R&D effort and US exports and foreign affiliate production of manufactures

Reuven GLICK *

Graduate School of Business Administration, New York University, New York, NY 10006 U.S.A.

Final version received April 1982

This paper examines the relationship between US R&D expenditures and the pattern of US manufacturing exports and foreign affiliate sales across industries and regions for the years 1966 and 1976. While differences in relative research capability between the United States and the rest of the world have narrowed over this period, research effort still significantly explains the pattern of US sales in foreign markets. For any region, the export and foreign affiliate sales performance of research-intensive industries exceeds that of non-research-intensive industries. The relative performance of the former is greater in regions with larger market size and high per capita income. The analysis also reveals that over the time period studied the ratio of US exports to foreign affiliate sales has generally fallen for all industries and foreign markets.

These observations accord with a broad interpretation of the product cycle theory. While the United States has lost its uniqueness as a location of innovation, the ability to develop and market new products through R&D expenditures is still a strong force behind its exports and sales abroad. The decrease in exports relative to foreign affiliate sales may reflect a more rapid shift in comparative advantage in the production of such products to foreign locations. Hence the positive effect on US exports of development of any given new product may be becoming more short-lived.

1. Introduction

The role of research effort in export and foreign affiliate production performance is well recognized both from theory and observation. The technology gap, product cycle, and, to a lesser extent, neo-classical theories all suggest links between research effort and patterns of international trade and production of manufactures. The existence of such links is best demonstrated by the strength of the United States since World War II as both an undertaker of research and technological innovation and as an exporter and foreign producer of manufactured products.

In recent years though it has been argued that relative to other countries the pace of US research and technological innovation has declined. Indeed the research and product innovation capabilities of foreign countries have increased significantly. Nevertheless, research effort still significantly explains the pattern of US export and foreign production performance across industries and regions.

This paper briefly reviews those theories which emphasize the relationship between research effort and international trade and production. It then examines recent evidence for the case of the United States. In particular, it addresses the following questions: (1) What have been the relative trends in factors conducive to product innovation in the United States and other countries? and (2) What has been the relationship between research effort and industry and regional patterns of US exports and foreign affiliate production of manufactures?

2. Technology gap and product cycle theories

The technology gap theory discusses how certain countries through research and development investments are able to innovate new and superior products at a faster pace than others. [1] This rela-

* Assistant Professor of Economics and International Business.
Financial support for this study was received from the New York University Project on the Multinational Firm in the United States and World Economy. I am indebted to Yui Kimura for research assistance.

[1] The technology gap model was first proposed by Posner [1].

Research Policy 11 (1982) 359–372
North-Holland Publishing Company

0048-7333/82/0000-0000/$02.75

tive ability to innovate constitutes a source of comparative advantage in international trade in manufactures which is additional or alternative to comparative advantage based on relative factor abundance. As long as the gap persists and the technology for production of such products is unavailable to foreign producers, demand in foreign markets is met by exports from the innovating country. Once the technology is transferred abroad to either affiliated or unaffiliated foreign firms exports will cease to grow and may decline.

The product cycle theory, which has many features in common with the technology gap theory, provides an explanation for why innovations occur in some countries only. [2] It asserts that a comparative advantage in innovating new products is engendered by a combination of location-specific demand and supply factors. On the demand side, factors such as high per capita income and large market size generate a strong preference for new products, particularly products which are differentiated and technologically sophisticated. On the supply side, factors such as plentiful research resources and relatively abundant capital and skilled labor and scarce unskilled labor spur production of new technology-intensive and labor-saving products. Differences between locations in these demand and supply characteristics convey a comparative advantage in innovation to those regions in which per capita income and market size is relatively great and research, capital, and skilled labor resources relatively more abundant and cheap.

The product cycle theory provides an explanation for the pattern of exports from innovating countries as well. It presumes that the marketing and production characteristics of new products follow a particular cycle over time which, in turn, influences the location of production. At the beginning of this cycle locations with a comparative advantage in innovation possess a comparative advantage in production as well. Demand in other locations for these new products is strongest where per capita income and market size are greatest and is met through exports. Changing input requirements resulting from increased standardization in production over the cycle diminish the optimum mix of research effort, capital, skilled labor, and other factors. This induces a shift in comparative advantage in production to other locations with more appropriate resource endowments and a corresponding fall in exports from innovating countries. [3] At some point innovating locations may even import. The location which possesses a comparative advantage in production in the long run depends on the optimum mix of factor inputs for which the production process stabilizes and on the relative factor abundance of different locations.

The product cycle theory also provides some insights into the pattern of foreign affiliate production. If the innovating producers are capable of maintaining full control over the knowledge they create, the changes in comparative advantage in production that occur over the product cycle will motivate the establishment of affiliates in other locations. This may be interpreted as an "offensive" direct investment decision. However, as the production process utilizing this knowledge standardizes, the knowledge is more easily imitated or transferred to others. If innovating producers are unable to exercise full control over their knowledge, the shift in comparative advantage abroad will be exploited at least in part by unaffiliated producers in foreign locations. Any establishment of foreign affiliates that occurs under these circumstances may be interpreted as arising from "defensive" as well as "offensive" reasons.

Changes in demand and resource endowments over time add additional dynamic complications to the picture by creating changes in a location's comparative advantage in innovation. Increases in per capita income, market size, and the relative abundancy of skilled labor and research resources in other locations may result in a shift in the comparative advantage in innovation to these locations.

Changes in demand and resource endowments over time may also affect the pattern of exports and foreign production. [4] Demand increases in locations with existing markets and emerges in the

[2] While there have been numerous writings on the product cycle theory, the most detailed descriptions are contained in Vernon [2] and Hirsch [3]. The discussion that follows is a stylized summary.

