**CENTER FOR SPACE RESEARCH**

**MASSACHUSETTS INSTITUTE OF TECHNOLOGY**

# THE R&D FACTOR IN INTERNATIONAL TRADE AND INTERNATIONAL INVESTMENT OF U.S. INDUSTRIES

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In the last ten or fifteen years, the field of international trade theory has been in continuous ferment.[1] The received doctrine drawn from the mainstream of Smith-Ricardo-Mill-Marshall-Heckscher-Ohlin has been re-examined from many different angles. Sometimes, there have been strongly revisionist reactions, such as those encountered in the economic development area.[2] In other contexts, the emphasis has

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[1]For authoritative summaries, see: John Chipman, "A Survey of the Theory of International Trade," Econometrica, Vol. 33, July 1965, pp. 477 to 519 and Vol. 33, October 1965, pp. 685 to 760; also J. Bhagwati, "The Pure Theory of International Trade: A Survey," The Economic Journal, Vol. LXXIV, No. 293, March 1964, pp. 1-84.

[2]This school is epitomized by the writings of Economic Commission for Latin America. See Werner Baer, "The Economics of Prebisch and ECLA" in Economic Development and Cultural Change, Vol. X, No. 2, Pt. 1, January 1962, pp. 169-82.

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been mainly on the further testing and refinement of the doctrine of comparative advantage and the role of factor endowments.

Much of the discussion of United States trade performance in recent years has taken for granted the main premises of classical and neo-classical theory. A considerable part of the debate over the interpretation of the Leontief paradox and much of the discussion of the implications of other recent empirical work have concentrated on questions of national factor endowments, or the response of national production functions to different factor prices, or other issues readily compatible with the classical theoretical structure. Leontief, for instance, was inclined to "explain" his familiar paradox by asserting that skilled labor may be relatively cheap in the United States economy.

Nonetheless, one can also detect an echo of the discontent voiced so effectively by Williams in 1929,[3] a discontent based on the view that classical doctrine is not structured to deal efficiently with the trade implications of a number of forces that may be of major consequence in any descriptive and analytical work.[4] For the most part, the literature of dissent seems

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[3]J.H. Williams, "The Theory of International Trade Reconsidered," The Economic Journal, June 1929, Vol. XXXIX, pp. 195-209.

[4]See Erik Hoffmeyer, Dollar-Shortage (Amsterdam: North Holland Publishing Co., 1958); G.O.A. MacDougall, The World Dollar Problem (London: Macmillian & Co., 1958); S.B. Linder, An Essay in Trade and Transformation (Uppsala: Almqvist and Wicksells, 1961); C.P. Kindleberger, Foreign Trade and the National Economy (New Haven: Yale University Press, 1962).

to have sprung out of efforts to explain the foreign trade patterns of the United States, especially the country's exports of manufactured goods. United States labor, it has been observed, is higher-priced than labor abroad, to an extent which greatly exceeds any productivity differences.[5] To be sure, United States capital is cheaper and less tightly rationed. But the effective interest rate for major industrial borrowers only differ by a few percentage points among the advanced countries. This difference hardly seems enough to explain the strength and persistence of United States exports in manufactured products.

From capital and labor cost considerations, therefore, attention has turned to questions of innovation, of scale, of leads and lags.[6] Approaches of this sort have tended to

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[5] Mordechai Kreinin, "The Leontief Scarce-Factor Paradox," The American Economic Review, Vol. LV, No. 1, March 1965, pp. 131-139.

[6] See M.V. Posner, "International Trade and Technical Change," Oxford Economic Papers, Vol. 13, No. 3, October 1961, pp. 323-341; C Freeman, "The Plastics Industry: A Comparative Study of Research and Innovation," National Institute Economic Review, No. 26, Nov. 1963, pp. 22-62; C. Freeman, "Research and Development in Electronic Capital Goods," National Institute Economic Review, No. 34, Nov. 1965, pp. 40-91; G.C. Hufbauer, Synthetic Materials and the Theory of International Trade (London: Gerald Duckworth & Co., 1965); Seev Hirsch, Location of Industry and International Competitiveness, an unpublished doctoral thesis at the Harvard Business School, 1965, shortly to be published by the Oxford University Press; and L.T. Wells, Product Innovation and Directions of International Trade, an unpublished doctoral thesis at the Harvard Business School, 1966.

stress the possibility that the United States may base its strength in the export of manufactured goods upon monopoly advantages, stemming in the first instance out of a strong propensity to develop new products or new cost-saving processes. This propensity has usually been credited either to the demand conditions that confront the American entrepreneur or to the scale and structure of enterprise in United States markets. In any case, the propensity has given American producers a temporary advantage which has been protected for a time either by patents or by secrecy. Eventually the monopoly advantage has been eroded; but by that time, the United States producers have seized the advantage in other products.

Of late, the tendency has been to search for hypotheses which "explain" not only the apparent strength in United States exports of manufactured products but also the apparent propensity of United States producers of those very products to set up manufacturing facilities abroad.[7] This line of speculation takes off from the observation that entrepreneurs in the United States are surrounded by a structure of domestic demand for producer and consumer goods that is in some respects a forerunner of what will later be found in other

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[7]See, e.g., Judd Polk, I.W. Meister, and C.A. Veit, U.S. Production Abroad and the Balance of Payments (New York: National Industrial Conference Board, 1966); also Raymond Vernon, "International Trade and International Investment in the Product Cycle," Quarterly Journal of Economics, May 1966.

countries. Labor is costly in relation to its productivity, while capital is comparatively plentiful, facts which influence the nature of the demand for producer goods. And per capita incomes are high by international standards, a fact which creates unique consumption patterns. This means that entrepreneurs in the United States are likely to be willing to gamble on the innovation of labor-saving and affluent-consumer products at an earlier point in time than their overseas competitors.

The hypotheses go on to project certain characteristic sequences in the foreign trade of products that have been innovated in the United States. According to the assumption, although the new products that satisfy high-income or labor-substituting wants may have their earliest and largest markets in the United States, some demand for them is generally assumed to exist elsewhere. And in the course of time, that demand will normally grow. For a time, then, the United States will have an oligopoly position in supplying foreign markets. And this oligopoly position will be strongest with respect to the products of those United States industries which have been making the largest research and development effort.

