goods, incomes, and income elasticities, there is the competitive effect which may be based on process innovation in old goods.

It may be noted that within the field of product innovation the product-cycle theory emphasizing supply and the Linder theory focusing on demand may each either explain trade or trade's drying up. Assume that technology spreads abroad. Direct investment may substitute for trade as a means of holding the market against local competition and may stop there. Trade is cut off, rather than reversed. In this instance it is hard to see how aggregated trade data can prove or disprove such a theory. In Linder's theory, rising incomes in a country may induce consumers to shift to products which are too expensive for the export market, i.e., American-type large cars which suit the home market but are too big and too voracious as consumers of taxed gasoline for the foreign market. Exports of large cars decline. Imports of small cars, however, reflect the demand for a different product, the second or third car in a family, which has a different income and price elasticity from the first car. The Linder theory can thus be used in slightly different circumstances to explain flourishing trade between countries on the same level of living, or a decline in such trade when incomes pass through certain zones. Rank-order correlations which fail to account for the distances between incomes will miss this possibility.

Let me now raise some technical problems. Both papers rely on cross-sectional analysis. Gruber and Vernon apologize for using the matrix of a given year to verify a dynamic model of trade. Hufbauer is unconcerned with the problem. If, however, different commodities find themselves at different stages of the product cycle, it is not clear what the average position portrays. One should normalize by the stage of the product cycle, and this cross-section data do not do. To measure the average height of a family with children of various ages produces no interesting result.

Both papers use United States coefficients widely and apologize for the practice. Hufbauer uses national attributes in his Table 4, but all except one of the product characteristics in his Table A-2 are of United States origin. This raises fundamental questions when it comes to measuring foreign industries. With no factor reversals and identical production functions, factor-input ratios may be compared only on the assumption of identical factor prices. None of these conditions is guaranteed. There is something of a presumption of no reversals on the basis of Lary's work, as I have said, but identity of production functions is excluded by the product-cycle hypothesis, and identical factor returns can be eliminated by casual empiricism. Gruber and Vernon particularly have trouble, it seems to me, when they assume that the same industries are research-intensive all over the world, and the same industries advertising-intensive. In fact, they express surprise that Japan does so well in advertising-intensive industries and seek to explain it by implicit theorizing to the effect that Japan compensates for lack of advertising by cutting costs—a hint of innovation in process rather than product which is otherwise missing from both papers.[1]

I also find unsatisfactory the implicit theorizing which adduces a new explanatory variable, the propensity to apply marginal pricing, to explain why the United States exports little and Japan a great deal in capital-intensive industry. This variable may differ from country to country, along with other sociologically and economically determined propensities which affect foreign trade, such as readiness to apply tariffs in periods of falling prices (Germany, France and Italy did so in wheat in the 1880's, but Denmark, Britain and the Netherlands did not); or business propensity to push exports in periods of slack domestic

[1] **Editor's note: The references to advertising intensity, which appeared in the conference version of the Gruber-Vernon paper, were eliminated in the final version.**

business, which is remarked to be high in Germany and low in the United States. But such explanations must not be introduced casually to explain away statistical results which depart from a priori expectations. If they are to be used they must be addressed explicitly and the basis for national differences demonstrated.[2]

In Hufbauer's paper, dating and standardization present particular problems. One can sympathize with the problem of trying to find intellectually satisfactory measures for these concepts on a world basis, but why limit the United States data, if one is restricted to a single country, to exports? The addition of imports would have helped, especially for the standardization coefficients. Hufbauer notices that cotton textiles a priori seem satisfactory in standardization but curious in first date. To limit unit values to 1965 exports eliminates cotton gray goods from the standardization index, the most important single item in world cotton-textile trade. It may even be that the United States did not export gray goods in the period since 1917, although, of course, it has imported them. First-date averages by countries in Table 2 seem very odd indeed, with no country having an average composition of 1965 exports earlier than 1944 and the latest country average coming only to 1948. It seems hard to say anything interesting about the product-cycle or technological gap theories of trade with data which average out most of the timing differences between countries and produce sixteen out of twenty-four averages in two years, 1946 and 1947.

Gruber and Vernon try to allow for distance, while Hufbauer apologizes for leaving the problem alone. But the Gruber-Vernon solution is not completely satisfactory for it fails to distinguish those goods (weight-losing or bulk-gaining) in which distance inhibits trade and those footloose industries in which it does not. The distance factor is important both for petroleum and coal and for furniture and fixtures. But what can one make of identical net regressions in Table 9 for drugs, on the one hand, and stone, clay and glass, on the other (−.005) and (−.567)? If more than physical distance is meant (i.e., such factors as established trade channels, market horizons customarily scanned, and the like), it is not certain that distance is an ideal proxy, especially when, in some goods, it has strong economic effects of a physical nature.