[3] Nelson and Norman [4] formulate a rigorous model of how the optimizing mix of factor inputs changes over a product cycle.

[4] Comparative advantage in production may change over time because of other developments as well, such as changes in tax or tariff levels.

lowest income locations as the income and market size of these locations grows. As a result of these demand changes exports from the innovating location initially increase. Only after production in other locations emerges will exports begin to fall, first to locations where production begins and later to other locations. Changes in resource endowments that result in a narrowing of differences in relative endowments between the innovating and foreign locations will cause a more rapid shift in the comparative advantage in production to foreign locations over the product cycle. [5] This quickens the transition from exports to foreign production in noninnovating locations.

The product cycle theory described above provides a quite general framework for explaining international trade and production patterns of manufactured goods. However, the overall validity of this framework has been questioned on the grounds that no one country is the sole source of new products and that many industries or products do not appear to display predictable cycles. Nonetheless, as demonstrated below, such apparent departures from the general patterns implied by the product cycle theory can be accounted for through flexible interpretation of the theory itself.

As a country with relatively high per capita income, large market size, and relatively abundant research resources and skilled labor, the United States has traditionally been regarded as the prototype innovating location in applications of the theory. It has been argued that in recent years the United States has lost its uniqueness as a location of innovation to Japan and countries in Europe because of an international narrowing of differences in factors which spur innovation (Vernon [5]). But while the product cycle theory originally served as a useful explanation for US export and foreign affiliate production behavior, only its simplicity and not its validity depends on the uniqueness of the United States as a location of innovation. As long as only some and not all countries are capable of innovating new products the product cycle theory remains potentially applicable.

It has also been argued that since multinational affiliates, particularly those of the United States, are now more widely spread through the world, this wider affiliate network has contributed to a shortening in the length of time between the innovation of new products and their subsequent production in foreign locations (Vernon [5]). Indeed, Vernon and Davidson [6] report that in a sample of products first produced by US-based multinational firms the proportion of such products produced by foreign affiliates within one year and three years of introduction in the United States has generally been increasing over the past 30 years. However, this evidence does not imply that new products do not go through a product cycle, but only that the transition between phases of this cycle, such as the shift in comparative advantage in production to foreign locations, may occur more rapidly. This more rapid transition may occur as a result of the narrowing in resource endowment differences between locations that a multinational firm network facilitates through a transfer of resources.

Others contend that in many industries there is little evidence of a tendency toward stability and standardization of products and their associated production processes over time. For example, Walker [7] argues that there is little evidence that technology innovations ever standardize over time in capital goods industries. The limited tendency towards standardization in some industries may be interpreted, however, as implying that some products, because of different competitive pressures, may have very truncated life cycles. It is, therefore, possible that in such cases the obsolescence rate of products may occur too rapidly, as new products supersede older ones, for the comparative advantage in production of noninnovating locations to emerge.

The product cycle theory thus provides a framework for explaining international variations from the general pattern. We now turn to examining the implications of the theory in the case of the United States.

[5] While the justification for this statement may not seem immediately apparent it is based on the assumption that the optimum input mix changes smoothly over the product cycle. Consider a world of two locations, one of which is the innovating location. The wider the difference in relative resource endowments between the two locations, the longer it will take for comparative advantage in production to shift away from the innovating location. This is so because it will take longer for the optimum input mix to evolve to the point where a production shift to the second location is optimal. If the endowment differences are narrower a production shift to the second location becomes optimal at an earlier period in the product cycle.

3. US Comparative advantage in product innovation

In order to ascertain the extent to which the uniqueness of the United States as an innovating location has been affected over the last 20 years it is necessary to examine data on location-specific characteristics which are conducive to the innovation of new products. Table 1 presents several rough measures of market size and product preference within various foreign regions. In the context of the product cycle theory these variables may be viewed as demand side factors that stimulate the innovation and production of new products. In order to more clearly draw a comparison between the strength of these factors abroad and in the United States, all figures in the table are expressed in ratio form relative to the corresponding US figures. It should be noted that foreign currency figures were rendered into common currency units by using current dollar exchange rates. This conversion probably overstates international differences in relative factor prices between the United States and the rest of the world. Therefore, an upward bias in foreign income levels is possibly introduced.[6] Nevertheless, the figures in table 1 are still instructive.

Gross domestic product and domestic consumption expenditures may be interpreted as approximate measures of market size. The figures reveal that between 1960 and 1978 all foreign regions grew in size relative to the United States. The region consisting of industrial countries other than Canada and Europe – primarily Japan – has grown proportionately the most. The gross domestic product there was 14 percent the size of that of the United States in 1960 and 54 percent in 1978.

[6] See Kravis, Kenessey, Heston, and Summers [8] and Kravis, Heston, and Summers [9] for alternative means of making international comparisons of gross product expenditures.