According to hypotheses of this genre, overseas investment eventually comes into the picture partly because the large-scale marketing of technically sophisticated products demands the existence of local facilities and partly because the protection of the oligopoly position of the United States producer eventually requires such investment. The threat of competition in foreign markets may come from local sources or from other outside producers, as the original technology-based oligopoly position of the United States producer in any given product begins to be eroded. At this point, with profits on exports being threatened, the United States company may see a high prospective marginal yield in an investment in local facilities, provided such facilities will help to buttress its existing market position.

A chain of hypotheses as complex as these needs extensive testing before it can gain much in credibility. This brief paper is much less than an adequate test of the chain. But it does contribute modestly to the credibility of the chain for some industries. At the same time, however, the data suggest that simple univariate explanations of the complex causal chain may be dangerous; that while the relevant explanations may involve "research" or "technology" or similar factors in one form or another, the causal role played by such factors may well be rather different from one industry to another.

## Research and Trade[8]

All roads lead to a link between export performance and R & D. Whether one accepts the cheap-skilled-labor hypothesis of Leontief or the oligopoly hypotheses in the tradition of Williams, one expects to see a link between exports and research effort. Table 1 provides a simple set of data typical of the evidence which relates research effort by U.S. industry to United States trade performance in 1962. The positive correlation between the "research effort" measures, $R_1$ and $R_2$, and the "export performance" measures, $E_1$ and $E_2$, is evident to the eye. The five industries with the greatest "research effort" are also the five industries with the most favorable trade position.[9] When the five industries with the highest research effort are separated off from the

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[8]Attempts to quantify the relationship between research and trade have begun to appear in the literature. The French have coined the term "technological balance of payments" and some quantitative measures of this concept are presented in C. Freeman and A. Young, The Research and Development Effort in Western Europe, North America and the Soviet Union (Paris: OECD, 1965), pp. 51-55, 74. The relationship between the employment of scientists and engineers and trade position has been tested by Donald B. Keesing (see his "Labor Skills and Comparative Advantage," in Proceedings of the 78th Annual Meeting, December, 1965, American Economic Review, Vol. 2, May, 1966). Keesing's findings in that paper and in some unpublished work parallel and agree with some of the findings in the first section of this paper.

[9]The Spearman rank coefficient for the association between $R_1$ and $E_1$, as those terms are defined in Table 1, is +0.69; between $R_1$ and $E_2$, is +0.79; between $R_2$ and $E_1$, +0.74; and between $R_2$ and $E_2$, +0.69. All coefficients are significant at the one percent level. Pearson least squares coefficients give similar results. In these correlation measures and in others presented hereafter, 22 sets of paired observations, rather than 19, are used, since each of the 3 digit industires shown in Tables 1 and 2 provides the basis for a separate observation.

Table 1

Research Effort and World Trade Performance

by United States Industries, 1962

| SIC number | Industry name | Research effort: Total R & D expenditures as % of sales $R_1$ | Research effort: Scientists & engineers in R & D as a % of total employment $R_2$ | Export performance: Exports as % of sales $E_1$ | Export performance: Excess of exports over imports, as % of sales $E_2$ |
|---|---|---|---|---|---|
| | All 19 industries | 2.0% | 1.1% | 3.2% | 0.6% |
| | 5 industries with highest research effort[b] | 6.3 | 3.2 | 7.2 | 5.2 |
| | 14 other industries | 0.5 | 0.4 | 1.8 | -1.1 |
| Industries arranged in descending order of research effort[b] | | | | | |
| 37 | Transportation | 10.0% | 3.4% | 5.5% | 4.1% |
| 372 | Aircraft | 27.2 | 6.9 | 8.4 | 7.6 |
| --- | Transportation (other than aircraft) | 2.8 | 1.0 | 4.2 | 2.6 |
| 36 | Electrical machinery | 7.3 | 3.6 | 4.1 | 2.9 |
| 38 | Scientific instruments | 7.1 | 3.4 | 6.7 | 3.2 |
| 28 | Chemicals | 3.9 | 4.1 | 6.2 | 4.5 |
| 283 | Drugs | 4.4 | 6.6 | 6.0 | 4.8 |
| --- | Chemical (other than drugs) | 3.8 | 3.7 | 6.2 | 4.4 |
| 35 | Machines (non-electrical) | 3.2 | 1.4 | 13.3 | 11.4 |

Table 1, Continued

| SIC number | Industry name | Research effort: Total R & D expenditures as % of sales $R_1$ | Research effort: Scientists & engineers in R & D as a % of total employment $R_2$ | Export performance: Exports as % of sales $E_1$ | Export performance: Excess of exports over imports, as % of sales $E_2$ |
|---|---|---|---|---|---|
| 30 | Rubber | 1.4 | 0.5 | 2.0 | 1.3 |
| 32 | Stone, clay & glass | 1.1 | a | 1.9 | -0.2 |
| 29 | Petroleum | 0.9 | 1.8 | 1.2 | -0.8 |
| 34 | Fabricated metals | 0.8 | 0.4 | 2.1 | 0.7 |
| 33 | Primary metals | 0.6 | 0.5 | 3.1 | -1.8 |
| 333 | Nonferrous metals | 0.8 | 0.5 | 4.2 | -4.7 |
| --- | Iron and steel | 0.5 | 0.4 | 2.5 | -0.2 |
| 31 | Leather | 0.6 | 0.1 | 1.7 | -3.4 |
| 27 | Publishing | 0.6 | 0.2 | 1.7 | 1.1 |
| 21 | Tobacco | 0.3 | 0.2 | 2.2 | 2.1 |
| 20 | Food & beverage | 0.2 | 0.3 | 0.9 | -1.2 |
| 22 | Textile | 0.2 | 0.3 | 3.4 | -1.1 |
| 25 | Furniture | 0.1 | 0.2 | 0.7 | a |
| 24 | Wood products | 0.1 | a | 2.0 | -6.2 |
| 26 | Paper | 0.1 | 0.3 | 2.1 | -3.5 |
| 23 | Apparel | 0.1 | a | 0.7 | -2.1 |

[a]less than 0.05%.

[b]research effort defined by ratio of R & D expenditures as a % of sales.

For sources and methods, see Statistical Appendix.

other 14 industries, it begins to grow clear that the export strength of United States industries is centered in the group of five; in fact, the 14 remaining industries exhibit a net import rather than a net export balance for the year 1962.

