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COMPARISONS OF COMPETITIVENESS IN U.S. AND SWEDISH MANUFACTURING

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ABSTRACT

Over the course of the last 10 or 15 years there appears to be taking place a fundamental shift in the "industrial paradigm" governing the nature of competition in advanced industrial markets. Among the characteristics of this shift are a transition from mass production to flexible manufacturing technologies, reduced time for development of new products, shorter product life cycles, increased product diversity, increasing expenditures on industrial R&D, shrinking firm size ("deglomeration"), specialization on "niches" or "core business areas", and more intense global competition even in products that previously seemed exempt from such pressures.

The object of this paper is to bring these themes together by examining the development of the competitive position in world markets of the United States and Sweden, two countries which are apparently pursuing very different strategies in dealing with the new challenges. The first part of the paper examines the international trade performance of the two countries with emphasis on different patterns of trade with respect to goods of varying research and development intensity. A simple model for analyzing the differences in performance is suggested in the second section. The third section draws together fragments of empirical evidence in support of the hypothesis.

COMPARISONS OF COMPETITIVENESS IN U.S. AND SWEDISH MANUFACTURING*

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I. Introduction

Since about the middle of the 1970s there appears to be taking place a fundamental shift in the "industrial paradigm" governing the nature of competition in advanced industrial markets. Among the characteristics of this shift are a transition from mass production to flexible manufacturing technologies, reduced time for development of new products, shorter product life cycles, increased product diversity, increasing expenditures on industrial R&D, shrinking firm size ("deglomeration"), specialization on "niches" or "core business areas" (at least in Western, if not Japanese, firms), and more intense global competition even in products that previously seemed exempt from such pressures.

The object of this paper is to bring these themes together by examining the development of the competitive position in world markets of the United States and Sweden, two countries which have seen their world market shares decline but which are apparently taking very different approaches in dealing with the new challenges. The central questions are: (1) What similarities and

* This version of the paper has benefitted from insightful comments by Paul A. David and Staffan Jacobsson which are hereby gratefully acknowledged. A further revision is in progress.

dissimilarities in the international trade experience of these countries can be identified, and (2) what are the likely causes of the observed patterns? The next section of the paper examines the postwar international trade performance of the two countries with emphasis on different patterns of trade with respect to goods of varying research and development intensity. In the third section, the Abernathy/Utterback model of product and process innovation in industry is adapted to analyze the differences in trade performance. It is argued there that differences in trade performance can be understood by examining the strategies pursued by domestic firms with respect to innovation and production. More specifically, it is hypothesized that U.S. firms which rely heavily on either product innovation or mass production have fared worse than Swedish firms which specialize on relatively slowly evolving industrial products whose production is characterized by flexible production methods. The reasons for different strategic choices are outlined. Section IV draws together fragments of empirical evidence in support of the hypothesis, and Section V concludes the paper.

II. Comparison of International Trade Performance

II.1 Aggregate Development

One of the most prominent features of the economic development during the postwar period is the internationalization of the world economy. This is manifested in increased exposure to foreign trade via both trade and capital flows. As can be seen in Figure 1, in the United States the exports/GNP ratio rose from somewhat below

5 percent in the 1950s to 10 percent in 1980 and then fell back to the 7 percent range in the mid-1980s. In Sweden, the exports/GNP ratio stayed constant at around 22 percent during the 1950s and 60s, then rose rapidly to 37 percent in 1984 before slacking off slightly in the most recent years. Thus, except for the fact that the first oil crisis and associated events in 1973-74 had extremely beneficial (but temporary) effects on Swedish exports, the U.S. and Swedish patterns are roughly parallel up to about 1980. In the 1980s, the Swedish export performance has improved while that in the United States has deteriorated.

Despite its increased participation in world trade, the United States has suffered a gradually declining share of the total exports of all industrial countries throughout the whole postwar period. As shown in Figure 2, the decline was fairly steady during the 1950s and 60s. The dominant position of the United States in many industrial markets at the end of World War II was elevated far above a sustainable level due to the physical destruction during the war in most of its major competing countries. It was only to expected that this dominance would be gradually reduced as Europe and Japan recovered from the war and the conditions for world trade were "normalized." The U.S. share moved somewhat erratically around a constant trend during the 1970s but has been in decline since 1981. The development in the 1970s and 80s will be dealt with in more detail below. But whatever the reason is for the gyrations of the U.S. world trade share in the last two decades, the net result is that the 25 percent U.S. market share loss in the 17 years after

1970 represents a continuation at an undiminished rate of the decline in the previous 20 years. Whereas postwar adjustments probably explain most of the decline in the 1950s and 60s, the explanation for the continued decline in the 70s and 80s must be sought elsewhere.

By contrast, the Swedish share of industrial country exports remained virtually unchanged from 1950 to 1975. Then, within a span of only six or seven years, Sweden lost over 20 percent of its share of industrial country exports. The reasons for this development are fairly well known: the oil price shocks of 1973-74 placed a heavy burden on Sweden, comparatively one of the world's largest importers of oil. But the negative impact of this price shock was masked for at least a year by sharp price increases on Swedish exports, particularly forest products. The result was a current account surplus and a sharp rise in industrial output which led to overly expansive fiscal policies and rapid wage inflation. Meanwhile, the reduced demand for oil diminished the demand for shipping services and hence for large oil tankers. The resulting overcapacity of the shipyards meant less demand for steel which also suffered because of the slump in the investment goods industries triggered by all the uncertainty in world markets. The worldwide overcapacity in the steel industry also reduced the demand for Swedish iron ore. Starting in 1975 a cyclical decline in paper and pulp exports aggravated the situation further. It has been calculated that the market for some 23 percent of Swedish exports suddenly disappeared, with little hope of regaining the lost markets for the products affected (outside of the forest-based products). (Carlsson et al., 1979, pp. 18-23.) As indicated above, there have been some signs of recovery in the last half of the 1980s; but as will be shown later, this recovery has been entirely in other lines of business than those directly affected in the 1970s. The essential problem remains: how to make the remaining industry large and competitive enough to regain the lost market share. Or, to use Dahmén's terminology: the question is whether Swedish industry has the "development power" to expand into new areas of industrial activity; this is not merely a matter of "competitiveness" in the usual sense of containing relative costs (which are affected by exchange rates and other cost factors) but of being able to generate new products and businesses. As indicated below, this is really the U.S. problem as well: not merely to close the trade gap but to gain world market share under conditions of balanced trade.

The recent loss in U.S. world market share is reflected also in the performance on current account in the balance of payments. As shown in Figure 3, the current account/GNP ratio fluctuated around zero in both countries (with wider amplitude in Sweden, as could be expected in view of the greater exposure to foreign trade) until the early 1980s, and then diverged sharply. It fell in the United States and rose in Sweden.