Table 1
Regional measures of market size and consumer product preference relative to the United States[a]

Year	Canada	Europe	Other industrial countries	Latin America	Other developing countries
Gross domestic product					
1960	0.08	0.59	[illegible]	0.12	0.11
1965	0.08	0.68	[illegible]	0.12	0.12
1970	0.08	0.71	[illegible]	0.13	0.11
1975	0.11	1.02	[illegible]	0.21	0.18
1978	0.10	1.05	[illegible]	0.20	0.18
Consumption expenditures					
1960	0.08	0.57	0.13	0.13	0.14
1965	0.07	0.67	0.17	0.14	0.14
1970	0.08	0.67	0.23	0.14	0.13
1975	0.10	0.97	0.38	0.22	0.17
1978	0.09	1.00	0.50	0.21	0.18
Per capita gross domestic product					
1960	0.81	0.36	[illegible]	0.13	0.03
1965	0.75	0.42	[illegible]	0.13	0.03
1970	0.81	0.44	0.3	0.13	0.03
1975	1.01	0.63	0.58	0.18	0.04
1978	0.90	0.66	0.74	0.17	0.04
Per capita consumption expenditures					
1960	0.82	0.35	0.19	0.14	0.04
1965	0.72	0.41	0.26	0.14	0.04
1970	0.74	0.42	0.33	0.14	0.03
1975	0.92	0.60	0.53	0.19	0.04
1978	0.82	0.63	0.68	0.18	0.04

[a] All figures are expressed as ratios relative to the United States.
Source: See appendix.

Sharp increases may be observed for the other regions as well. With the exception of Europe, however, foreign regional markets are still markedly smaller than that of the United States; in 1978 all were generally half or less in size. Only the European market now exceeds that of the United States in size, though only slightly.

Per capita gross domestic product and consumption expenditures may be interpreted as measures of product preference since higher per capita spending should be associated with a relative preference for sophisticated products. Table 1 indicates that between 1960 and 1978 foreign per capita spending in all regions grew in relation to that of the United States. Except for Canada, however, these figures were still significantly less than for the United States in 1978. While Canada's per capita gross domestic product was 90 percent that of the United States, for all other regions it was no greater than 74 percent.

Table 2 reports various research resource characteristics of the United States; France, West Germany, and the United Kingdom grouped together; Japan; and Canada. In the context of the product cycle theory these variables may be viewed as supply side factors that contribute to the innovation and production of new products.

Table 2 shows that for 1965 US per capita employment of scientists and engineers and total expenditures on research and development (R&D) were more than twice as much as any of its major rivals in innovation. Between 1965 and 1977 the differential between the United States and the other countries decreased, particularly with respect to Japan. In 1977 the United States employed 57.4 scientists and engineers for every 10,000 people; Japan 49.9. While in absolute terms total US R&D expenditures still dwarf those of the other countries, the differential in R&D expenditures as a percentage of gross national product has also narrowed. In 1961 the United States spent 2.7 percent of GNP on R&D, above the level of 1.7 percent for France, Germany, and the United Kingdom combined, and 1.4 percent for Japan. In 1977 the US figure had fallen to 2.3 percent, and the figures for the other two areas had risen to 2.1 and 1.9 percent, respectively.

There are a number of reasons that may account for the narrowing differential in R&D activity between the United States and the foreign countries mentioned above. First, the continuing postwar recovery of the latter countries during the 1960s and early 1970s has enabled them to increase significantly their expenditures for R&D. Second, US R&D activity leveled off in the latter part of this period as the result of cutbacks in defense and space-research programs which were not offset by increases in industry-financed research. In 1965 US government sponsored research for defense and space exploration accounted

Table 2
Characteristics of R&D activity in the United States and selected foreign countries

	United States		France, West Germany and United Kingdom		Japan		Canada	
	1965	1977	1965	1976 [a]	1965	1977	1965	1973
No. of scientists and engineers in R&D (thousands)	494.5	571.1	158.4	250.3	117.6	272.0	15.[illegible]	23.2
Scientists and engineers engaged in R&D per 10,000 labor force population	64.1	57.4	21.7	33.7	24.6	49.9	7.7	10.5
	1961	1976	1961 [b]	1976 [a]	1961	1976	1965	1974
R&D expenditure (billions of US $)	14.3	38.6	3.9	21.2	0.8	11.2	0.6	1.5
R&D expenditure as a percentage of GNP	2.7	2.3	1.7	2.1	1.4	1.9	1.2	1.1

[a] Figures for United Kingdom from 1975.
[b] Figures for Germany from 1962.
Source: See appendix.

for over 50 percent of total US R&D expenditures. By 1976 this figure had fallen to 32 percent.[7] A third factor accounting for the narrowing of the technology gap has been the increased transfer abroad of advanced technology through foreign investment and licensing by US firms.[8] It has been estimated that in the early 1970s about one-half of the company-financed R&D performed in Canada and about one-seventh of that in Germany and the United Kingdom was done by US-owned firms.[9]

The above examination of particular demand and supply factors that stimulate innovation indicates that for any given factor the US advantage appears to be diminishing. European market size slightly exceeds that of the United States. Certain countries, such as Canada, have comparable per capita incomes. Japanese research intensiveness is approaching that of the United States. Nevertheless, the United States is still the leading country in its combination of advantage in all such factors. Moreover, it should be noted that while other countries may be making more current *additions* to their stocks of scientific and technical knowledge, the United States still possesses a much larger accumulated *stock* of knowledge. The latter may constitute a more important indicator of technological capabilities. So while other regions appear increasingly more capable of innovating, the United States still appears qualitatively dominant in this activity.

4. US research effort and export and foreign affiliate production performance of manufacturing industries

This section examines the role of research effort, proxied by R&D expenditures, as a measure of the comparative ability of different industries to innovate and market new products in order to explain cross-industry and cross-region patterns of US export and foreign affiliate performance in 1966 and 1976.[10] In addition, attention is given to the role of regional income variables in explaining the observed patterns. Much of this analysis parallels an earlier tabular study by Gruber, Mehta, and Vernon [11] based on data for 1962.[11] The analysis here also presents industry-region multiple regression results.

Table 3 illustrates the link between research effort and export and foreign affiliate sales performance of US manufactures in 1966 and 1976.[12,13] It shows that in both years the four industries with the greatest research effort, as measured by R&D expenditures as a percentage of

[7] See [10, tables 1-5 and 2-2].