[2] Editor's note: These points also were stricken from the Gruber-Vernon paper in response to criticism such as this.

Tariff barriers are ignored in both papers, although Gruber and Vernon include a variable for preferences, apparently on the assumption that tariffs are otherwise uniform. This is a dubious omission, especially if one believes, with Hufbauer and Travis, that tariffs may be sufficiently distortionary to account for the Leontief paradox.

On scale economies, Hufbauer did not consider the work of Jacques Drèze in two interesting, important, but difficult-to-obtain papers.[3] Drèze observes that Belgium concentrates its production and exports on standardized products, not only by broad classes such as semifinished iron and steel, flat glass, and photographic film, but within categories which vary in standardization. Thus Belgium produces white china, but not colored or decorated (i.e., the standardized quality rather than the qualities subject to taste) and, within automobile components, such products as standardized batteries, tires, windows, upholstery fabrics, wiring harnesses and radiators, rather than engines, bodies, and their components, which vary among producers, models, and countries. This extends Hufbauer's analysis, though he does not allow for production of standardized products for export by small countries beyond mentioning it. But Hufbauer is puzzled by the phenomenon which Drèze fails to take into account, the specialization by Denmark, the Netherlands, and Sweden in scale-economy goods to a greater extent than their manufacturing output would justify. Switzerland could be added to this list, if its trade had been covered. These countries are style-setters which achieve their scale economies through exports. The attempt to identify scale economies with certain goods, and associate these goods with certain size countries in exports, must be modified on two counts: first, the possibility that small countries can achieve exports in scale-economy goods where the standardization is set by large countries; and second, the possibility that the differentiated products of small countries, such as Dutch electrical equipment, Swedish machinery and telephones, Danish furniture, and Swiss pharmaceuticals (but not Belgian products), get accepted as the international standard.

But it is time to conclude. The Hufbauer and Gruber-Vernon papers,

[3] See "Les exportations intra-C.E.E. en 1958 et la position belge," *Recherches Economiques de Louvain.* 1961, and "Quelques réflexions sereines sur l'adaptation de l'industrie belge au Marché Commun," *Comptes Rendus des Travaux de la Société Royale d'Économie Politique de Belgique,* No. 275, December 1960.

for all the nitpicks of details I have produced, are surely in the right direction—that of empirical verification of the theory of trade overall and on the average, even though contrary examples and exceptions abound in the small.

Hufbauer and Gruber and Vernon differ in the evaluation of their overall findings. Gruber and Vernon find the persistent strength in explaining trade of differences in human-resource development "a major fresh conclusion." [4] Hufbauer characterizes his conclusion that physical-capital and human-skill theories produce enviable results with little *ad hoc* manipulation or theoretical amplification "distressingly simple and orthodox." One may wonder on the basis of the pioneering work of Kenen and Keesing how fresh is the discovery of human resources as a basis for trade. And a textbook writer who has just finished a new edition may be pardoned if he does not find the simple and orthodox view "distressing."

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The Hufbauer and Gruber-Vernon papers are similar in that each represents an imaginative effort to extend our understanding of the factors that determine the commodity composition of international trade in manufactures. They are alike also in the success each enjoyed in the choice of explanatory variables, including one or two that might at first blush appear rather unlikely.

Several of the explanatory variables in each paper represent factor proportions of one sort or another such as capital-labor ratios in the Hufbauer paper, the capital-output ratios in the Gruber-Vernon paper, and the relative importance of highly qualified workers in both papers. Other explanatory variables represent the economies of scale, such as Hufbauer's elasticity of value added with respect to the number of employees per establishment. Still others reflect monopolistic elements

[4] Editor's note: The final version of the paper is more modest in tone and does not contain this reference.

arising either from technological gaps, such as Hufbauer's measure of the lateness of the appearance of each category of exports in trade, or resulting from industrial concentration such as Gruber-Vernon's use of the concentration ratio. With one exception in the Hufbauer paper, the values of each of the explanatory variables assigned to each export category are derived from U.S. data; thus, it is assumed that there are no factor reversals.