II.2 Macroeconomic Explanations

Why this divergent behavior in the 1980s? There are likely to be both macroeconomic and microeconomic reasons. As far as macroeconomic explanations are concerned, it is often argued that a country's trade performance is governed in part by the exchange rate; the exchange rate is a function of relative interest rates which in turn are influenced by domestic imbalances reflected prominently in government deficit spending. The development of the government deficits in both countries is illustrated in Figure 4. Again it turns out that the patterns are very similar until the late 1970s, with the Swedish deficit/GNP ratio fluctuating more widely than that in the United States. However, given the superior Swedish trade performance in the 1980s in comparison with the United States, it may be surprising at first glance that until quite recently the government deficit was substantially larger in Sweden than in the U.S. But the puzzle is fairly easily solved by an examination of the development of exchange rates. Figure 5 shows that in the Swedish case there is a close relationship between the balance on current account and (the reciprocal of) the exchange rate. The declines in the exchange rate in 1977 and 1982 (by 10 % and 16 % nominally, respectively, represented by upturns in Figure 5) were due to devaluations of the Swedish krona. Similarly, there appears to be a strong correlation between the exchange rate (not its reciprocal) and the size of the government deficit: the larger the deficit, the lower the exchange rate (see Figure 6). It also appears that changes in these variables are simultaneous rather than lagged in relation to each other.[1]

The corresponding development in the United States is represented in Figure 7. The U.S. picture differs from the Swedish one in two ways: (1) there appears to be a two-year lag between changes in the government deficit and the (reciprocal of the) exchange rate, and a further two-year lag between the exchange rate and the trade balance. (2) Secondly, the relationship between the government deficit and the exchange rate appears to be opposite of that in Sweden: as the budget deficit increases, the value of the currency rises. This presumably has to do with (1) the status of the U.S. dollar as a reserve currency and international store of value and (2) the sensitivity of the exchange rate to interest rates which are positively correlated with the size of the government deficit. Thus, it seems fair to say that in the U.S., domestic economic policy has contributed to further losses of U.S. world market share in the 1980s, adding burdens on U.S. industry in addition to the problems which have generated the long-term decline in U.S. world market share. In Sweden, disastrous domestic

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[1] The visual impressions of Figures 5 and 6 are confirmed in the following regressions:

$$\underset{}{RECXCHRT} = \underset{(44.37)}{10.14\ C} + \underset{(3.79)}{0.41\ CURRACCT}; \quad \text{Adjusted } R^2 = 0.53$$

$$RECXCHRT = \underset{(16.93)}{8.90\ C} - \underset{(-3.17)}{0.25\ GOVDEFCT}; \quad \text{Adjusted } R^2 = 0.45$$

where RECXCHRT = reciprocal of the effective exchange rate; CURRACCT = balance on current account; GOVDEFCT = government deficit; C = a constant, and t-values are given in parentheses.

policies in the late 1970s and early 1980s designed to preserve failing industries and to avoid unemployment have been compensated for by devaluations which seem to have been relatively successful. Further, it is likely, following the argument in a recent study by Mancur Olson (1989), that the reason the burden on the growth rate and trade performance of the Swedish economy placed by the complex of welfare state policies has not been as severe as might have been expected is that the economy has remained open and exposed to the intense pressure of foreign competition.

II.3 Microeconomic Explanations

II.3.1 Disaggregation with respect to R&D intensity

The microeconomic story behind the aggregate development just outlined is fairly complex. There are several ways to approach it in more detail. One is to analyze the trade performance in both countries with respect to research and development (R&D) intensity. The development of R&D expenditures in relation to GNP in various countries over the period 1961-1987 is shown in Figure 8. Four features stand out: (1) the United States, with a strong lead in the 1960s, saw its absolute level of R&D spending as a percentage of GNP decline until the late 1970s. (2) In other countries (except the United Kingdom), R&D spending has increased over the period as a whole. (3) Despite a sharp increase in R&D spending during the 1980s, the U.S. has not reached the level of the early 1960s and has lost its leadership role. (4) Other countries, notably Sweden, Japan, and West Germany, now spend more on R&D in relation to their respective GNP than does the United States.

If one divides manufacturing exports into goods characterized by high, medium, and low R&D intensity[2], respectively, the following picture emerges (see Table 1): The U.S. appears to have lost export shares across the board between 1970 and 1984, but particularly in medium R&D-intensive goods. As shown in the lower part of Table 1, the U.S. share of OECD manufacturing exports in such products was 21 percent smaller in 1984 than in 1970. In high R&D-intensive goods and low R&D-intensive goods, the market share loss was 12 and 11 percent, respectively. The Swedish shares were reduced even further: by 27 percent in high R&D-intensive goods and by 14 percent in both medium and low R&D-intensive goods.

The development in terms of trade balances in manufactured goods, using the classification of products with respect to R&D intensity, is shown in Figure 9. The United States maintained a positive trade balance in high and medium R&D-intensive goods until the early 1980s while sustaining a steadily increasing import surplus of low R&D-intensive goods. Sweden, on the other hand, had a small negative balance of highly R&D-intensive goods and gradually increasing positive balances in medium and low R&D-intensive goods. For comparison it may be pointed out that Japan experienced sharply increasing positive trade balances in both high and medium R&D-intensive goods, while the EEC had an increasingly

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[2] For a definition of high, medium, and low R&D-intensive goods, see Table 3 below.

positive trade balance in medium R&D-intensive goods and a small export surplus in the other two categories.

Another way to represent the development is by examining apparent comparative advantage. A country is said to have an apparent comparative advantage in a particular commodity if it has a proportionally larger share of world exports of that good than of world exports in the aggregate. According to Table 2, the U.S. maintained a considerable comparative advantage in high R&D-intensive goods over the period 1970-84 and a considerable comparative disadvantage in low R&D-intensive goods. In medium R&D-intensive goods, it lost the small comparative advantage it had initially. In Sweden, the development was very different. Its apparent comparative disadvantage in high R&D-intensive goods remained substantial, as did its comparative advantage in low R&D-intensive goods. Its comparative disadvantage in medium R&D-intensive goods diminished considerably.

However, if one further disaggregates these still highly aggregated numbers, a somewhat different picture emerges. The classification of industries into high, medium, and low R&D intensity is based on OECD-wide average expenditure/output data. Industries with R&D/sales ratios higher than 5 % are classified as high R&D intensity industries. Those between 1 and 5 % are classified as medium R&D intensity industries, and those with lower R&D/sales ratios than 1 % are classified as low R&D intensity industries. But, as pointed out by Jacobsson (1988), these intensities can vary substantially between countries and over time.

For example, as shown in Table 3, the R&D intensity in aerospace, the most R&D intensive industry in the OECD area, varies from 5.3 % in Sweden in 1983 to 13.7 % in the United States (1980) and 22.7 % (1980) in the OECD as a whole. In some instances, the differences are sufficient to warrant re-classification of certain industries from one category to another. Thus, in the case of Sweden, it appears that the motor vehicles industry spends enough on R&D to warrant classification as a high R&D-intensity industry. The shipbuilding and ferrous metals industries should be viewed as medium R&D-intensity industries, while rubber & plastics and non-ferrous metals should fall into the low R&D-intensity category. Similar anomalies appear in the U.S. data as well.

These classification problems would be of no importance, were it not for the fact that they may distort the view of what is actually happening in the economy. In Table 4 the shares of the United States and Sweden in total output, by industry, in the 11 largest OECD member countries are presented. It appears that the United States lost a substantial percentage of OECD manufacturing output in all of the high and medium intensity R&D industries over the period 1970-80, while Sweden made considerable gains in most of these industries. Particularly noteworthy is the relatively rapid Swedish growth in electronic components, drugs and medicine, and motor vehicles. (But note also the rapid increase in aerospace and petroleum refineries, where the Swedish R&D intensity is far below the OECD average, and the loss of market share in computers where the Swedish R&D/sales ratio is also relatively low.)