In speaking of export strength, however, one has to exhibit a certain caution. The phrase may have many different meanings, and a word or two about the measures contained in Table 1 will be helpful to clarify some of the concepts involved.

Measure $E_1$, a ratio of exports to total sales in each industry, can hardly be thought of as a measure of United States comparative advantage for the industry. Such a measure, after all, is not only a function of the competitive position of United States industry; it also reflects, inter alia, the structure of demand overseas as compared with the United States, as well as the effects of transport and tariff frictions on international trade.

Measure $E_2$--namely, the excess of exports over imports taken as a percentage of sales--goes a little way in the direction of allowing for the effects of demand differences and trading frictions. We observed earlier that differences in demand, rather than in competitive position, might account for a low level of United States exports at an earlier stage in a product's development; but there is a respectable body of opinion for the view that in products for which U.S. demand differs greatly from demand in foreign markets, the risk of heavy imports from abroad is not very great.[10] Where demand differences were holding down exports, therefore, they might also be expected to hold down imports. The same is true of transport frictions; if these were responsible for a poor export showing, it would not be utterly unreasonable to suppose that the same forces might be discouraging imports.

It is slightly reassuring to observe, therefore, that both measures of export performance act in a remarkably parallel fashion, generally reflecting a strong export position for research-oriented industries and a weak export position for industries without large research inputs. To be sure, the parallelism cannot be said to prove too much; the so-called correction provided by the second measure need not wipe out all biases of the sort mentioned earlier, if they exist. But we propose to show, as the analysis progresses, that the simple ratio of exports to sales is not wholly misleading as a measure of international competitive strength.

There is still another kind of problem which data of the sort presented in Table 1 may well involve. Each unit of observation in Table 1 is an "industry," arbitrarily defined. Each such "industry" can be proliferated into two or more, by schism. Has the arbitrary grouping used in Table 1 provided an impression of the export importance of

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[10] Characteristic of this view is the case made in S.B. Linder, op. cit.

the research-oriented industries which distorts the absolute contribution of these industries to the United States economy? The data in Table 2 lay that fear to rest. The figures show that the five industries with the strongest research effort accounted for 72.0 per cent of the nation's exports of manufactured goods though they were responsible for only 39.1 per cent of the nation's total sales of such goods. The same five industries were also responsible for 89.4 per cent of the nation's total R & D expenditures, and 74.6 per cent of the company financed R & D expenditures. The five industries concerned, therefore, represent both the heart of United States export strength in manufactured products and the heart of its industrial research effort.

In groping for some credible measure of comparative advantage, however, it is not necessary to stop with the measures presented in Tables 1 and 2. Still another set of measures can be devised which relate United States industry export performance to the export performance of the same industry localized in prospective competitor countries. In this case, the "normalizing" variable becomes the total industry exports of all the countries concerned, rather than the total shipments of United States industry. Neither normalizer is wholly without latent error as a measure of comparative advantage. But the use of another approach offers an opportunity to expose any lurking anomalies and to generate more information about the underlying forces.

Table 2

Distribution of Research Effort Sales, and Export among United States Industries, 1962

| SIC number | Industry name | Total R & D expenditures | Company financed R & D expenditures | Scientists & engineers in R & D | Sales | Exports |
|---|---|---|---|---|---|---|
| | | Percentage distribution of | | | | |
| | All 19 industries | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 |
| | 5 industries with highest research effort[b] | 89.4 | 74.6 | 85.3 | 39.1 | 72.0 |
| | 14 other industries | 10.6 | 25.4 | 14.7 | 60.9 | 28.0 |
| | Industries arranged in descending order of research effort[b] | | | | | |
| 37 | Transportation | 45.6 | 24.1 | 25.3 | 13.5 | 19.7 |
| 372 | Aircraft | 36.7 | 9.3 | 21.1 | 3.7 | 8.9 |
| --- | Transportation (other than aircraft | 9.0 | 14.7 | 4.2 | 9.5 | 10.8 |
| 36 | Electrical machinery | 21.1 | 17.7 | 27.1 | 8.5 | 9.4 |
| 38 | Scientific instruments | 4.0 | 4.9 | 5.9 | 1.6 | 3.0 |
| 28 | Chemicals | 10.5 | 18.6 | 16.7 | 7.9 | 13.0 |
| 283 | Drugs | 1.8 | 3.9 | 3.5 | 1.2 | 1.9 |
| --- | Chemical (other than drugs) | 8.7 | 14.7 | 13.2 | 6.7 | 11.1 |
| 35 | Machines (non-electrical) | 8.2 | 9.3 | 10.3 | 7.6 | 26.9 |
| 30 | Rubber | 1.2 | 2.1 | 1.0 | 2.5 | 1.4 |

Table 2, Continued

| SIC number | Industry name | Total R & D expenditures | Company financed R & D expenditures | Scientists & engineers in R & D | Sales | Exports |
|---|---|---|---|---|---|---|
| | | Percentage distribution of | | | | |
| 32 | Stone, clay & glass | 1.0 | 2.0 | 1.1 | 2.7 | 1.4 |
| 29 | Petroleum | 2.7 | 5.7 | 1.7 | 8.9 | 2.8 |
| 34 | Fabricated metals | 1.3 | 2.4 | 2.2 | 5.1 | 2.9 |
| 33 | Primary metals | 1.6 | 3.3 | 2.5 | 7.4 | 6.1 |
| 333 | Nonferrous metals | 0.9 | 1.4 | 1.0 | 2.5 | 2.8 |
| --- | Iron and steel | 0.9 | 1.9 | 1.6 | 4.8 | 3.3 |
| 31 | Leather | 0.2 | 0.4 | 0.2 | 1.2 | 0.5 |
| 27 | Publishing | 0.5 | 0.9 | 0.3 | 2.5 | 1.1 |
| 21 | Tobacco | 0.1 | 0.2 | 0.1 | 1.4 | 0.8 |
| 20 | Food & beverage | 1.1 | 2.4 | 2.7 | 15.5 | 3.9 |
| 22 | Textile | 0.2 | 0.5 | 1.4 | 3.8 | 3.5 |
| 25 | Furniture | a | 0.1 | 0.3 | 0.3 | 0.2 |
| 24 | Wood products | a | a | a | 1.7 | 0.9 |
| 26 | Paper | 0.6 | 1.3 | 1.0 | 3.6 | 2.0 |
| 23 | Apparel | a | 0.1 | 0.2 | 3.4 | 0.6 |

[a] less than 0.05%.