[8] It is somewhat paradoxical that while at the time of the Vietnam war, overall US military expenditures increased significantly, expenditures for military research were reduced. Increases in the US military budget in the late 1970s indicate a partial reversal in priorities for the use of defense funds in the direction of more research.

[9] Conference Board [11].

[10] A variety of measures of the comparative ability of industries to innovate and market new products have been employed in studies similar to this. The most common measure, used here, has been the level of research effort as proxied by research and development expenditures [12]. Other proxies for research effort include the number of employed scientists and technical personnel and the ratio of skilled labor to total labor [13]. Hufbauer [14] has used the degree of product differentiation, proxied by the variance in product prices, as a measure of ability to market new products. Finger [15] contends that the rate of new product turnover is more consistent with what the product cycle theory implies is important for marketing capability. He uses a proxy based on year-to-year changes in 7-digit items listed in US export schedules.

[11] Since this study makes extensive use of foreign affiliate sales data which are available on a limited disaggregated basis, the data reported here are generally classified into only nine manufacturing categories. In the study by Gruber, Mehta, and Vernon [12] data for nineteen manufacturing categories were reported. Of these nineteen categories, five were classified as displaying relatively greater research effort. Four of these five categories – transportation, electrical machinery, chemicals, and non-electrical machinery – match up with what are classified in this study as research-oriented industries. The fifth category, instruments, is here contained in 'other manufacturing.' This tends to blur slightly the otherwise sharp differences between research-oriented industries and the other industries. Of the remaining fourteen categories in the Gruber, Mehta, and Vernon study, only rubber, food, paper, and metals (primary and fabricated together) are broken out here separately. The rest are contained in other manufacturing, with the exception of petroleum and coal manufactures, which are excluded here altogether.

[12] These figures are also affected by differences across industries in transportation, tariffs, and factor costs.

[13] Foreign affiliate sales figures include local sales, sales to the United States, and sales to third countries. Exclusion of sales to the United States does not significantly affect any of the reported conclusions, except as indicated below in the case of Canada.

Table 3
Research effort and export and foreign affiliate sales performance by US manufacturing industry, 1966 and 1976

Industry name [a]	Total R&D expenditures as percentage of sales of domestic firms		Exports as percentage of sales of domestic firms		Foreign affiliate sales as percentage of sales of domestic firms		Exports and foreign affiliate sales as percentage of sales of domestic firms	
	1966	1976 [b]	1966	1976	1966	1976	1966	1976
Transportation	9.6	7.1	4.7	14.9	15.6	39.5	20.3	54.4
Electrical machinery	8.9	8.6	4.6	14.3	10.8	28.7	15.4	43.0
Chemicals	3.4	2.9	6.5	11.9	18.2	48.1	24.7	53.6
Machinery, non-electric	2.6	2.8	11.8	22.2	14.0	35.7	25.7	57.9
Rubber	1.4	1.0	1.4	1.8	15.1	20.8	16.5	22.6
Other manufacturing	0.6	0.7	1.6	3.4	3.9	10.0	5.5	13.4
Paper	0.6	0.6	2.1	3.9	9.3	24.2	11.4	28.1
Metals	0.5	0.5	2.2	3.0	4.9	9.6	7.1	12.7
Food	0.2	0.2	0.7	0.8	7.1	11.8	7.8	12.6
All nine industries	2.9	2.3	3.6	7.5	9.3	20.5	12.8	29.4
Four industries with highest research effort	6.6	5.2	6.7	15.8	14.7	38.7	21.5	54.5
Five other industries	0.5	0.5	1.5	2.5	5.7	11.9	7.3	14.4

[a] Industries arranged in descending order of research effort in 1966, defined by R&D expenditure as a percentage of total sales of domestic firms.
[b] R&D and sales figures for 1975.
Source: See appendix.

total sales by US domestic firms, displayed the best export and foreign affiliate sales performance in relation to sales of domestic firms. In 1966 these four industries – transportation, electrical machinery, chemicals, and non-electric machinery – spent the equivalent of 6.6 percent of their sales on R&D compared to 0.5 percent for the remaining industries. They exported 6.7 percent of their sales compared to 1.5 percent for the remaining industries and sold through foreign affiliates the equivalent of 14.7 percent of sales compared to 5.7 percent. [14]

Reflecting the increasing openness of the US economy over time, total US manufacturing exports and foreign affiliate sales roughly doubled between 1966 and 1976. As a group the four research-intensive industries more than doubled their export and foreign affiliate sales percentages over this period and improved their export and foreign sales performance in relation to the five other manufacturing industries. In 1976 they exported 15.8 percent of their sales compared to 2.5 percent for the remaining industries and sold through foreign affiliates the equivalent of 28.7 percent of sales compared to 11.9 percent.

The figures in table 3 are somewhat arbitrarily influenced by the way in which industries are categorized. Table 4 gives a better indication of the proportionate role of the reported industry categories in overall manufactures for 1966 and 1976. Table 4 reveals that in 1966 the four industries classified above as research-oriented accounted for 89.4 percent of total R&D expenditures and 79.7 percent of company-financed R&D expenditures in US manufacturing. They accounted for 73.4 percent of total manufacturing exports and 65.5 percent of foreign affiliate sales, but only 39.1 percent of the total sales by domestic US firms. In 1976 they were responsible for an even slightly greater proportion of total exports and affiliate sales – 79.0 and 66.1 percent, respectively – while accounting for only 37.5 percent of total

[14] It should be noted that addition of exports and foreign affiliate sales may overstate the extent of US foreign market penetration to the degree that US exports serve as intermediate inputs for foreign affiliate production. This bias in the data cannot be eliminated.