Summing up, the U.S. international position in goods with varying R&D intensity has weakened across the board since 1970 but most particularly in medium R&D-intensive products. This is reflected in the development of U.S. shares of OECD exports of manufactured products, the trade balance, revealed comparative advantage, and shares of OECD manufacturing output.

Similarly, according to the data presented here, the Swedish position in the OECD export market weakened across the board but most notably in high R&D-intensity products. Sweden maintained a significant and growing positive trade balance in medium and low R&D-intensity goods and a slightly negative balance in high R&D-intensity goods. It maintained a comparative disadvantage in goods with high R&D intensity and a comparative advantage in goods with low R&D intensity while reducing its comparative disadvantage in goods with medium R&D intensity. Sweden gained shares of OECD manufacturing output in most industries, most particularly in electronic components, aerospace, drugs and medicine, and motor vehicles, while it lost output shares in computers, textiles and apparel, and shipbuilding. In view of the fact that the Swedish R&D intensity tends to differ from the OECD average in several key industries, this is interpreted as signifying a strong Swedish position in goods requiring medium skill intensity.

II.3.2 Disaggregation by product groups

Another way to disaggregate the trade performance picture is to examine export performance by product group or industry. Figure 10 shows the development of U.S. net exports of merchandise 1965-88. Until about 1975, the net exports of capital goods (primarily nonelectric machinery, computers, and aircraft) were large enough to outweigh net imports of "other" goods (consisting mainly of apparel, footwear, and consumer durables); there was roughly balanced trade in automotive vehicles and parts, agricultural and petroleum products, and industrial supplies (consisting mainly of fuels, metals, and chemicals). In the late 1970s, agricultural exports fell and imports of consumer goods increased, while exports of capital goods stagnated, resulting in a negative merchandise trade balance of about $30 billion annually. In the 1980s, net exports of capital goods have declined precipitously while net imports of automobiles and consumer goods have increased. Meanwhile, the reduction of the negative balance in agricultural and petroleum products has not been large enough to counterbalance these negative developments, resulting in a sharply declining total U.S. merchandise net exports position. The main problem indicated by this development seems to be the following: the "development power" in the capital goods and automotive industries (which together make up the engineering industry sector) has not been great enough to outweigh the long-term and seemingly irreversible erosion of the domestic base in consumer goods.

A more detailed picture of U.S. net export performance in engineering (metalworking) industries is provided in Table 5, where the various industries are ranked according to their net exports in 1983. The top export performers in both 1973 and 1983 were the aircraft, construction machinery, and office machines & computer industries. Engines and turbines, engineering and scientific instruments, refrigeration and merchandising machines, as well as general industrial machinery were also among the top 10 net export product groups in both years. Product groups whose net exports grew particularly rapidly are guided missiles & space vehicles, miscellaneous electric equipment and supplies, miscellaneous transport equipment, and ordnance & accessories. On the other hand, the net exports of radio & TV receiving equipment fell by nearly $ 4 billion, and those of special industrial machinery, electronic components & accessories, motor vehicles & supplies, and communication equipment by more than $1 billion each. The number of industries with a negative trade balance increased from 8 in 1973 to 15 in 1983, even though the net export surplus for the engineering industries as a whole increased by over $10 billion. It is noteworthy that some of the heaviest "losers" (electronic components and communication equipment) as well as strongest "gainers" (aerospace and electrical machinery) are among the group of industries with the highest R&D intensity. Thus, R&D intensity per se seems to confer no particular advantage, except perhaps in combination with other factors.

The corresponding development in Sweden is represented in Figure 10A. Until 1970, Swedish exports and imports of the three major categories of industrial products were roughly in balance.In the early 1970s, Sweden was becoming a net exporter of semi-manufactures and finished goods, while trade in raw materials continued roughly in balance. But the oil price shocks in 1973 and 1979 shattered the tranquility. Even though prices on Swedish raw material exports rose, the oil prices increased much faster and resulted in a large negative trade balance in raw materials and a negative trade balance overall. The oil price declines since 1980 have sharply diminished the negative trade balance in raw materials, and combined with continued increases in net exports of semi-manufactures in particular but also of finished industrial goods, have resulted in a positive overall merchandise trade balance since 1983.

Further analysis of this development is provided in Figures 10 B-D. Figure 10 B shows that the changes in net exports of raw materials are explained almost exclusively by the changes in fuel impports. Increases in exports of wood pulp and wood products have been counterbalanced by increases in imports of food products.

According to Figure 10 C, most of the changes in net exports of semi-manufactured goods are due to increases in net exports of paper and paper products, and to some extent of iron and steel products. Net imports of textiles and chemicals have stabilized at about the level reached in the mid-1970s.

Figure 10 D, finally, shows the composition of net exports of finished manufactures. Transport equipment is the largest net export category and showed steady increases until about 1980, when exports stagnated. Net exports of telecommunication equipment roughly counterbalance net imports of electrical machinery and office machines. Net imports of "Miscellaneous" products (consisting mainly of clothing and footware) increased steadily until 1980 but have diminished somewhat in the 1980s.

III. A Model for Analyzing Trade Performance

While macroeconomic factors can explain a large part of the overall trade performance of a country, they cannot explain the differential behavior among product groups and industries. For that, a different set of explanatory factors is needed. We turn now to an attempt to formulate such a model.

III.1 The Abernathy/Utterback Model

Over a decade ago, William J. Abernathy and James M. Utterback (1975 and 1978; see also Utterback 1979) proposed a model for the analysis of product and process innovation in industry, presented in basic outline in Figure 11. According to the model, each major industrial technology follows a particular three-stage pattern over time. In the first stage, the main emphasis is on definition of the characteristics, function, and market of the product itself. Frequent changes occur in the specification of the product as a result of experimentation and feedback from users. Given the lack of a well-defined product, the production process has to be flexible so as to accommodate frequent changes in product design; general-purpose equipment is used, requiring highly skilled labor. Generally available materials are used as inputs, requiring virtually the entire chain of fabrication processes to take place in-house.

In the second stage, the product specification has stabilized. There are no more major changes in product design, although there may be new variants introduced. The major thrust of the innovation process now focuses on process development. Some special-purpose machinery is used, some processes having been automated. The output having reached a certain level, it is now possible to buy some parts and components from specialized suppliers. The production plant is medium-scale, operating in batch mode.

In the third stage of the development of the technology, product changes are incremental and fairly infrequent. The competitive emphasis is on cost reduction, achieved via product standardization and mass production. The product is now manufactured in highly efficient but rigid processes with highly dedicated and automated machinery in large-scale plants.

Pavitt and Rothwell (1976) have criticized this model on the grounds that available industry data do not in general confirm the pattern hypothesized. However, the power of the model would seem to lie in its analysis of <u>technologies</u> over their life cycles, not industries at a given moment in time. It should be recognized that an industry usually consists of a whole set of technologies and that the length of the life cycle, as well as the relative length of each of the stages, may be different for each technology even if it follows the overall pattern just outlined. To my knowledge, no attempt (other than that by Pavitt & Rothwell) has been made to subject the model to empirical verification. One suspects the main reason is the difficulty of obtaining the relevant data.

Nevertheless, the model has considerable intuitive appeal and yields important insight into the evolution of technologies over time.

III.2 A Dynamic Trade Model

What will be proposed here are two modifications of the Abernathy-Utterback model. The first is the application of the model to the analysis of trade performance of countries rather than innovation patterns in various technologies. This requires (a) that it is possible to classify the major thrust of industrial innovation in each country according to the scheme contained in the model, i.e. in terms of stages of the innovation process, and (b) that trade flows can be analyzed in terms of this classification and not only in terms of types of products -- the scheme more ordinarily used. This essentially static version of the model, if verified empirically, should be useful in examining trade flows at a particular point in time.