[b] research effort defined by ratio of R & D expenditures as a % of sales.

For sources and methods, see Statistical Appendix.

The results of the new approach are presented in Table 3. In general the figures in the table tend to add a little more credence to the view that the export performance measures used in earlier tables are a function of the international competitive strength of the United States industries they represent.

The extreme left-hand column of Spearman coefficients in Table 3 presents measures of correlation between (1) the indicated measures of each United States industry's research effort and (2) United States exports in each industry taken as a percentage of the exports of the OECD countries in the industry.[11] The resulting relationships are practically indistinguishable from the rank correlations between R & D and export performance done for the data in Table 1.

In the next two columns of Table 3, however, almost all these relationships fall apart. In these columns, United States exports to the world are "normalized" by calculating them respectively as a ratio to United Kingdom world exports and to German world exports. The result is that, suddenly, almost all the statistically significant relationships disappear. What this means, of course, is that the United Kingdom and the German export profiles must be very much like that of the United States. Wherever the United States has a large volume of exports, the United Kingdom and Germany also have a large volume of exports.

[11] The ratio of U.S. exports to the sum of the exports of a group of nations has been called "trade competitive power" by Donald Keesing. He found that there was a rank correlation of +0.60 between "trade competitive power" and of scientists and engineers as a percentage of total employment for a sample of 35 non-natural-resource processing industries (Keesing, op. cit., p. 256).

Table 3

World Exports of U.S. Industries
Related to the World Exports of
OECD Countries in 1962

Spearman coefficient of rank correlation for indicated cell

| Industry characteristics | U.S. world exports in 1962 as a percent of world exports of: OECD countries[a] | United Kingdom | West Germany | France |
|---|---|---|---|---|
| | (1) | (2) | (3) | (4) |
| Total R & D expenditures as a % of sales in 1962 | +0.68 | +0.28[b] | +0.08[b] | +0.60 |
| Scientists and engineers in R & D as a % of total employment in 1962 | +0.64 | +0.37 | +0.24[b] | +0.59 |

[a]Although Japan did not join the OECD until after 1962, Japan is included in the data.

[b]These coefficients are not significant at the 5 per cent probability level. All other coefficients in the table are significant at that level or at a lower probability level.

Does this mean that all our prior indications of the causes of United States export strength were misleading? Not at all. It means rather that the United Kingdom and Germany, also being at the top of the advanced country list with relatively high incomes and a relatively heavy stress on industrial innovation and product development, derive their export strength from roughly the same characteristics as those that govern United States export performance. Their export performance differs from that of the other OECD countries in the same general way that United States export performance differs from that of the OECD countries.

The extreme right-hand column of Table 3 offers some parallel data for United States exports in relation to those of France. These data are more tantalizing than they are revealing. When French exports to the world are used as the normalizer, as the table shows, the significant correlations return; French exports evidently have a profile much more nearly corresponding to the less developed of the OECD countries than to those of the United Kingdom and Germany.

The common view of French industry does paint a picture of an institution that is different in structure, in outlook, and in innovational habits than the industry of the United States, the United Kingdom and Germany. Table 4 indicates that French industrial research is not on a smaller scale, relatively speaking, than that of Germany. The research tends to be controlled, however, to a greater degree by government

Table 4

Characteristics of R & D Activity in United States, United Kingdom, West Germany, and France, 1962

| | United States | United Kingdom | West Germany | France |
|---|---|---|---|---|
| Number of scientists and engineers in R & D ('000's full-time equivalents) | 435.6 | 50.7 | 40.1 | 28.0 |
| R & D personnel as a % of working population | 1.0 | 0.6 | 0.4 | 0.4 |
| R & D expenditure (billions of U.S. dollars)[a] | 17.5 | 1.8 | 1.1 | 1.1 |
| R & D as a % of GNP[a] | 3.1 | 2.2 | 1.3 | 1.5 |
| R & D expenditures performed in the business section as a % of total national R & D expenditures | 71 | 63 | 61 | 48 |

[a]No adjustment was made for differences in relative factor prices.

Source: C. Freeman and A. Young, The Research and Development Effort in Western Europe, North America and the Soviet Union (Paris: OECD, 1965) pp. 71-72.

institutions which are said to have less concern with industrial applications. Furthermore, French industry's ingenuity, as illustrated by the automobile producers, is said to be devoted to highly differentiated, highly individual tastes. Up to a point, such innovation might have the same export possibilities as the differentiated products of the United States, the United Kingdom and Germany. Pushed very far, however, stress on this kind of output has the effect of encouraging an industrial structure which is not highly concentrated, hence a structure which reflects few scale economies in either production or (more importantly, in this context) in research servicing or in sales. The sale of products for the overseas markets, especially products that have high technical inputs, cannot easily be achieved by an industry of small firms whose innovational stress borders on artistry. The United States model of the highly concentrated mass innovator seems more closely to approximate the effective pattern for the successful exporter.

We now come to another group of measures, slightly different in approach, which appear to offer some added evidence of the sources of United States export strength. In Tables 1, 2, and 3, it should be remembered, we were concerned with analyzing and comparing the world exports of each United States industry expressing those exports by various relative measures. Table 5 disaggregates the data into U.S. trade with Europe and U.S. trade with non-Europe. It will be observed that in every case there is a better relationship

Table 5

Research Effort and Trade Performance with Europe and Non-Europe by United States Industries, 1962

| | Spearman coefficient of rank correlation for indicated cell | | | |
|---|---|---|---|---|
| | Trade of U.S. industries with Europe | | Trade of U.S. industries with Non-Europe | |
| Industry characteristics | Exports as a % of sales | Excess of exports over imports as a % of sales | Exports as a % of sales | Excess of exports over imports as a % of sales |
| Total R & D expenditures as a % of sales | +0.63 | +0.35[a] | +0.73 | +0.78 |
| Scientists and engineers in R & D as a % of total industry employment | +0.65 | +0.48 | +0.74 | +0.67 |

[a]Not statistically significant at the .05 level. All other coefficients are significant at that level or lower.

between research intensity and trade with Europe. In fact, the relationship between (1) R & D as a per cent of sales and (2) trade advantage as measured by the excess of exports over imports as a per cent of sales does not exist at a significant level.