Another important assumption which the two papers have in common is that factor scarcities can be judged purely in physical terms without reference to demand factors. In this respect they follow the practice developed by Leontief in his famous paper suggesting the factor paradox for U.S. trade, and their findings tend to confirm the fact that U.S. exports are not particularly intensive in physical capital. The expansion of the concept of capital to include human capital, suggested by Peter Kenen and others, and the capitalized value of the knowledge produced by R&D expenditure, recently suggested by Harry Johnson, will probably operate so as to increase the relative quantity of capital in the U.S. economy and the relative quantity embodied in U.S. exports.

There is, however, a potentially important factor on the demand side which has been overlooked and which would in a sense tend to place a greater burden of explanation on these suggestions for broadening the concept of the capital supply. It is the capital intensity of U.S. consumption patterns relative to that of foreign consumption patterns. Housing and durable goods, the consumption categories in which the excess of U.S. over foreign per capita consumption tends to be largest, absorb large amounts of capital. In 1958, the last date for which Goldsmith, Lipsey, and Mendelson prepared a national balance sheet,[1] nonfarm households actually held tangible assets which in value were almost 30 per cent greater than those held by nonfinancial corporations, the entities which presumably generated our manufactured exports. The value of residential structures owned by nonfarm households was almost twice the value of nonresidential structures held by nonfinancial corporations, and consumers' durables were almost 15 per cent higher than producers' durables held by nonfinancial corporations. This large household demand for capital must be taken into account in any assessment of

[1] R. W. Goldsmith, R. E. Lipsey and M. Mendelson, *Studies in the National Balance Sheet of the United States,* II, Princeton for NBER, 1963, pp. 68–69.

relative factor scarcities in the U.S. economy compared to that of other countries.

There are of course differences as well as similarities in the approach followed by the two papers. The authors of the two papers have, for example, organized their data differently. The advantage of the Hufbauer approach is that he uses a more detailed breakdown of exports of manufactures, involving more than a hundred three-digit SITC groups. Gruber and Vernon, on the other hand, set a much more demanding test for themselves. In the first part of their paper, they seek to explain the relative size of each country's exports of manufactures in terms of their explanatory variables; that is, they correlate each country's export shares for each of the twenty-four industries with certain characteristics of each industry. (In the second part of their paper they correlate, for each of the twenty-four industries, the size of the bilateral trade flows of the exporting and importing partners with certain national characteristics, or with differences in these characteristics.) Hufbauer works only with successive correlations of the ranks of countries when they are arrayed according to two different variables, one measuring the relative amount of a given characteristic embodied in each country's total exports of manufactures and the other measuring the amount of the corresponding national attribute found for each country.

A major disadvantage which both studies encounter, in common with other empirical investigations of trade flows, is that the classifications used for industrial production and international trade really are not relevant to the purposes at hand. Now it may be thought that this objection is not valid in view of the high degree of success of both papers in explaining international trade flows by variables which are calibrated in terms of the existing categories. However, there is no reason to believe that the classifications are equally appropriate or equally inappropriate for each of the several explanatory variables. It is possible, for example, that the categories may contain groups of products that are more homogeneous with respect, say, to the skill ratio than with respect to the economies of scale. Indeed, there is some reason to believe that the classifications are particularly deficient for purposes of measuring economies of scale. Scale economies are a function not only of the size of plant, which can be measured in terms of the existing classifications and which Hufbauer does measure, but also of the product mix within plants, which is more difficult to measure and which is omitted from

Hufbauer's net. In the case of the United States, at least, the scale economies that are important in exports are often more a function of the size of the market than of the size of plants or establishments. In the study of international price competitiveness that Robert Lipsey and I have been conducting at the National Bureau,[2] we have encountered a number of cases in which the size of the U.S. market enables U.S. producers to reach large volume production for relatively specialized product variants for which markets are thin in any one of the smaller, competing economies. In the antifriction bearing industry, for example, the U.S. imports commonly used bearings which can be produced in large volume both here and abroad, but the United States has nevertheless enjoyed a net export position in bearings owing to exports of specialized kinds capable of meeting precision needs, resisting heat or rust, or bearing great weight.

Scale economies that may or may not be unique to the U.S. economy also arise where there is a high degree of product specialization by each of a large number of small firms. Brown and Rosenberg have reported this situation as characterizing the machine tool industry;[3] each plant type typically produced one or at most only several types out of the four hundred kinds of tools produced in the industry.

It may also be questioned whether either study has found a satisfactory measure of product differentiation. Hufbauer attempts, with great ingenuity, to measure product differentiation in terms of the coefficient of variation for U.S. export unit values to different destinations for each of his three-digit categories of goods. However, even if we put aside the well-known erratic character of unit value data, export unit values to various destinations may vary widely for a number of reasons not just because of product differentiation. In the first place, a wide variety of standardized products may be found even in some of the seven-digit classifications which Hufbauer uses to build up his three-digit measures, and the product mix sent to different destinations may be different. Even a cursory check of U.S. 1965 export data[4] brings up some suggestive illustrations: unit values of exports to different destinations for

[2] *Price Competitiveness in World Trade,* Chap. 2, forthcoming.