In order to explain changes in trade flows over time, a dynamic version of the model is required. Thus, the position of a country may change over time because of the particular technologies it chooses and the life cycles these technologies follow. The position may also change because of pervasive technological changes affecting all industrial production. Making the model dynamic so that it is suitable for analyzing changes over time in international trade performance constitutes the second modification of the model.

The basic hypothesis is as follows. The stages of technological innovation in which the U.S. is most heavily represented, both now and historically, are Stage I and Stage III of the model. This means that the U.S. is hypothesized to have a comparative advantage in entirely new technologies where product development dominates over process development, and also, due in large measure to a huge domestic market, in mass production of standardized goods as well. The latter goods are characterized by modest R&D expenditures as far as both products and processes are concerned. Sweden has traditionally been strong in Stage II of each technology (modern but not new products; highly specialized products for sophisticated industrial users rather than standardized, mass-produced consumer goods) but seems to have shifted more towards Stage I in recent years (as reflected in sharply increasing R&D expenditures). Japan has moved from Stage III in the early postwar period to Stage II in the 1970s and seems to be expanding into Stage I at the present time. The West European economies have traditionally been found in Stages II and III but are now moving away from Stage III and closer to Stage I, as their aggregate R&D expenditures are rising.[3] The developing countries, finally, are represented primarily in Stage III.

It is hypothesized here that the position of the United States has been eroding since the mid-1970s due to several simultaneous

[3] A notable exception is the United Kingdom which seems to have a comparative advantage in Stage I-type goods, as well as in Stage III-type goods, i.e., a specialization similar to that of the U.S.

developments. The increased degree of integration between product and process development (dealt with more specifically below) achieved by the Japanese during the 1980s has reduced the length of time the product innovator can enjoy a supernormal profit. Given the relative weakness of U.S. firms in Stage II, they have not been able to increase their rate of product innovation sufficiently to counteract the reduction in the life span of each product or generation of products in order to maintain their relative international position. At the same time, generic improvements in batch-type technology (involving computer-integrated manufacturing, CIM, flexible manufacturing systems or cells (FMS or FMC)) typical of Stage II has not only speeded up the transition from Stage I to Stage II for a number of technologies but has also diminished the viability of large-scale mass production, thus eroding the strength of the U.S. in Stage III as well.

For Sweden, the development has been largely the opposite. Having suddenly lost a large chunk of late-Stage-II goods in the aftermath of the oil crises of the 1970s, sustaining a substantial initial shock, Sweden has benefited more than most other countries from the improvements in flexible manufacturing technology. Given its specialization in low to medium volume industrial goods which are subject to much lower rates of product innovation than consumer goods, Sweden has suffered less than many other countries from shortened product life cycles and has also been able to avoid having to hand products over to developing countries pursuing Stage III strategies. Sweden has further strengthened its position in

Stage II goods by increasing its expenditures on R&D, particularly product R&D, thus moving closer to Stage I.

IV. Empirical Observations Supporting the Model

The model as outlined here needs to be empirically tested. While such a test is beyond the scope of the present paper, there are several empirical observations which can be made in support of the model.

IV.1 Basic Positions: U.S. Strength in Stages I and III; Swedish Strength in Stage II

The characterization of the U.S. position as one of strength in Stage I-type goods is based on the data presented in the previous section, as well as on the following. Data are scant as to the distribution of R&D expenditures on products and processes, but according to a recent study by Mansfield (1988a), R&D expenditures in the United States are heavily oriented towards products as distinguished from processes, much more so than in Japan (68 % in the U.S. vs. 36 % in Japan). Also, 47 % of U.S. R&D expenditures are devoted to entirely new products and processes, compared to only 32 % in Japan. Furthermore, Mansfield has found that U.S. firms put more emphasis on marketing start-up and less emphasis on tooling, equipment, and manufacturing facilities than do Japanese firms. (Mansfield 1998b.)

Similarly, according to Ohlsson & Vinell (1987, p. 64), over 60 % of Sweden's industrial R&D expenditures in 1985 were devoted to product development. This corroborates findings in interviews with leading Swedish industrial firms a decade ago (Carlsson et al., 1979, p. 167) which indicated that product development expenditures clearly dominated over process development expenditures. Thus, the Swedish R&D expenditures seem to have roughly the same distribution as those in the U.S. However, in view of the fact that Swedish firms tend to be strong in the medium and low R&D-intensive products rather than highly R&D-intensive goods, this seems to indicate relative strength in Stage II-type goods. In other words, Swedish firms seem to have a strong orientation to product development of Stage II-type goods, whereas the Japanese seem to spend most of their R&D on process development for Stage II-type goods and American firms emphasize development of entirely new Stage I-type goods.

According to Oppenländer (1989), only 20 % of West German industrial R&D expenditures are for "offensive" purposes, the remaining 80 % being for "defensive" purposes. While it is not clear to what extent "defensive" R&D is process-oriented, the numbers indicated would suggest a West German orientation towards Stages II and III rather than Stage I.

As far as classifying industries with respect to production equipment and organization is concerned, an examination of Figure 12 is helpful. The graph shows the relationship between the degree of automation and the volume of production in engineering industries. In certain industries, the volume of production is not sufficient to justify investments in automation. Thus, most operations in these industries are manual. These correspond to Stage I in our model. In other industries, the production volume is so large that virtually all operations are mechanized (via highly dedicated, fully automated systems, called transfer lines). This corresponds to Stage III. The grey area in between is the domain of flexible machinery and corresponds to Stage II. As described in Carlsson (1984), the application of computers to machine tools (resulting in numerically controlled, NC, machine tools), beginning in the late 1940s, has made small and medium scale operations much more productive than earlier. As this technology has expanded in both directions, the grey area (the extent of which in the figure reflects the situation in the United States in 1981) has made inroads into both transfer lines and manual operations. Prior to the 1950s, the grey area was virtually absent, as there was no technology specifically designed for batch-type processing.

There is certainly no doubt that the United States has a traditionally extremely strong position in mass production technology. The rapid growth of the automobile industry following Henry Ford's introduction of the moving assembly line in 1913 engendered technological change in mass production technology not only in the auto industry itself but also in the supplying industries. Other industries soon followed suit, creating rapid growth of mass-produced consumer capital goods up to the Depression. The new technologies (transfer machines and cemented carbide tools) which emerged during the 1930s were diffused extremely rapidly and effectively in connection with the massive build-up, re-orientation, re-organization, and equipping of American industry to play the role as the Arsenal of Democracy in supplying the allied forces with military hardware throughout the Second World War. As I have indicated elsewhere (Carlsson 1984), when this enormous new capacity was converted to civilian production shortly after the war, the result was a "production machine" for mass production of capital goods far superior in terms of both technology and production capacity to that anywhere else in the world. In fact, many of the machine tools installed then are still in use, or to the extent they have been replaced, have largely confined the changes in plant organization and layout to the production concept embodied in them. The further development of this production concept in the form of "Detroit Automation" (the linking together via mechanical devices of a series of transfer machines such that the system is capable of operating with very limited manpower) in the early 1950s represents another step in the same direction.