The United States margin of competitive strength in the research intensive industries is challenged by Europe, therefore, more effectively than by other countries. This is almost self-evident and has already been suggested by the data on the United Kingdom and German trade patterns. We propose shortly to show that part of the result was due, beyond much doubt, to the patterns of United States industry's investments in overseas productive facilities. But before we turn to that phase of the analysis, it will be useful to pin down more firmly what is meant by the research-intensive industries.

## Characteristics of Research-Intensive Industries

So far the presentation has referred to research-intensive and research-oriented industries, as if a research orientation was synonymous with a new product orientation, as if the new product orientation was the most likely characteristic of those industries to be linked with their export strength. However, a number of different industry characteristics are related to research effort, and some of these characteristics may provide equally plausible explanations of export performance. This proves to be an especially important point because of the message projected by the data in Table 6.

That table begins by reassuring us in one respect. It indicates that the industries with the strongest research effort are also those with the strongest new-product orientation. But the table goes on to demonstrate that a high research and development effort in an industry is closely correlated with various other characteristics. The table demonstrates that industries with a heavy complement of scientists and engineers in research and development also have a heavy complement of scientists and engineers in production, as well as in sales. To a considerable extent, therefore, high technical effort at any stage of the design-production-marketing process is associated with high technical effort at all the other stages.

The measures in Table 6 tell us more, however. They indicate that the intensity of the research and development effort is greatest in industries in which the degree of employment concentration is high, and in industries in which large firms are particularly dominant.

So far, the statistical picture is familiar enough.[12]

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[12] Compare, for instance, the findings in J.S. Worley, "The Changing Direction of Research and Development Employment among Firms," in Universities-National Bureau Committee for Economic Research, The Rate and Direction of Inventive Activity (Princeton: Princeton University Press, 1962) pp. 233-251).

Table 6

Relationship between Measures of Intensity of Research Effort and Other Characteristics in United States Industries[a]

| Industry characteristics | Spearman coefficient of rank correlation for indicated cell | | | Average of industry characteristics | |
|---|---|---|---|---|---|
| | Total R & D expenditures in industry as % of industry sales 1962 | Company financed R & D expenditures as % of industry sales 1962 | Scientists & engineers in R & D as % of total industry employment 1962 | 5 most research intensive industries | 14 other industries |
| **Research & technology** | | | | | |
| Percentage of companies indicating majority of R & D efforts for new products, 1958 | +0.63 | +0.64 | +0.51 | (f) | (f) |
| Scientists & engineers in R & D as % of total industry employment, 1962 | +0.81 | +0.82 | +1.00 | 3.2% | 0.4% |
| Scientists & engineers in production as % of total industry employment, 1962 | +0.76 | +0.79 | +0.92 | 2.1% | 0.8% |
| Scientists & engineers in sales as % of total industry employment, 1962 | +0.84 | +0.87 | +0.86 | 0.9% | 0.1% |
| **Scale & concentration** | | | | | |
| Index of employment concentration, 1958[b] | +0.66 | +0.66 | +0.59 | 47.0% | 21.1% |
| Index of asset scale, 1961[c] | +0.48 | +0.47 | +0.60 | 67.1% | 46.1% |
| Index of sales scale, 1961[d] | +0.58 | +0.57 | +0.70 | 35.0% | 21.1% |

Table 6, Continued

| Industry characteristics | Spearman coefficient of rank correlation for indicated cell: Total R & D expenditures in industry as % of industry sales 1962 | Company financed R & D expenditures as % of industry sales 1962 | Scientists & engineers in R & D as % of total industry employment 1962 | Average of industry characteristics: 5 most research intensive industries | 14 other industries |
|---|---|---|---|---|---|
| Cost characteristics | | | | | |
| Indirect labor costs as % of value added, 1957 | +0.64 | +0.63 | +0.68 | 24.7% | 17.2% |
| Depreciation expenses as % of value added, 1957 | -0.11[e] | -0.08[e] | +0.03[e] | 4.3% | 5.3% |
| Net fixed assets as % of value added, 1957 | -0.09[e] | -0.03[e] | +0.09[e] | 0.31% | 0.41% |

[a]The number of industries for which relationships in the table could be calculated was not the same throughout. In some cases, data were not available for some industries.

[b]The index, calculated for each SIC 2-digit industry, consists of a ratio whose numerator is employment in constituent SIC 4-digit industries in which the largest 8 firms accounted for 60% or more of 2-digit total employment, and whose denominator was total employment in the 2-digit industry.

[c]The index, calculated for each SIC 2-digit industry, consists of a ratio whose numerator is the assets of firms with $50 million or more in assets, and whose denominator is total sales in the industry.

[d]The index, calculated for each SIC 2-digit industry, consists of a ratio whose numerator is sales in firms with one half billion dollars or more in sales, and whose denominator is total sales in the industry.

Table 6, Continued

[e]These coefficients are not significant at the 5 per cent probability level. All other coefficients in the table are significant at that level or at a lower probability level.

[f]not available.

Source: See Statistical Appendix.

Where the statistics begin to break some new ground is in their indication that the large-scale high-concentration pattern is not associated with high capital intensity. To be sure, high indirect labor costs are positively correlated with high research effort; and high indirect labor costs could well be consistent with high capital intensity. But the picture of high capital intensity is virtually dispelled by the two final measures in Table 3. Here, two fairly sensitive measures of capital intensity fail to display any systematic relation with high research effort.[13]

These findings, when drawn together, paint a fairly consistent picture. They suggest the existence of national markets in which economies of large scale and barriers to entry stem from the requirements of successful product innovation and successful marketing, rather than from capital intensity.[14] The forces that determine the propensity to gamble on product innovation are no doubt extraordinarily complex, and lend themselves only grudgingly to easy

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[13]This result is consistent with analyses done by George E. Delehanty, in which he finds that the ratio of nonproduction employment to production employment in United States industries is more closely correlated with the degree to which scientists and engineers are in the work force of the industry than with the capital:labor ratio of the industry. See Delehanty, "An Analysis of the Changing Proportion of Nonproduction Workers in U.S. Manufacturing Industries," unpublished doctoral thesis at M.I.T., 1962.