[3] M. Brown and N. Rosenberg, "Prologue to a Study of Patent and Other Factors in the Machine Tool Industry," *The Patent, Trademark and Copyright Journal of Research and Education,* Spring 1960, p. 45.

[4] U.S. Department of Commerce, *U.S. Exports, Commodity by Country,* FT 410, December 1965.

"screws, rivets, washers, and similar articles of iron or steel" (Schedule B commodity number 6942130) ranged from 22.6 cents per pound (to Korea) to $4.26 per pound (Greece), while for "industrial sewing machines except shoe sewing machines, new" (7173030) the range went from $214 (to Salvadore) to $988 (to Vietnam) per unit; the coefficients of variation were 0.74 for screws, etc. and 0.52 for industrial sewing machines. It is rather doubtful that these differences in range and variation of the unit values to different destinations reflect the relative impact upon these two categories of the product cycle. Secondly the seven-digit classification sometimes includes used machinery along with new, as in the printing machinery categories (7182210 to 7182960 inc.), and in other instances it provides separate categories for used equipment, as in industrial sewing machinery (7173040). Thus, the coefficient of variation is sometimes affected by the extent to which used machinery is exported to some destinations and new machinery to others, and it cannot be assumed that the relative importance of second-hand products is the same from one category to another. Finally, price discrimination as between different destinations, which is not unknown even in U.S. export trade, would also affect unit values.

The a priori doubts about the adequacy of the standardization coefficient are reinforced by an examination of the way in which the coefficient ranks the three-digit groups. While the author is correct in saying "reasonable coefficients seem to emerge, at least in some instances," there are many that appear to be unreasonable. According to this measure, for example, office machinery (SITC 714) and agricultural machinery (712) are more standardized than zinc (686) and paper and paperboard (641). A perusal of Hufbauer's Table A-2 will show that such outcomes are not uncommon.

It is possible, however, that the significant correlation between the ranks of the various countries with respect to their export-weighted coefficients of variation for export unit values and their ranks with respect to manufacturing sophistication (as measured by GDP per capita) has another and important meaning. It may reflect the greater variety of goods available in high income countries rather than measuring the extent to which sophisticated countries are able to offer differentiated products.

Putting this implication aside for the moment, it is worth pointing out that an important new line of investigation is suggested explicitly by the Gruber-Vernon paper and implicitly by Hufbauer's paper, although not very much explored in either. In the empirical and theoretical work dealing with the commodity composition of trade over the past twenty or twenty-five years, the main effort has been devoted to the search for explanations of the contrasting trade patterns of different countries. Gruber and Vernon remind us that something can be learned by studying the similarities of trading patterns; perhaps we have given inadequate attention to the difference between tradeable goods and home goods. Economists of a former generation used to describe the characteristics of traded goods in three terms: homogeneous, high in value in relation to bulk, and in universal demand. Perhaps technological progress, particularly the reduction of the cost of transport, has altered the restrictive impact of all three of these characteristics upon the kinds of goods that are traded. Perhaps with the spread of industrial production and with higher real income levels, differentiated goods are as prone or more prone to be traded than homogeneous products.

Although the point about homogeneous versus differentiated goods is speculative, the similarity of export patterns of the main manufacturing countries is clearly shown by the Gruber-Vernon correlations. This similarity of export patterns is not dependent on the use of twenty-four relatively large industrial categories but persists, I have found, when the exports of manufactures of the major industrial countries are correlated at the three-digit level (about 100 categories); the Spearman coefficients in the matrix of correlations involving the United States, the United Kingdom, Germany, and Japan range from .54 to .82.[5]

What is the significance of these similarities? One possibility is that all advanced manufacturing countries tend to produce highly similar baskets of goods and to export them to nonmanufacturing countries. It is true that there are striking similarities in the structure of production among the important manufacturing countries; for example, the Spearman coefficient for the rank correlation between nineteen two-digit industries is 0.72 for Japan and the United States and 0.83 for Germany and the United States.[6]

[5] Using OECD data on 1964 exports.
[6] Based on data in United Nations, *The Growth of World Industry, 1953–65*, New York, 1967.