IV.2 Technological Change Affecting Country Positions

But with the advent of computers and their application to machine tools in the late 1940s, technological change in manufacturing began to take a new direction. The need for new technology to manufacture complex parts and components for military hardware led to the development of numerically controlled (NC) machine tools. In the beginning, these machine tools incorporated hardwired circuitry (i.e. were not very flexible) and were extremely costly. They were highly versatile machines geared for low-volume production of high-precision, complex parts. Only large firms making complex parts for the military on cost-plus contracts could afford them. For this reason, the diffusion of NC machine tools was very slow. Even as late as the early 1970s, some 20 years after the first commercial application of NC machine tools, only 13-14 % of the total machine tools produced in the United States were numerically controlled, and only 2-3 % of the total stock of machine tools were numerically controlled. These percentages were significantly lower in other countries. (Carlsson 1989b.)

But around 1975 some Japanese firms began using microcomputers as the basis for the numerical control unit, replacing the earlier hard-wired NC units by CNC (computer numerical control). This increased the versatility and flexibility of the machine tools and simplified their programming. Even more importantly, due to the fact that in Japan the demand for improved technology was driven by the automobile industry and its suppliers, as well as other consumer-oriented capital goods industries (rather than by defense needs, as in the United States) operating under intense competitive pressure, there was a greater need for highly productive, reliable, general-purpose, standard machine tools. By simplifying the product, making it more general-purpose, and aiming it for small and medium-size firms, the Japanese machine tool producers completely changed the market. The potential number of users now suddenly numbered in the thousands rather than the hundreds. This allowed the Japanese sharply to increase the volume of output and thus to take advantage of scale economies to an extent not possible with the small batches prevailing before, thereby significantly lowering costs. (Carlsson 1989b.)

The results of this revolution in machine tool technology can be seen e.g. in Tables 6 and 7. Table 6 shows that the United States, which was the unquestionable leader up until the late 1970s, saw its relative position declining as other countries devoted more of their machine tool investments to numerically controlled machine tools. Table 7 shows that the further integration of computers into manufacturing technology in the form of industrial robots and flexible manufacturing systems (FMS) has been extremely rapid in some countries with a great deal of small and medium-scale, batch-type processes and with emphasis on flexibility, notably Japan and Sweden, while it has been considerably more modest in the United States.

Thus, because of its historical orientation to mass production in combination with the strengthening of medium and small-scale batch-type production technology vis-à-vis mass production technology, the United States has gradually lost the technological advantage in production technology it had at the beginning of the postwar period. The loss of comparative advantage has been greatest in standardized consumer goods (both durable and non-durable) as demonstrated by automotive and "other" goods in Figure 10 above, but capital goods other than automobiles have also been affected.

Thus, the viability of reliance on Stage III-type goods has been severely weakened in the United States, at the same time as the U.S. is relatively weak in Stage II-type goods.

Conversely, Sweden's historical orientation to small and medium-scale production of investment goods for industrial use, in combination with the technological trends favoring that position which have been outlined above, has strengthened Sweden's comparative advantage in Stage II-type goods.

The relative weakness of U.S. industry in small and medium-size manufacturing firms is corroborated by recent findings by Kelley and Brooks (1988). They found the linkages between customer and supplier firms in U.S. manufacturing industries to be weak. Only 3 percent of parts suppliers receive financial assistance from their customers towards purchases of new technology; only 20 percent report that their customers will "lend" them engineers to supplement their own technical expertise. (Kelley and Brooks, p. 5.) This contrasts sharply with Japan and Sweden, for example, where such arrangements appear to be common. The lack of customer-supplier linkages may hamper the adoption of new technology and thus help to explain the relatively slow adoption in the U.S. of flexible automation: it is not completely independent small firms that are likely to adopt new technologies such as programmable automation but rather well-connected small firms which can rely on the greater technical and engineering talent of its large business customers to help implement the new technology. (Kelley, Brooks and Branscomb, 1989, p. 8.)

It is interesting in this connection to note that the industries in the United States whose net exports increased the most between 1973 and 1983 (see Table 5 and comments above) are also the industries with the largest shares of NC machine tools and other batch-type processing equipment. In another paper (Carlsson, 1989c), I have shown that some 30-60 % of the variation among U.S. engineering industries in net exports can be explained by such differences in technology. Conversely, industries characterized by mass production technology saw their net export position deteriorate sharply.

IV.3 Reduced Viability of Stage I-Type Strategies

Because of its historical tradition of large R&D spending and a strong emphasis on product as distinct from process R&D, the U.S. has enjoyed a traditionally strong comparative advantage in Stage I-type goods. That position, too, has weakened in recent years, due to several developments.

The first of these is a compression of Stage I, i. e., the time it takes to develop a new product and the process required for its manufacture. The Japanese have been in the forefront of this development. In the automobile industry, for example, it now takes Japanese firms only three to four years to develop a new model, whereas it takes American and European firms five to six years.

The compression of the product and process development cycle appears to be the result of a re-organization of the development work from the traditional sequential mode to a parallel mode:

instead of a number of sequential steps (developing a prototype, testing it first in the lab and then in the market, handing it over to the engineering department for final design, then to the manufacturing department for production and finally to marketing), an increasing number of firms now try to organize ad hoc, often informal, project groups representing all the necessary areas of expertise, enabling them to work closely in parallel with each other within the group. The practice of "reverse engineering" which seems to be common in many Japanese firms appears to have yielded two benefits to these firms: (1) rapid adaptation and diffusion of new technology, and (2) a flexible type of organization which is extremely efficient and speeds up the development process. (See Freeman 1987, Ch. 2.) By taking a competitor's product, disassembling it, examining it from several points of view simultaneously (functionality, design, reliability, manufacturability, marketability, safety, etc.), and then re-assembling it after the appropriate changes have been made, one builds the organizational know-how which is essential in effectively utilizing the technical expertise which already exists in the firm. Having learned how to organize and coordinate the process, these firms can then use the same mechanism to develop their own products once they have reached the technological frontier.

The development by the Japanese of the 4-megabyte computer chip appears to be an example of the process just outlined. The traditional method has been first to develop a prototype, then to develop and finally to perfect the manufacturing process, resulting in a very low yield of acceptable chips in the beginning, then gradually improving as experience is gained. As they have done in other areas of manufacturing, the Japanese have concentrated on taking a broad-based, generic approach to solving the manufacturing problem from the very start, with the result in this case that they have been able to start up full-scale, high-yield production ahead of their competitors.

Preliminary results of an ongoing study of "multi-technology corporations" in Sweden, Japan, and the United States provide further evidence along similar lines. Japanese firms tend to put more emphasis on the simultaneous pursuit of multiple technologies in each product area and seem to be better able to integrate them both technically and organizationally than their Swedish and particularly their American counterparts. (Jacobsson et al., 1989.)

The impact of these developments is the following. With the compression of the product and process development cycle, the economic life expectancy of new products is diminished; even if each product generation has the same physical life expectancy as before, there are now more product generations "living" in parallel, and the risk of being overtaken by entirely new products is greater. This means, in turn, that a strategy of relying solely on product innovation without the accompanying process development becomes less viable. It also means there will be an increasing variety of products on the market. For example, food distributors claim, and the everyday shopper can verify it, that the average supermarket in the U.S. today stocks roughly twice as many items on its shelves as it did ten years ago. Similarly, the number of car models offered in the American market has increased from 408 in 1980 to 572 in 1989 (Wall Street Journal, October 24, 1989, p. B1). With only a small share of the total market for each product, the prospects of attaining a sales volume sufficient to sustain mass production are slim; they are made slimmer still by the likelihood of the product becoming obsolete before ever reaching the mass production stage. The fact that R&D expenditures have been rising in relation to GNP in most of the industrialized countries may result in more duplicative efforts being made in each area, or in more genuinely new products. In either case, the likely result is more product variety and shorter life expectancy.