[14]This, of course, is hardly a new thought; see Joe S. Bain, Barriers to New Competition (Cambridge: Harvard University Press, 1956). See also C. Freeman's observations about the "reasons for the United States lead" in electronics, in his "Research and Development in Electronic Capital Goods," cited earlier, p. 51.

generalization. A firm that can spread its research risks over a large number of efforts will have a more predictable pay-out in any finite period than one which does not have the resources for a large number of tries, especially if the anticipated yield on any single effort is not systematically different for large firms than for small.

Once the new product has been invented, scale continues to play a part in success. The sale of technically complex producer goods, for instance, requires a detailed understanding of the needs of customers, a continuing sales service, readily accessible spare parts, and a high level of research activity to keep the product competitive. The act of exporting to foreign markets, therefore, represents a marketing investment which one would expect to be associated with significant scale economies.

In sum, one derives a picture of high research effort being correlated with industries that experience substantial trade surpluses. These research-intensive industries, although large and concentrated, are not systematically capital-intensive. It is in these industries that the United States trade advantage lies.

Trade and Investment in Foreign Manufacturing Subsidiaries

Neither the theory of international trade nor the theory of international capital movements has much to offer in explanation of managerial decisions to invest in production facilities abroad. International trade is explained largely in comparative advantage and factor endowment terms; long-term capital movements are seen largely as a reflection of the process of equating the marginal efficiency of capital in different countries. Yet intuitively one is aware that the prospective foreign investor, debating whether to invest in a production facility in a foreign market, is engaged in an evaluation process which juggles a number of additional major variables.

One way of looking at the overseas direct investments of United States producers of manufactures is that they are the final step in a process which begins with the involvement of such producers in export trade. The export trade of the United States, according to the data presented earlier, is heavily weighted with products that demand large scientific and technical inputs in the selling process. Products of this sort, as we noted earlier, ordinarily demand an apparatus for learning customer needs and for subsequent technical servicing and consulting. Once such an organization has been established for sales purposes, the marginal costs of setting up a facility for production may be sharply reduced; for "marginal cost" in this context should be read not solely as a direct money expenditure but also as a measure of the pain of acquiring information regarding a country, negotiating for entry in a foreign economy, altering the company's organization to accommodate the new element, and tolerating the high subjective risks involved in a novel venture. Once the marginal costs are reduced in this sense, the probability that the venture may appear economical is of course enhanced. Whence it follows that industries with comparatively high export sales of products involving scientific and technical aspects in their sales and servicing, ceteris paribus, will have a high propensity to invest in manufacturing subsidiaries in the markets they serve.

This hypothesis appears particularly plausible if additional factors are considered. The research-intensive industries tend to be highly concentrated, and suggest the existence of strong oligopoly forces. It is in such industries that rule-of-thumb measures of success such as "maintaining our share of world markets" can be expected to enter most strongly into the investment decisions. In industries with lower concentration characteristics, the individual firm presumably finds share stability a less reliable gauge of its long-run survival or profit-maximizing prospects than in industries in which the principal rivals are few in number. In the oligopoly industries, therefore, individual firms are likely to consider foreign investments as important forestalling tactics to cut off market preemption by others. And they are likely to feel obliged to counter an investment by others with an investment of their own.

The available figures on foreign direct investment by United States enterprise do nothing to undermine the credibility of these hypotheses. The figures in Table 7 indicate in various ways that the propensity for United States industry to build facilities or otherwise to invest abroad, when "normalized" by the United States investment level, is higher in the research-oriented industries than in other industries. The figures on sales by U.S. subsidiaries abroad exhibit the same general characteristics as those for investment; when "normalized" by sales in the United States, sales of United States subsidiaries abroad are weighted heavily in favor of the research-oriented groups. The figures in the table have to be interpreted with a certain caution since investments in the non-Europe areas are heavily weighted with resource-oriented activities, such as paper and food processing. But the very limited conclusion suggested above obviously holds.

The figures in Table 8 permit slightly deeper probing of the investment patterns of United States industries in foreign countries. In this table, the focus is on the relationship between United States exports and the sales of United States subsidiaries located abroad. For this purpose, the sales of United States subsidiaries have been adjusted to exclude sales to the United States by United States subsidiaries abroad. The figures in the table, therefore,

Table 7

Plant & Equipment Expenditures, Investment Expenditures and Sales in the United States and Foreign Countries by United States Industries[a]

| | 4 research intensive industries | 14 other industries | Ratio of 4 research intensive industries to 14 other industries |
|---|---|---|---|
| | (billions of dollars) | | (per cent) |
| Plant and equipment expenditures 1958-64 | | | |
| In U.S. | $ 32.7 | $ 50.8 | 64.4% |
| In Europe, by U.S. owned subsidiaries | 4.3 | 1.6 | 266.3 |
| In non-Europe, by U.S. owned subsidiaries | 3.9 | 3.0 | 133.4 |
| Direct investment, 1964[c] | | | |
| In U.S. | 71.7 | 94.9 | 75.6 |
| In U.S. owned subsidiaries in Europe | 4.5 | 2.0 | 227.5 |
| In U.S. owned subsidiaries in non-Europe | 5.2 | 4.9 | 106.0 |
| Sales, 1964 | | | |
| In U.S. | 143.4 | 205.7 | 69.7 |
| By U.S. owned subsidiaries in Europe | 8.4 | 3.7 | 227.0 |
| By U.S. owned subsidiaries in non-Europe | 8.7 | 7.3 | 119.3 |

[a]Data on the petroleum industry, SIC 29, are not included because not available for all parts of the table.

[b]Some of the data on the scientific instruments industry, SIC 38, are not available separately and have to be included in the "14 other industries" totals. This tends to blur slightly the otherwise sharp differences between the research-intensive indistries and the other industries.

[c]For United States, the figures presented represent total equity interest; for the non-United States data, the figures are equity and debt in foreign subsidiaries owned by U.S. parents.

Source: See Statistical Appendix.