Such an explanation cannot, however, be more than part of the story, since, as is well known, intratrade among the industrial countries is quite important. Indeed, in 1964, half of U.S. and U.K. manufactures exports and three-quarters of Germany's went to OECD countries.[7]

Conceivably, for purposes of this intratrade, each major industrial country might specialize in a different group of industries, but this seems unlikely in view of the similarities in the industrial composition of their exports. Also, a direct check of a single case, U.S. and German intratrade, indicates a significant degree of similarity in the industrial pattern of each country's exports to the other; the Spearman coefficient was .53 for eighty-six three-digit categories for which OECD data for 1964 exports were available. This coefficient, which is significant at the 1 per cent confidence level, leaves room for some industry specialization, but it also indicates a considerable amount of what looks like cross exporting.

It is possible that a better explanation of this trade might come from a comparison of the economic characteristics of home goods and tradeable goods. Neither of these papers tells us, for example, whether the goods that are generally exported in relatively large volume by the major manufacturing countries are particularly capital-intensive, or unusually subject to the economies of scale as compared to goods that are exported in smaller volume. Neither do they indicate whether there are differences between the economic characteristics of the manufactures the industrial countries export to one another and those they send to other destinations. Until we have the answers to questions like these, we shall not fully understand the forces that determine the commodity composition of trade.

Meanwhile, it is possible to outline a hypothesis to explain this intratrade that can be viewed in one sense as an extension of the availability argument I offered some years ago;[8] that is, trade consists to a significant degree of products, or still more importantly, of product variants that are not available in the recipient country. Before drawing on the Gruber-Vernon and Hufbauer papers to suggest why this occurs, I may call attention to two bits of evidence (both reported in the forthcoming

[7] See also H. Grubel, "Intra-Industry Specialization and the Pattern of Grade," *The Canadian Journal of Economics and Political Science,* August 1967.

[8] "'Availability' and Other Influences on the Commodity Composition of Trade," *Journal of Political Economy,* April 1956.

study by Lipsey and me) that indicate that the availability factor does operate for manufactures and particularly for machinery, as businessmen perceive the situation. The first suggests that U.S. exports of metal products and machinery depend to a considerable extent upon differences in design and other aspects of product differentiation. The second is a survey by the IFO Institute of Munich in which German firms that purchased foreign factory equipment reported that 63 per cent of their purchases were due to the fact that the desired equipment was not available at home; another 12 per cent was purchased because of the superiority of foreign equipment; and only 7 per cent for price advantages.

Some of the reasons underlying the availability of different products or product variants in various supplying countries are found in the technological gap or in the kind of product differentiation along national lines (Belgian lace, French wine, British china, etc.) which I mentioned earlier. In addition, the combination of an increase in the variety of products—for producers' goods as well as for consumer goods—and the economies of long production runs may result in specialization by product variant rather than by industry or type of product.

Although economies of long production runs explain why countries are led to concentrate on a limited range of products, even when they are capable of producing the full range, the determination of the particular variants each country will specialize in depends on systematic as well as random factors. In general, the larger the market the wider the range of products for which the country will be able to obtain the economies of long runs,[9] and the more likely it is to be able to export a variety of materials and equipment catering to specialized needs which have a demand extensive enough to warrant production beyond the handicraft, custom, or special-order stage and yet infrequent enough to prevent the attainment of scale economies in smaller markets.

A country with a small home market would specialize in the less esoteric and more widely demanded products in which it could achieve

[9] A recent study of the Canadian economy shows the cost disadvantages that ensue from the attempt to produce a wide range of product variants in a small market. See D. J. Daly, B. A. Keys, and F. J. Spence, *Scale and Specialization in Canadian Manufacturing,* Staff Study No. 21, Economic Council of Canada, March 1968.

long production runs; this has been pointed out by Drèze who has advanced a "standardization" hypothesis to explain Belgium's export pattern in which semimanufactures are important.[10]

As between countries with the same size market, the one with greater physical and human capital might provide the leadership in developing new variants, losing its comparative advantage in each new variant as it became more widely used in the other country. As between countries equal in market size and in physical and human capital, the pattern of specialization in the production of different variants in long runs might depend on systematic elements such as differences in tastes and natural resource endowments or on chance factors.