Taken together, these developments mean that if one chooses a Stage I-type strategy, it is necessary "to run harder just to stay in place." Product development efforts made by competitors, shorter product development cycles, reduced product life expectancy, and increased product variety -- in addition to the relative ease of imitation in comparison with original innovation -- make it necessary either to increase the rate of product development effort or to integrate product and process development more closely (perhaps by expanding activity from Stage I into Stage II), or both. The former involves great risk and expense, while the latter appears to be an area where U.S. manufacturers are more vulnerable than their competitors elsewhere.

V. Conclusion

This paper has compared the export performance of the United States and Sweden over the postwar period. It was found that the U.S. share of world industrial exports declined continuously from 1950 to 1970, fluctuated cyclically in the 1970s, then continued to decline in the 1980s. The corresponding Swedish world market share was virtually constant from 1950 to 1975, then fell dramatically until the early 1980s and showed tendencies of recovery in the last few years.

The trade performance in both countries in the 1970s and 1980s can be explained to a large extent by macroeconomic factors, while the long-term changes in world market shares and the changes in commodity composition of trade are explained by microeconomic factors. The most prominent among these are differences among countries in specialization with respect to research and development efforts and the type of production technology used. Both of these are based on historical experience. Given different initial positions, countries fare differently as a result of the same set of technological changes.

A model originally proposed by Abernathy and Utterback for the analysis of industrial innovation has been adapted here for the analysis of international specialization and its changes over time. According to this analysis, the long-term weakening of the U.S. competitive position in manufacturing (as reflected also in the changing composition of its exports) can be attributed to (1) reduced viability of innovation strategies focused primarily on products with insufficient attention to process innovation, and (2) weakening of the technological base for mass production. An important driving force generating both of these changes is the improvement which has taken place in the last 40 years in small and medium-scale, flexible, batch-type manufacturing technology as represented in numerically controlled (NC) machine tools and related technologies such as industrial robots and flexible manufacturing systems (FMS).

Because of their historical orientation to different ends of the manufacturing spectrum, the U.S. which relies heavily on mass production of standardized goods has faced greater adjustment problems than Sweden which has always depended heavily on small and medium-scale batch-type production of industrial goods whose manufacture has benefited the most from this technological trend.

At the same time, the speed-up of product and process innovation resulting from increased research and development (R&D) expenditures throughout the industrial countries and the development of technologies for better organization, coordination and management of industrial innovation have led to sharply reduced product life cycles and increased product diversity. This has benefited flexible firms with a high degree of integration between product development and the production process (prevalent in Sweden and Japan, for instance) at the expense of more vertically integrated, less flexible firms relatively prevalent in the United States.

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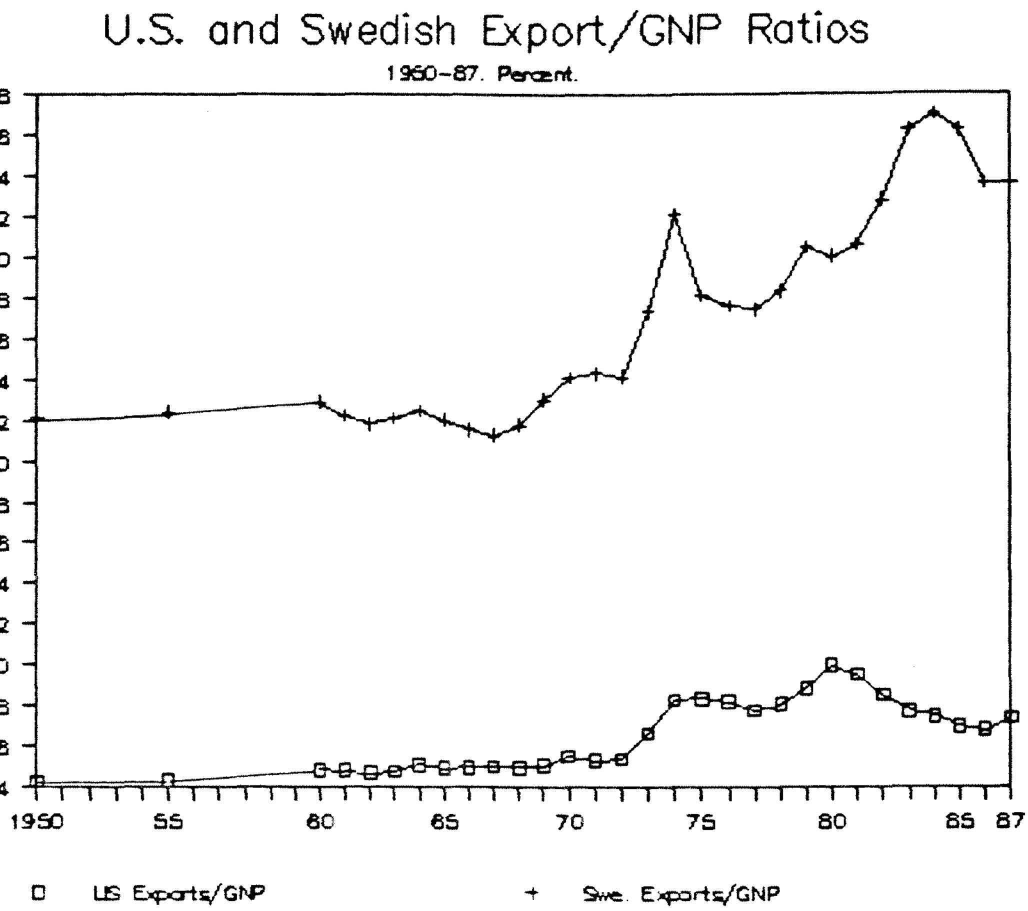
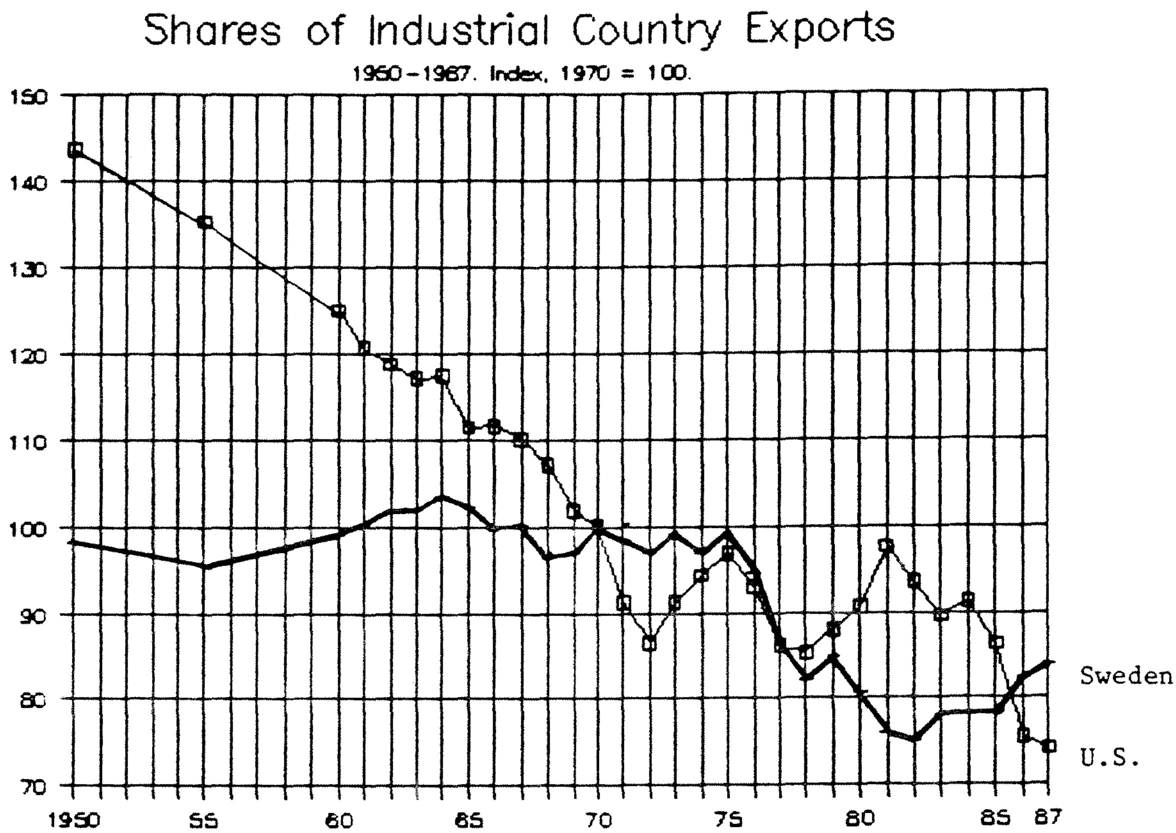
Figure 1