Table 4
Distribution of research effort and sales of domestic firms, exports, and foreign affiliates among US manufacturing industries, 1966 and 1976

Industry name [a]	Percentage distribution									
	Total R&D expenditures		Company financed R&D expenditures		Domestic firm sales		Export sales		Foreign affiliate sales	
	1966	1976	1966	1976 [c]	1966	1976	1966	1976	1966	1976
Transportation	46.8	36.8	26.7	23.4	14.0	11.7	18.5	23.4	23.5	21.0
Electrical machinery	24.7	25.1	21.1	21.9	8.0	6.6	10.3	12.7	9.3	8.7
Chemicals	9.6	12.0	18.1	17.5	8.0	9.3	14.6	13.6	15.7	20.3
Machinery, non-electrical	8.3	12.1	13.8	16.6	9.1	9.9	30.0	29.3	13.7	16.1
Rubber	1.1	1.3	2.2	1.9	2.3	2.8	1.0	0.7	3.8	2.7
Other manufacturing	4.9	7.0	8.6	9.9	23.3	22.3	10.3	10.0	9.8	10.2
Paper	0.8	1.1	1.7	1.8	4.0	4.3	2.4	2.2	4.0	4.7
Metals	2.6	3.1	5.4	4.7	15.7	15.4	9.7	6.3	8.2	6.8
Food	1.1	1.5	2.4	2.3	15.6	17.7	3.1	1.8	11.9	9.6
All nine industries [b]	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
Four industries with highest research effort	89.4	86.0	79.7	79.4	39.1	37.5	73.4	79.0	62.2	66.1
Five other industries	10.6	14.0	20.3	20.6	60.9	62.5	26.6	21.0	34.5	33.9

[a] Industries arranged in descending order of research effort in 1966, defined by total R&D expenditures as a percentage of total sales of domestic firms.
[b] Totals may not add to 100.0 due to rounding error.
[c] Figures for 1975.
Source: See appendix.

sales by domestic firms. Table 4 thus confirms the impression created by table 3 that research-oriented industries serve as the major producers of US manufacturing exports and foreign affiliate sales as the product cycle theory suggests. This accords with Gruber, Mehta and Vernon's findings for 1962 as well.

Table 5 disaggregates export and foreign affiliate sales figures by region as well as by the four industries with most research effort and the other

Table 5
Foreign affiliate sales and exports by region and research effort [a] of US manufacturing industry, 1966 and 1976

Region	US foreign affiliate sales (billions of dollars)						US export sales	
	All nine industries		Four industries with highest research effort		Five other industries		All nine Industries	
	1966	1976	1966	1976	1966	1976	1966	1976
All regions	47.4	212.8	29.5	140.5	17.9	72.3	18.2	72.5
Europe	21.7	112.2	14.7	76.8	7.0	35.4	5.2	18.7
Canada	14.9	49.3	8.5	30.0	6.4	19.3	5.0	19.0
Other industrial	3.9	18.4	2.8	13.1	1.1	5.3	1.7	6.8
Latin America	5.9	26.3	3.0	16.0	2.8	10.3	3.6	12.8
Other developing	1.0	6.6	0.4	4.7	0.6	1.9	2.7	15.1

[a] Research effort of industries defined by total R&D expenditure as a percentage of total sales of domestic firms in 1966.
Source: See appendix. Data disaggregated individually by industry are available from the author upon request.

five industries, for the years 1966 and 1976, respectively. It shows that for both years the pattern observed above between exports and foreign affiliate sales of research-intensive and non-research-intensive industries holds across regions as well. For any given region, exports and foreign affiliate sales of research-intensive industries exceed those of the remaining industries. If these figures had been expressed relative to sales of domestic firms the differences would appear even greater since, as noted earlier, sales of domestic firms in research-oriented industries are smaller than those of other industries. In 1966 the sales of domestic firms in research-oriented industries and in other industries were $199.8 billion and $311.7 billion, respectively. In 1976 the corresponding figures were $363.1 billion and $606.6 billion.

Upon further inspection of the figures in table 5 a particular cross-region pattern emerges as well. Recalling the per capita and total income figures reported in table 1, the categorization of Europe, Canada, and 'other industrial countries' as developed regions and Latin America and 'other developing countries' as developing regions is apparent. From calculations based on the figures in table 5 it is possible to discern that in 1966 the ratio of affiliate sales of products in research-oriented industries to products in the remaining industries for the three developed regions together, 1.80, is greater than that for the two developing regions, 1.01. A similar, though less strong, relationship exists for exports as well, 2.88 to 2.61, respectively. This pattern accords with the implication of the product cycle that sophisticated, technological products should be realtively more marketable in comparison to less sophisticated products in regions with large market size and high per capita income. This pattern holds up for foreign affiliate sales in 1976 as well. The ratio of affiliate sales of products in research-oriented industries to products in the remaining industries for the developed regions was then 2.00, compared to 1.69 for the developing regions. The pattern does not hold up for exports in 1976. For that year the export ratio for the developed regions was 3.35 and for the developing regions, 4.59. The figure for developing regions is somewhat biased upwards because of unusually large aircraft sales in the transportation category that occurred in that year. However, even if this bias is removed, it does not reverse the relationship. Possibly this may be accounted for by increased shipments of manufactured components and equipment to affiliates in developing countries for use in the production of products subsequently marketed in more developed regions.