An important systematic element is the tendency for domestic production in each country to consist of product variants that cater to the tastes and needs of the home market. Drèze and (I think) Linder, among others, have seen this trade-creating aspect of product differentiation chiefly in connection with consumers goods. Lipsey and I have been struck in the course of our National Bureau study with a number of examples of a similar phenomenon in connection with producers' goods. Equipment is usually designed in each country to meet local conditions such as the usual scale of output and the prevailing relative factor prices. In each country, however, there is apt to be a small demand for equipment which is different from that which serves most local needs. This small demand can be better satisfied by equipment designed for conditions that happen to prevail in another country. European equipment for such industries as printing, baking, and pharmaceuticals, for example, is designed for smaller volume, lower speed, and greater versatility than American equipment for the same industries. In each area most domestic needs are met by domestic production, but Americans do import some low-volume versatile machines from Europe and export some high-volume specialized machines to Europe.

Obviously, this basis for specialization is closely related to the diseconomies of small-scale production or of special orders. However, one

[10] Jacques Drèze, "Quelques réflexions sereines sur l'adaptation de l'industrie Belge au Marché Commun," *Comptes rendus des Travaux de la Société Royale d'Économie Politique de Belgique,* No. 275, December 1960.

may suppose that the ability of a country to participate in this trade, particularly in sectors of rapidly changing technique, is related to its possession of the attributes which are required for the production and development of special designs of equipment—viz., physical and human capital, particularly R&D skills.

An explanation along these lines is consistent with the similarity of export profiles found by Gruber and Vernon, the associations between commodity characteristics and national attributes stressed by Hufbauer, and the importance of intratrade pointed out above.

This is not to claim that specialization by product variant can explain all intraindustrial country trade flows in manufactures. The truth probably is that manufactures move across international boundaries owing to a variety of causes. Some—and probably a significant fraction—can be explained in terms of the classical factor proportions theory. The emergence of textile exports from developing countries, despite hostile commercial policies by the developed countries, may be a reflection of such tendencies. Other flows are due to favorable financing, to past flows (parts for machinery, extensions of past installations of systems such as railroad, electrical, and telephone), and to speed of delivery. Lipsey and I are inclined to the view that the importance of delivery speed in accounting for U.S. exports has not been given sufficient weight. To take an extreme example, the United States was able to export ships after the Suez Crisis in 1957 despite prices that were perhaps double those abroad. This suggests, as do some of our authors' results, that the factors that are important in explaining one country's trade may differ from those that loom large in explaining another country's, and that there is some evidence that the main forces at work in influencing U.S. trade patterns in particular tend to differ from those operating in other countries.

Doubtless other explanations and hypotheses about the meaning of the results that have placed before us by Gruber and Vernon and Hufbauer will be forthcoming. Their work has broken new ground in the effort to understand the factors that determine the commodity composition of trade. They have, to amend slightly the words of one of the papers, provided valuable grist for the mill of theory.

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Although the papers presented at the conference fall within the realm of the "pure theory" of international trade, it appears that various speakers address themselves to three different questions, to wit: (1) an assessment of the gains from international trade (Arrow); (2) an explanation of the commodity composition of trade (Hufbauer, and Gruber and Vernon); and (3) the development of a guide for trade policy for individual nations, particularly within a development context (Bruno). These are certainly not mutually exclusive, and an "ideal" theory should contain answers to all three. But within an empirical context, one would be doing well to test for one or two of them at a time. The following remarks are addressed to the Hufbauer and Gruber-Vernon papers on the supposition that their main objective is to explain the commodity composition of international trade.

In the received theory of exchange both supply and demand play a role in the process of price determination. Translated into the (barter) theory of international trade—based on the doctrine of comparative advantage—we find supply factors determining the boundaries to mutually beneficial trade and demand considerations determining the commodity terms of trade within these boundaries. But the Heckscher-Ohlin model, as tested by Leontief and in the vast literature that ensued, assumes away international differences in demand. Likewise, most of the theories tested in these two papers are exclusively of the supply variety.

In actual fact, supply models can be expected to explain rather well the portion of world trade that consists of homogeneous commodities. When it comes to industrial products, which constitute the bulk of trade among the developed countries, the patterns of demand and the degree to which they are influenced by product differentiation can be expected to play an important role. None of the models tested here can shed light on the mutual exchange of Fiats, Renaults, and Volkswagens among the three major EEC countries. On a priori grounds, supply factors would dominate trade relationships only when they result in a price differential large enough to swamp the demand effects in monopolistically competitive markets. Consequently, it would make sense to test the supply models only for these commodities which differ substantially in the product characteristic being tested. This brings me to the next operational suggestion.