Table 8

U.S. Exports and Foreign Subsidiary Sales to Elsewhere than U.S. by U.S. Manufacturing Industries in 1962[a]

| SIC number | Industry name | U.S. exports | | | Sales by foreign subsidiaries[b] | | | Foreign subsidiary sales related to exports | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | Total | Europe | Non-Europe | Total | Europe | Non-Europe | Total | Europe | Non-Europe |
| | | (in millions of dollars) | | | | | | (in per cent) | | |
| | All 18 Industries | $13,917 | $3,378 | $ 10,539 | $26,773 | $11,885 | $14,888 | 192.4% | 351.8% | 141.3% |
| | 4 most research intensive | 9,875 | 2,285 | 7,590 | 16,686 | 8,235 | 8,451 | 169.0 | 395.0 | 111.3 |
| | 14 other industries | 4,042 | 1,093 | 2,949 | 10,087 | 3,650 | 6,437 | 249.6 | 333.9 | 218.3 |
| Industries arranged in descending order of research effort | | | | | | | | | | |
| 37 | Transportation | 2,819 | 315 | 2,504 | 6,590 | 3,235 | 3,355 | 233.8 | 1027.0 | 134.0 |
| 36 | Electrical machinery | 1,344 | 273 | 1,071 | 2,553 | 1,210 | 1,343 | 190.0 | 443.2 | 125.4 |
| 28 | Chemicals | 1,866 | 627 | 1,239 | 4,280 | 1,745 | 2,535 | 229.4 | 278.3 | 204.6 |
| 35 | Machinery (non-electrical) | 3,846 | 1,070 | 2,776 | 3,263 | 2,045 | 1,218 | 84.8 | 191.1 | 43.9 |
| 30 | Rubber | 193 | 43 | 150 | 1,322 | 455 | 867 | 685.0 | 1058.1 | 578.0 |
| 33 & 34 | Primary and Fabricated Metal | 1,286 | 367 | 919 | 1,946 | 710 | 1,236 | 151.3 | 193.5 | 134.5 |
| 20 | Food | 553 | 187 | 366 | 3,287 | 1,180 | 2,107 | 594.4 | 631.0 | 575.7 |
| 26 | Other[c] | 1,721 | 408 | 1,313 | 2,777 | 1,225 | 1,552 | 161.4 | 300.1 | 118.2 |

[a]Data on the petroleum industry, SIC 29, are excluded because figures for foreign direct investment and foreign subsidiary sales are not available.

Table 8, Continued

[b]Sales to the United States have been deleted from the total sales of foreign subsidiaries leaving only sales to local markets and to other countries by such subsidiaries.

[c]Data on the scientific instruments industry, SIC 38, are not available separately and with the "14 other industries". This tends to blur slightly the otherwise sharp differences between the research-intensive industries and the other industries.

Source: See Statistical Appendix.

begin to approach a comparison between United States exports and foreign sales which could conceivably be (but need not necessarily be) export-substituting from the United States viewpoint.

Once again, some familiar patterns emerge. In the European area, the sales of United States subsidiaries are more important in relation to United States exports than in the non-European areas; if subsidiary sales are a substitute for United States exports, then the process would seem to have gone further in Europe than elsewhere. The tendency for Europe to have a higher ratio of subsidiary sales to exports than non-Europe is true both for the research-intensive and the other industries, but the research-intensive industries exhibit the tendency to a somewhat more marked degree. All this is consistent with expectations. Where scale factors are important, large markets are more likely to stimulate the ultimate commitment of a production facility than small markets.

The one new morsel of information which the table affords is an indication of the extent to which the "other" industries of the United States have moved their overseas operations from the sphere of exports to that of sales through overseas subsidiaries. In these industries, as we have repeatedly observed, neither exports nor overseas investment have much prominence, at least when "normalized" by the level of activities of those industries in the United States. However, of the two externally directed activities, exports and foreign subsidiary sales, the export position appears even less prominent than the subsidiary sales position. In terms of Table 8, the ratio of subsidiary sales to exports is fairly high.

There are at least two observations worth making concerning the high ratios of subsidiary sales to exports in these "other industries." One fits well enough into the theme of this article; the other opens wholly new avenues of inquiry.

The observation that fits fairly well has to do with the present export position of these "other" industries. Time was, some decades ago, when the United States was a heavy exporter of most of the materials included in "other industries"--paper, food, rubber and metal products, in particular. In the course of time, the initial trade advantage of United States industries in these products was eroded. In partial response, those industries set up overseas subsidiaries to service their erstwhile export markets. The subsidiaries did not always do precisely what their parents had done by way of exports; while the subsidiaries of the rubber companies may have taken over the tire markets once serviced by their parents' exports, the subsidiaries of the food companies no doubt engaged in many new activities which could not have been supported by way of exports. In any event, in the end, subsidiary sales were a means by which contact with foreign markets was maintained.

But there is obviously another phenomenon involved. United States firms such as those in food distribution and food processing are commonly found investing in foreign markets for reasons which have little to do with salvaging an export position. Some of these firms, in effect, are seeking to sell a technique of production, finance, marketing or general organization, this is certainly the interpretation to be placed on such investments as those of Libby, McNeill & Libby and General Foods in Europe. It is not sufficient, therefore, to explain United States overseas investment with a simple set of hypotheses based on the protection of markets previously acquired.

As a more complete explanation is developed of the forces behind United States overseas investment, the issue of market defense and market protection will no doubt play a part. But the strengths that derive from research and from the capacity to organize and maintain large complex organizations will surely figure in some independent sense as well.

Further research on the functioning of research and development in the creation of new products, new processes and new systems, and on the forces that lead to industrial concentration and large scale operations will be particularly fruitful in shedding more light on the problems that have been only partially answered in this paper.

## Statistical Appendix

Tables 1 & 2*

1. Research and development: Industry research and development expenditures in 1962 from NSF 65-18, Basic Research, Applied Research, and Development in Industry, 1962 (Washington, D.C.: U.S. Government Printing Office, 1965), p. 95 for total research and development and p. 105 for company-financed research and development. The National Science Foundation divides these figures by the sales of the responding firms that do research and development in order to get a ratio of research and development expenditures as a percentage of sales. This seemed to be inadequate for our purpose of developing an index of research intensity for an industry as it omitted the sales of the firms that do not do research and development. We divided by total industrial sales as measured by the FTC-SEC Quarterly Financial Reports. NSF lumped some industries together [22 + 23; 24 + 25; 21, 27 + 31]. We estimated industry inputs by disaggregating the NSF data by the ratios of scientists and engineers in these industries as reported in U.S. Bureau of the Census, U.S. Census of Population: 1960 Subject Reports Occupation by Industry, Final Report PC (2) - 7C (Washington, D.C.: U.S. Government Printing Office, 1962), Table 2. It is unlikely that errors resulting from this method of estimation would affect the findings because of the very small amounts of research and development to be allocated in these seven industries. In this case a little bit more or less of a very small amount will cause insignificant errors.