Table 5 also presents ratios of exports to affiliate sales across industries and regions for the years 1966 and 1976. In both years for any given industry, exports in relation to affiliate sales are lower for the developed regions than for the developing regions. The research-intensive industries exhibit this pattern to a somewhat more marked degree. Thus it appears that the composition of products marketed abroad by the United States may be such that developed countries have a comparative advantage in production compared to de-

(billions of dollars)				Ratio of US exports to foreign affiliate sales					
Four industries with highest research effort		Five other Industries		All nine Industries		Four industries with highest research effort		Five other Industries	
1966	1976	1966	1976	1966	1976	1966	1976	1966	1976
13.4	57.3	4.8	15.2	0.39	0.34	0.45	0.41	0.27	0.21
3.7	14.0	1.5	4.6	0.24	0.17	0.25	0.18	0.2[illegible]	0.13
3.8	15.0	1.2	4.0	0.34	0.38	0.44	0.50	0.19	0.22
1.[illegible]	5.3	0.4	1.6	0.43	0.37	0.48	0.40	0.33	0.28
2.6	10.1	1.0	2.7	0.61	0.49	0.87	0.64	0.34	0.26
1.9	12.8	0.8	2.3	2.66	2.29	4.70	2.7[illegible]	1.29	1.21

veloping countries, particularly with respect to research-intensive goods.

It should also be noted that between 1966 and 1976 the ratio of exports to foreign affiliate production generally fell for all regions and industries, with the broad exception of Canada where imports from the United States are strongly affected by multinational intrafirm transactions. This trend may indicate that the comparative advantage in production of new products has shifted abroad at a faster rate or that the greater availability of production knowledge to unaffiliated firms has prompted greater foreign affiliate expansion for defensive reasons. The falloff of US exports relative to foreign affiliate production does not necessarily imply that US ability to penetrate foreign markets through new product innovation has been declining. The product cycle theory implies that a country's comparative advantage in innovation manifests itself through both exports and foreign affiliate production. The observation that US exports are falling in relation to foreign affiliate production may simply reflect the quickening transition from exports to foreign production. This accords with the contention discussed earlier that a narrowing of relative factor endowments between countries and wider affiliate networks may have contributed to a shortening in the length of time between the innovation of new products in the United States and subsequent production in foreign locations. More particularly, as the extreme relative capital and skilled labor abundance of the United States has eroded, it has become less important to maintain production of newly innovated products in the United States at the earlier stages of their development. [15] The growth of US foreign affiliates abroad as well as the spread of technical knowledge to unaffiliated firms may have further facilitated the trend of increasing foreign production relative to exports. [16]

It is interesting to compare changes in US exports and foreign production to overall foreign market growth. While total sales from all sources would constitute the ideal measure of foreign market size, such data is unobtainable on a consistent basis across all regions. As a crude approximation, regional income is used instead. Ta-

[15] See Bowen [16] for empirical measurement of the changing resource structure of the United States and various foreign countries. He finds that the US world share of physical capital fell from 42 percent in 1963 to 33 percent in 1975. The US share of skilled labor fell correspondingly from 29 to 26 percent.

[16] Protectionist barriers may also have played a role in inducing increases in US foreign affiliate production abroad. However, over the period 1965 to 1976 tariff barriers faced by US exports in developed countries fell. Non-tariff barriers which are more difficult to measure, may have been increasing. It should be noted that an earlier study [17] of effects of formation of the European Economic Community could find no effects of tariff barriers influencing US direct investment within the area.

Table 6
Foreign affiliate sales and exports relative to regional income by region and research effort [a] of US manufacturing industry, 1966 and 1976

Region	Ratio of US foreign affiliate sales to regional income						Ratio of US export sales to	
	All nine industries		Four industries with highest research effort		Five other industries		All nine industries	
	1966	1976	1966	1976	1966	1976	1966	1976
All regions	0.054	0.067	0.034	0.044	0.020	0.023	0.021	0.023
Europe	0.043	0.069	0.029	0.048	0.014	0.022	0.010	0.012
Canada	0.254	0.250	0.146	0.152	0.109	0.098	0.086	0.096
Other industrial	0.027	0.026	0.019	0.018	0.007	0.007	0.011	0.010
Latin America	0.063	0.076	0.033	0.046	0.030	0.030	0.039	0.037
Other developing	0.013	0.022	0.005	0.015	0.008	0.006	0.035	0.050

[a] Research effort of industries defined by total R&D expenditure as a percentage of total sales of domestic firms in 1966.
Source: See appendix. Data disaggregated individually by industry are available from the author upon request.

ble 6 presents figures on the ratios of US exports and foreign affiliate production to regional income for 1966 and 1976. Several broad conclusions may be drawn from this data. First of all, both US exports and foreign affiliate sales to all regions aggregated together rose faster over the period than foreign income. However, a more enlightening pattern emerges when the data is categorized by industry research effort. With the exception of foreign affiliate sales in Europe, US exports and foreign affiliate sales in the less research-intensive industries have either remained flat or have fallen in relation to foreign income. With the exception of the 'other industrial countries' region, US exports and foreign affiliates sales in the most research-intensive industries have all risen in relation to foreign income.[17] Thus US ability to penetrate foreign markets appears to have kept pace with foreign market size only in research-intensive industries. This pattern holds for developing regions as well as for developed regions. As the market in developing countries has grown their demand for research-intensive products has grown as well.

The interpretation of the product cycle theory and the tabular analysis above have both suggested the existence of a positive relation between US foreign market penetration, through either US exports or foreign affiliate production, and industry R&D (RD), regional market income (Y), and regional per capita income (PY).[18] These hypotheses were further tested by estimating joint industry and region cross-section regressions of the sum of total US exports and affiliate production on these variable for the years 1966 and 1976. The estimated coefficients may be regarded as average measures of the effects of the independent variables on US foreign market penetration across different industries and regions.