The papers under discussion are of immense value in analyzing the various characteristics of commodity groups entering international trade. It would have been preferable to carry out such an analysis for each of the five-digit SITC categories; but evidently this is precluded on practical grounds. Now, by running multiple regressions and adding independent variables, one can certainly increase the portion of the variance being explained. But as this process progresses, the theory loses operational simplicity and therefore practical significance. The logical simplicity of a theory (like that of the Heckscher-Ohlin model) has a value which should be preserved even while the theory is made more sophisticated. Moreover, even by employing dozens of variables, we may not reach satisfactory explanations of all trade by all countries.

I would therefore like to suggest an alternative method of using the data gathered in the papers. As a first stage we wish to test the explanatory power of each commodity characteristic by relating it to the respective structure of the economy. (Incidentally, this link is missing in the first half of the Gruber-Vernon paper because the country-endowments counterpart of each industry characteristic is not given.) Assume, for example, that we start by testing the factor proportions model. I propose that we rank all commodity groups by capital per man and then eliminate from the test, say, a fifth of the industries which fall right in the middle. Better cut-off points can perhaps be decided upon after an examination of the data; but any decision would of necessity be arbitrary. We test the theory with the industries at the two ends—those falling in two groups that contrast sharply with each other in terms of capital per worker—thus generating a powerful "supply effect." Homogeneous products can perhaps be included even if they fall in the middle group.

One can proceed in the same fashion with the other characteristics to be tested; namely, by excluding the respective "middle group" and testing the theory for those industries which differ considerably from each other. A theory that cannot explain trade in its own "end group" products can be discarded.

Subsequently, in order to compare the relative effectiveness of the theories, an iterative process can be employed. For each commodity characteristic one can start from the two ends and work toward the middle by adding industries, until the explanation loses power. The characteristic that explains a larger share of world trade is presumably the superior one. From there we can proceed with a theoretical and empirical approach based on reasonable combinations of the characteristics which came out well in the tests.

In sum, what is suggested here is that instead of attempting an explanation of all trade using a multiplicity of variables, it might be better to try to explain a portion of total trade by a simple theory. But instead of deleting a country, as Hufbauer has done, it is proposed here to exclude commodities. It is reasonable to expect that much of the unexplained portion would be due to differences in demand patterns under monopolistically competitive conditions, and unexplainable by supply models.

Having completed this stage of the analysis, one can embark on two alternative courses. The first course would involve merging the explanatory factors that came out well into a composite variable on grounds that make theoretical sense. Hufbauer's suggestion of neofactor proportions and neotechnology variables come to mind in this connection. And, if necessary, the relative explanatory power of the competing composite variables can be assessed by the same iterative procedure outlined above. The second alternative is to incorporate in the theory different explanations for trade in different types of commodities. Such a result might emerge if the various factors were equally powerful in explaining trade in different, but distinct, types of goods.

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In the concluding summary of that part of his paper concerned with the "nature of trade," Hufbauer refers to the explanatory power of a measure I have employed elsewhere [1] to explain trade flows—i.e., value added per employee as an index of the combined inputs of physical and human capital into different manufacturing industries. It may therefore be useful to add this composite variable to Hufbauer's list of product characteristics embodied in exports and imports and to relate the results to whichever of his national attributes seems most appropriate.[2] Gross domestic product per capita commends itself for this purpose, given the broad content of value added by manufacture.

Table 1 gives the average value added per employee obtained by applying U.S. coefficients for different industries to the product composition of each of the twenty-four countries' exports and imports of manufactures. When the export series (of primary interest for reasons given by Hufbauer) is matched with GDP per capita, the following correlations are obtained (comparable to those given in Table 5 of Hufbauer's paper):

Rank correlations, unweighted	
24 countries	.765
23 countries (Mexico excluded)	.871
Rank correlation, weighted	.928

These results compare favorably with those given by Hufbauer's skill analysis, being distinctly higher than the correlations with skill ratios embodied in trade and slightly lower than the correlations with wage rates. Conceptually, the value-added criterion seems more appealing. As Harry Johnson says in his paper in this volume, "it picks up not only the neofactor proportion elements of material and human capital, but also to some extent the neotechnology elements of scale economies, and of product age and differentiation, insofar as these last are reflected in selling prices." This may be true of still other inputs of "intellectual capital" into the production process.

[1] *Imports of Manufactures from Less Developed Countries,* New York, NBER, 1968. As explained there (pages 21–22), "Differences from industry to industry in value added per employee are here assumed to measure differences in the aggregate flows of services from the factors of production employed in the manufacturing process (and exclude therefore indirect factor inputs such as materials used). It is further assumed that these services may be ascribed either to human capital or to physical capital, and that, in interindustry comparisons, the wage-and-salary part of value added is a good proxy for the first and the remainder of value added a good proxy for the second."