2. Scientists and Engineers in Research and Development in 1962 from B.L.S. Bulletin No. 1418, Employment of Scientific and Technical Personnel in Industry, 1962 (Washington, D.C.: U.S. Government Printing Office, 1964), p. 35. Employment by industry taken from B.L.S., Employment and Earnings Statistics for the United States 1909-64 (Washington, D.C.: U.S. Government Printing Office, 1965).

3. Exports and imports from OECD Statistical Bulletins: Foreign Trade Series B, Analytical Abstracts Jan. - Dec. 1962, (Paris: OECD, 1963), numbers 1 and 5.

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*Where data is used again in subsequent tables, it is not referenced. For example, scientists and engineers as a percentage of total employment is a variable used in Tables 3 and 5 as well as in Tables 1 and 2.

Tables 3 & 5

1. World exports of U.S. and all OECD countries--see A-3 above, numbers 1-6. Japan was not included in the OECD until after 1962, and her world exports taken from U.N. Department of Economic and Social Affairs, Trade Statistics According to SITC, Series D. Vol. XII, Number 1-20. Jan.-Dec. 1962. In order to be able to perform parametric tests, a range of values from 0.2 to 5.0 was set. For example, a positive value divided by zero would give a measure of absolute advantage equal to 5.0. Similarly, a zero divided by a positive number would be given a value of absolute disadvantage of 0.2. The conversion from SITC to SIC was done according to the following:

| | SIC | SITC |
|---|---|---|
| Food and beverage | 20 | 013, 023, 024, 032, 046, 047, 048, 053, 055, 061, 062, 091, 099, 111, 112 |
| Tobacco | 21 | 122 |
| Textiles | 22 | 065 |
| Apparel | 23 | 084 |
| Lumber & wood products | 24 | 063, 243 |
| Furniture | 25 | 082 |
| Paper & allied products | 26 | 064 |
| Printing | 27 | 892 |
| Chemicals | 28 | 005 |
| Drugs | 283 | 541 |
| All other chemicals | --- | 005 - 541 |
| Petroleum products | 29 | 332 |
| Rubber and plastic products | 30 | 062, 893 |
| Leather | 31 | 611, 612, 613, 083, 085 |
| Stone, clay & glass | 32 | 661, 662, 663, 664, 665, 666 |
| Primary metals | 33 | 067, 068 |
| Iron and steel | 331 | 067 |
| Non-ferrous metals | 333 | 068 |
| Fabricated metals | 34 | 069 |
| Machinery other than electric | 35 | 071 |
| Electric machinery | 36 | 072 |
| Transportation equipment | 37 | 073 |
| Aircraft | 372 | 734 |
| All other transport | --- | 073 - 734 |
| Scientific instruments | 38 | 086 |

Table 6

1. The percentage of companies indicating majority of research and development efforts for new products from the 1958 McGraw-Hill Survey of Capital Spending.

2. Scientists and engineers in production and in sales as a percentage of total industry employment in 1962 from B.L.S. Bulletin No. 1418, op. cit., p. 35.

3. Index of employment concentration: The Conference Board Record (April 1964), p. 52.

4. Index of asset scale, 1961 and index of sales scale, 1961: U.S. Treasury Dept. Internal Revenue Service, Statistics of Income 1961-62: Corporate Income Tax Returns, Table 2.

5. Cost characteristics: U.S. Bureau of the Census, Census of Manufactures, 1958, Vol. 1, Summary Statistics, Table 3.

Table 7

1. Plant and equipment expenditures from 1958-64 in the U.S.: Survey of Current Business, July 1961, p. 29, and September 1965, p. 6. Plant and equipment expenditures of U.S. corporations in Europe and non-Europe: Survey of Current Business, October 1960, p. 20; September 1961, p. 21; and September 1965, p. 29.

2. Direct investment in the U.S. in 1964: FTC-SEC, Quarterly Financial Reports, First Quarter, 1965. For U.S. owned subsidiaries in Europe and non-Europe: Survey of Current Business: September 1965, Table 5, p. 87.

3. For sales in the U.S. in 1964: FTC-SEC, Quarterly Financial Reports, First Quarter, 1965. For sales of U.S. owned subsidiaries in Europe and non-Europe: Survey of Current Business: November 1965, p. 19.

Table 8

See sources for Table 7.

Major limitations of the data

The following weaknesses of the data should be considered when the findings presented in the paper are evaluated: (1) The conversion of activity from SITC to SIC is only approximate in some cases; (2) the definition of R & D as used by companies in NSF reports differs between firms and industries; (3) the SIC 2-digit level aggregates dissimilar industries; (4) research and development data is gathered at the company level and this distorts the inputs by industry for diversified firms; (5) there is often not a complete matching of industry classification for various measures of activity (e.g. scale data is by company while employment data is by establishment, etc.); (6) some goods should not be expected to move in international activity (e.g. newspapers) and this lowers the ratio of trade performance to sales; (7) trade with Canada may not be a result of the forces under examination, but may result from the partial integration of the two economies; (8) activities related to natural resources have, in general, not been eliminated; (9) other forces such as the differential impact of the "Buy American" provision of U.S. foreign aid have not been considered; (10) indirect exports have not been evaluated (e.g. shipments of instrumentation from SIC 36 that enter into airplanes that are exported by SIC 37).

None of these limitations would affect the ordinal division of manufacturing activity into the five most research-intensive industries and the fourteen less research-intensive industries. There still would be a substantial gap between the fifth and sixth industries in order of research intensity.

These weaknesses, together with the arbitrary definition of the industries and the differences in the size of industries, have led us to use the methodology of dividing manufacturing activity into five research-intensive and fourteen less research-intensive industries. The summation of manufacturing activity into two classes of activity helps to make manifest the differences that exist between the research-intensive and the less research-intensive. This measure is less subject to the enumerated statistical weaknesses and is in harmony with the measures of Spearman rank correlation that were given. But it does not permit a disregard for the very substantial limitations that are inherent in the data.