The results of these regressions are reported in table 7. All variables were found to conform with expected positive signs. PY and RD were significant throughout at the 0.01 level. Y was significant at the 0.05 level for both years. In order to determine whether there was any change in the cross-section regression coefficients over time, the data for the two years 1966 and 1976 were pooled and the equation was estimated with the inclusion of dummy interaction terms. The null hypothesis that there was no change in the coefficient between 1966 and 1976 was accepted for Y and PY, but was rejected for RD at the 0.01 level. The coefficient for RD was slightly more positive in 1976 as compared to 1966. This suggests that

[17] The divergent pattern of the 'other industrial countries' region probably arises from an upward bias in the dollar value of Japanese income due to the sharp appreciation of the yen in the mid-1970s.

[18] In order to capture the relation of product technology to the accumulated stock, rather than the flow, of technical knowledge, the RD variable was calculated by summing up the previous five years annual R&D expenditures.

regional income				Ratio of US exports and foreign affiliate sales to regional income					
Four industries with highest research effort		Five other Industries		All nine industries		Four industries with highest research effort		Five other industries	
1966	1976	1966	1976	1966	1976	1966	1976	1966	1976
0.015	0.018	0.005	0.005	0.074	0.090	0.049	0.062	0.026	0.028
0.007	0.009	0.003	0.003	0.053	0.081	0.036	0.056	0.017	0.025
0.065	0.076	0.021	0.020	0.341	0.347	0.211	0.228	0.130	0.118
0.009	0.007	0.002	0.002	0.038	0.035	0.028	0.026	[illegible]	0.010
0.028	0.029	0.010	0.008	0.102	0.112	0.061	0.046	0.041	0.037
0.025	0.042	0.010	0.008	0.048	0.072	0.030	0.058	0.018	0.014

Table 7
Region-industry cross-section regressions on US total foreign market penetration, 1966 and 1976

Year	C	Y	PY	RD	R^2	RSE
1966	−0.265	0.0031	0.636	0.056	0.57	0.627
	(1.07)	(2.51)*	(6.02)**	(4.10)**		
1976	−1.257	0.0042	0.618	0.213	0.45	0.752
	(0.929)	(2.09)*	(3.67)**	(4.31)**		

Regressions corrected for heteroscedasticity by scaling variables by linear functions of Y estimated from residuals of unscaled regressions. Two-tailed levels of significance are indicated as *(0.05) and **(0.01), with t-statistics reported in parentheses. R^2 is the unadjusted coefficient of determination for scaled regression equations. RSE is the standard error of each scaled regression relative to the mean of its dependent variable.

R&D expenditures have been having more of an impact on US foreign market penetration over the course of the period. [19] Possibly more rapidly diminishing US relative advantage in other endowments, such as physical capital, have encouraged this increasing R&D intensity of US overseas sales.

Identically specified regression equations were estimated for foreign affiliate production and exports separately. The results, which are not shown here, indicate that for foreign affiliate production all variables had the expected signs. The coefficients on all variables, including the constant term, were statistically significant at the 0.05 level for 1966 and slightly below 0.05 for 1976. There was evidence that the coefficients on Y, PY, and RD were significantly more positive in 1976 than in 1966. This suggests that foreign affiliate sales have become more sensitive to these variables over time. For exports the results were much less satisfactory. Y was found to be insignificant in all cases. PY had the correct sign and was significant at the 0.10 level for 1966, but was not significant for 1976. Only RD was found to have the correct sign and be significant for both years. There was also evidence that the coefficient on RD was more positive in 1976 than in 1966. In some sense the greater instability over time of the coefficients of the regional variables, Y and PY, in these separate regressions points indirectly to the trade-off between exports and foreign affiliate production as means of penetrating foreign markets. While it would have been desirable to include measures of trade barriers as explanatory variables, this did not prove possible given difficulties in obtaining such measures for the aggregated industry and regional categories used for two dates in time.

[19] A similar result was found in a study by Stern and Maskus [18].

5. Conclusions

Research effort still plays a great role in explaining the pattern of export and foreign affiliate production performance of the United States across industries and regions. Notwithstanding the narrowing of differences in relative research capability between the United States and the rest of the world, the US industries which are research-intensive perform best in foreign markets. The relative performance of these industries is greater in those regions with large market size and high per capita income. In addition, it is observed that over the period between 1966 and 1976 the ratio of US exports to foreign affiliate sales has generally fallen for all industries and foreign markets. This possibly reflects a quickening in the transition from exporting of new products to their foreign production.

These observations accord with a broad interpretation of the product cycle theory. While the United States has lost its uniqueness as a location of innovation, the ability to develop and market new products through R&D expenditures is still a strong force behind its exports and sales abroad. The decrease in exports relative to foreign affiliate sales may reflect a more rapid shift in comparative advantage in the production of such products to foreign locations. Hence the positive effect on US exports of the development of any given new product may be becoming more short-lived.

Appendix

This appendix describes the sources and transformations of data used in text tables.

Annual data on gross national product and consumption expenditures in national currency units, average exchange rates expressed in dollars per unit of national currency, and population figures for individual countries listed in table 8 were taken from the IMF International Financial Statistics tape for April 1981. National currency figures converted into dollar terms and population figures were then summed over countries in each regional category.