[2] I am grateful to Professor Hufbauer for his interest in this exercise and for putting his basic trade data at my disposal and grateful also to his assistant, Melissa Patterson, for doing the computations.

TABLE 1

Value Added by Manufacture per Employee, Embodied in 1965 Exports and Imports and GDP Per Capita, Twenty-Four Countries

(in dollars; rank order given in parentheses)

	Value Added Per Employee		GDP Per Capita
	Exports	Imports	
Canada	14,671 (2)	13,820 (12)	2,110 (2)
United States	14,340 (4)	13,079 (21)	3,000 (1)
Austria	12,319 (15)	13,747 (13)	1,030 (13.5)
Belgium	13,235 (10)	13,529 (15)	1,460 (10)
Denmark	12,346 (14)	13,492 (16)	1,680 (8)
France	14,071 (6)	14,239 (7)	1,580 (9)
Germany	14,276 (5)	13,265 (19)	1,770 (6)
Italy	12,572 (13)	14,709 (3)	1,030 (13.5)
Netherlands	13,469 (9)	13,332 (18)	1,430 (11)
Norway	13,721 (7)	12,465 (22)	1,880 (4)
Sweden	13,196 (11)	13,429 (17)	2,100 (3)
United Kingdom	13,715 (8)	13,209 (20)	1,710 (7)
Australia	14,397 (3)	13,893 (11)	1,810 (5)
Japan	11,880 (16)	15,212 (2)	720 (15)
Israel	8,841 (21)	12,227 (24)	1,090 (12)
Portugal	9,813 (19)	14,102 (9)	420 (18)
Spain	13,116 (12)	14,403 (5)	550 (16)
Yugoslavia	11,564 (18)	14,211 (8)	250 (19)
Mexico	15,909 (1)	15,500 (1)	430 (17)
Hong Kong	7,845 (24)	12,418 (23)	200 (20)
India	8,634 (22)	13,637 (14)	80 (23.5)
Korea	9,084 (20)	14,508 (14)	140 (21)
Pakistan	8,157 (23)	13,918 (10)	80 (23.5)
Taiwan	11,795 (17)	14,397 (6)	130 (22)

Source: Value-added averages are obtained by applying coefficients derived from U.S. 1963 Census of Manufactures (converted to SITC in accordance with Hufbauer's Table A1) to the percentage distribution of each country's exports or imports among the 102 three-digit SITC categories used in Hufbauer's analysis. The GDP series is taken directly from his Table 4.

As would be expected, the import series in Table 1 is negatively related to GDP per capita, though much less strongly than exports.[3] Most countries with high average value added in exports show the opposite for imports, and vice versa. It is particularly noteworthy that, on this more comprehensive definition of capital inputs, the export average is distinctly higher than the import average for the United States. This result—not surprising in the light of previous findings by Kravis, Keesing and others relevant to the skill content of exports and imports—suggests that a basic flaw in the Leontief paradox was reliance on an inadequate physical concept of capital.

Mexico and Israel stand out as the most deviant countries, the first with a much higher, the second a much lower, average value added in exports than their GDP per capita would lead one to expect. Hufbauer has already commented on the reasons for Israel's behavior. That of Mexico is strongly influenced by the fact that nonferrous metals and certain pharmaceuticals and chemicals—all strongly resource-oriented—make up more than half of its exports of manufactures according to Hufbauer's grouping. In a ranking excluding all nonferrous metals and chemicals, Mexico falls to fifteenth place in exports on the value-added criterion.[4] As Hufbauer indicates, there is reason to look critically at his coverage of "manufactures." The same question arises with regard to the Gruber-Vernon selection, which contains even more essentially resource-oriented items.

The computations given here on value added per employee may be criticized, as the Hufbauer and Gruber-Vernon computations have been, because of the use of American coefficients. Strong similarities across countries in the pattern of value added per employee according to industry make me doubt that this is, in fact, a major weakness in the analysis.[5] But, clearly, there is room for further empirical work using and comparing other countries' coefficients.

[3] The simple correlation is −.407 compared with .668 for exports.

[4] The unweighted rank correlations obtained on this basis (.856 for all twenty-four countries and .9185 with one country, Israel, omitted) are higher than those reported above for all products in Hufbauer's selection, but the weighted correlation (.914) is slightly lower. More study, however, needs to be given to the criteria of selection and, in particular, to the identification and exclusion of industries whose location is determined mainly by natural resources rather than by labor, capital, technology, or other factors.

[5] See Chapter 3, "International Comparisons of Factor Intensities," in *Imports of Manufactures from Less Developed Countries.*