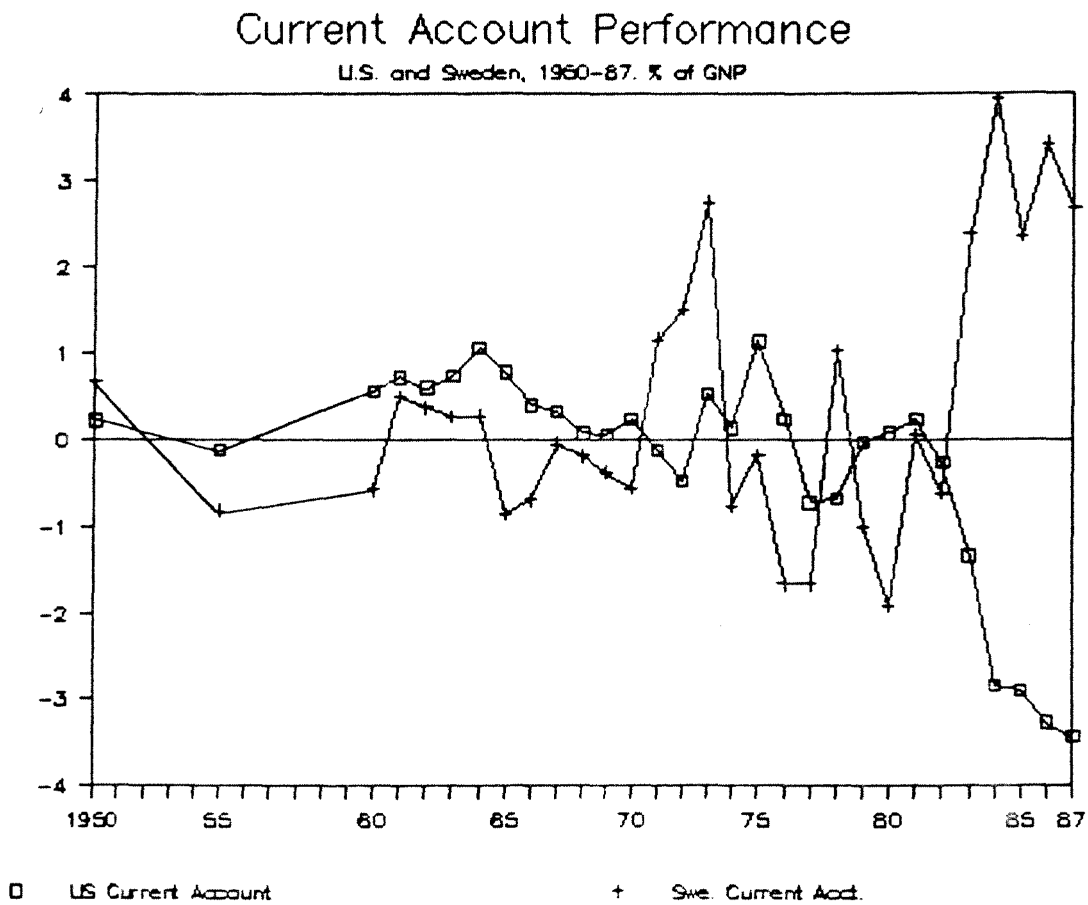
Source: IMF, International Financial Statistics Yearbook 1988.

Figure 2



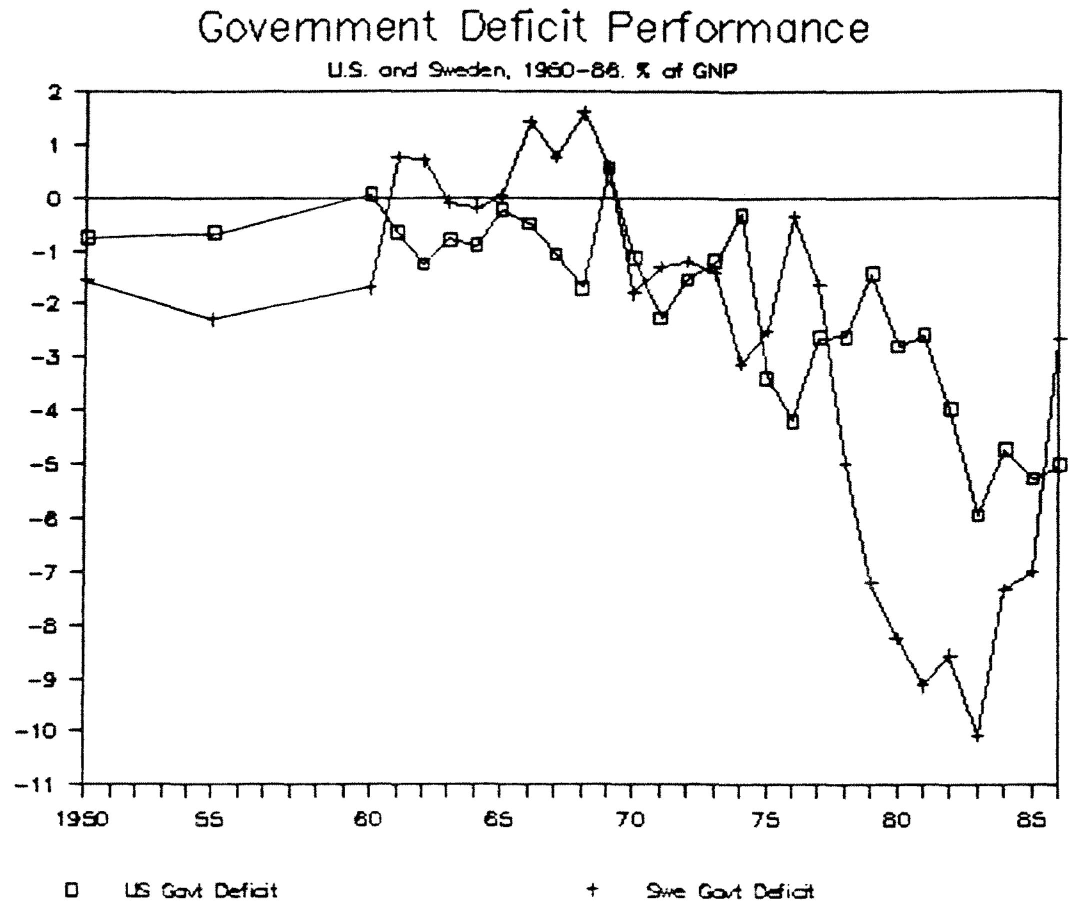
Source: IMF, International Financial Statistics Yearbook 1988.