National R&D activity measures – number of scientists and engineers in R&D, scientists and engineers engaged in R&D per capita, R&D expenditure, and R&D expenditure as a percentage of GNP – were taken from NSF *Science Indicators, 1978*, tables 1-1 and 1-3, pp. 140–141, 143 [10]. Where necessary, national currency figures were converted into dollar units by average annual dollar exchange rates. Annual industry level total R&D expenditures for 1966 were taken from NSF *R&D in Industry, 1971*, 73-305, table B-3, p. 28 [19]; and for 1975 from NSF *R&D in Industry, 1976*, 78–314, table B-3, p. 30 [19]. Company-financed R&D expenditures for 1966 were taken from [19] 73–305, table B-11, p. 36; and for 1975 from [19] 78–314, table B-9, p. 36. Industry categories referred to in the text were defined according to the SIC schedule described in table 9.

Annual total sales of domestic firms by industry were measured by value of shipments data. Figures for 1966 were obtained from US Bureau of the Census, *Annual Survey of Manufactures, 1971*,

Table 8
Countries contained in regional measures of gross domestic product, consumption expenditure and population

Region				
Canada	Europe	Other industrial	Latin America	Other developing
Canada	Germany	Japan	Argentina	Indonesia
	Italy	New Zealand	Brazil	Iraq
	France	Australia	Mexico	Nigeria
	United Kingdom	South Africa	Venezuela	Egypt
	Sweden		Colombia	Israel
	Spain		Peru	India
	Netherlands			Korea
	Belgium			Philippines
	Greece			
	Turkey			

Table 9
Concordance between Commerce Department manufacturing categories and SITC and SIC schedules

	SITC	SIC
Food Products	013, 023, 024, 032, 046, 047, 048, 053, 055, 061, 062, 091, 099, 111, 112	20
Paper products	64	26
Chemicals	5	28
Rubber	62	30
Primary and fabricated metals	67, 68, 69	33, 34
Non-electrical machinery	71	35
Electrical machinery	72	36
Transportation	73	37
Other manufacturing	61, 63, 65, 66, 8, 122	21, 22, 23, 24, 25, 27, 31, 32, 38, 39

M71(AS)-10 [19], and for 1975 and 1976 from US Bureau of the Census, *Annual Survey of Manufacturers, 1976*, M76(AS)-7 [20]. Foreign affiliate sales figures by industry and region were constructed from US Department of Commerce data in unpublished tables and in the *Survey of Current Business*, August 1974, May 1976, and May 1978 [21]. US export figures by industry and region were constructed from annual issues of OECD, *Trade by Commodities*, Series B [22].

References

[1] M.V. Posner, International Trade and Technical Change, *Oxford Economic Papers* (1961).

[2] R. Vernon, International Investment and International Trade in the Product Cycle, *Quarterly Journal of Economics* (May 1966).

[3] S. Hirsch, *Location of Industry and International Competitiveness*, (Clarendon Press, Oxford, 1967).

[4] R. Nelson and V. Norman, Technological Change and Factor Mix Over the Product Cycle *The Journal of Development Economics* (March 1977).

[5] R. Vernon, The Product Cycle Hypothesis in a New International Environment, *Oxford Bulletin of Economics and Statistics* (Nov. 1979).

[6] R. Vernon and W. Davidson, Foreign Production of Technology-Intensive Products by U.S.-Based Multinational Enterprises, Working Paper 79-5, (Harvard Business School, Cambridge, Mass., 1979).

[7] W. Walker, *Industrial Innovation and International Trading Performance*, (JAI Press, Greenwich, Ct., 1979).

[8] I. Kravis, Z. Kenessey, A. Heston and R. Summers, *A System of International Comparisons of Gross Product and Purchasing Power* (John Hopkins University Press, Baltimore, 1975).

[9] I. Kravis, A. Heston and R. Summers, Real GDP Per Capita for More Than One Hundred Countries, *Economic Journal* (June 1978).

[10] US National Science Foundation, *Science Indicators, 1978* (Government Printing Office, Washington, DC, 1979).

[11] Conference Board, *Overseas Research and Development by U.S. Multinationals, 1966–1975* (Conference Board, New York, 1976).

[12] W. Gruber, D. Mehta and R. Vernon, The R&D Factor in International Trade and Investment of U.S. Industries, *Journal of Political Economy* (Feb. 1967).

[13] S. Hirsch, The Product Cycle Model of International Trade: A Multi-Country Cross-Section Analysis, *Oxford Economic Bulletin of Economics and Statistics*, (Nov. 1975).

[14] G. Hufbauer, The Impact of National Characteristics and Technology on the Commodity Composition of Trade in Manufactured Goods, in: R. Vernon (ed.) *The Technology Factor in International Trade* (National Bureau of Economic Research for Columbia University, New York, 1970).

[15] T. Finger, A New View of the Product Cycle Theory, *Weltwirtschaftliches Archiv* (1975).

[16] H.P. Bowen, Changes in the International Pattern of Factor Abundance and the Composition of Trade. Economic Discussion Paper 8 (US Department of Labor, Office of Foreign Economic Research, 1980).

[17] A. Scaperlanda and L. Mauer, The Determinants of U.S. Direct Investment in the EEC, *American Economic Review* (Sep. 1969).

[18] R. Stern and K. Maskus, Determinants of the Structure of U.S. Foreign Trade, 1958–1975, *Journal of International Economics* (May 1981).

[19] U.S. National Science Foundation, *Research and Development in Industry, 1971* (NSF 73-305), *1976* (NSF 78-314) (Government Printing Office, Washington, DC, 1973, 1978).

[20] US Bureau of the Census, *Annual Survey of Manufactures, Industry Profiles, 1971*, M71(AS)-10 *1976*, M76(AS)-7 (Government Printing Office, Washington, DC, 1973, 1978).

[21] US Department of Commerce, *Survey of Current Business* (Government Printing Office, Washington, DC, various issues).

[22] OECD *Statistics of Foreign Trade, Trade by Commodities, Series B* (Paris, 1966–1976).