Figure 3



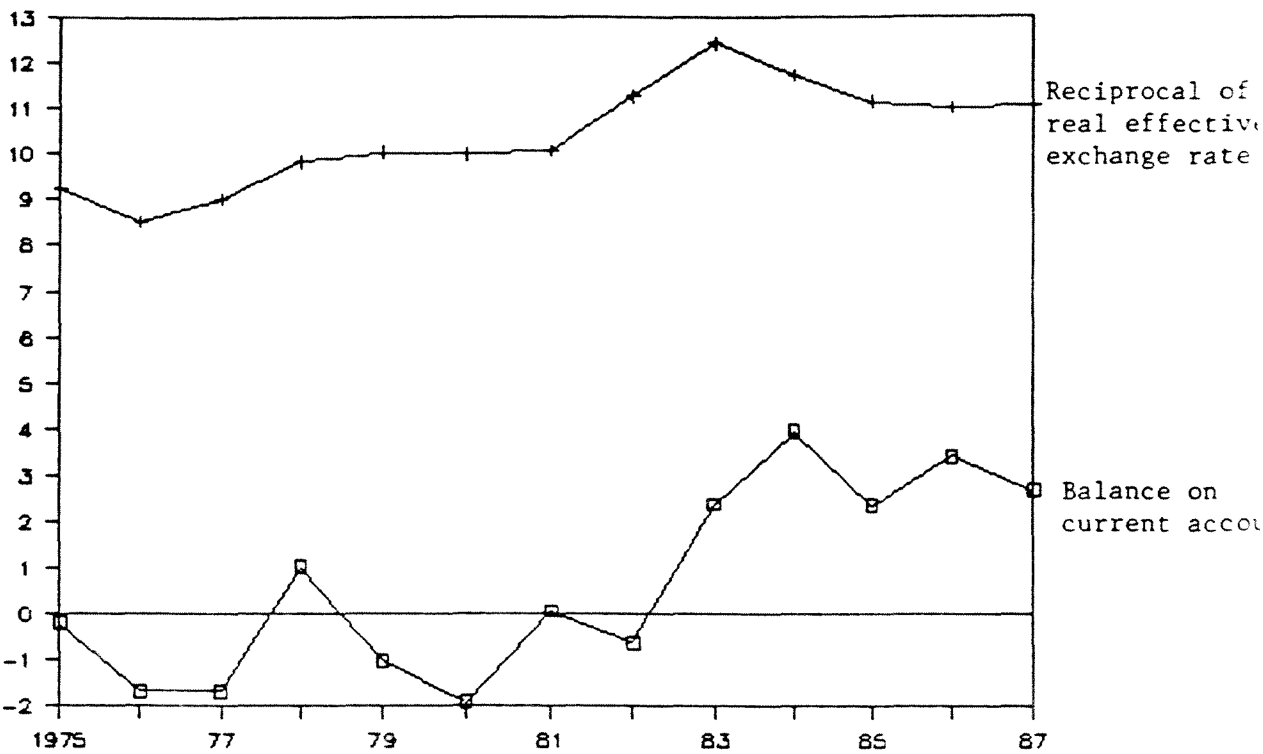
Source: IMF, International Financial Statistics Yearbook, 1988.

Figure 4



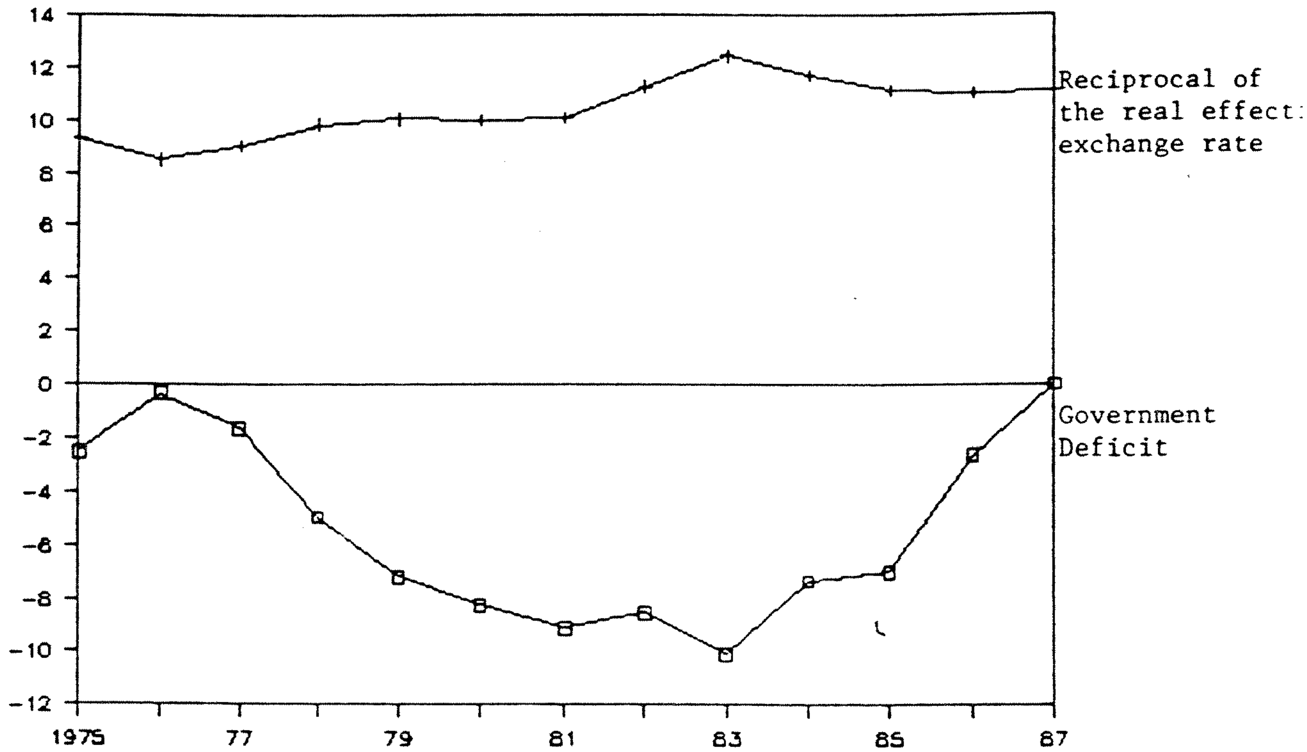
Source: IMF, International Financial Statistics Yearbook, 1988.

Figure 5 Balance on Current Account (in % of GNP) and the Reciprocal of the Exchange Rate. Sweden, 1975-87.



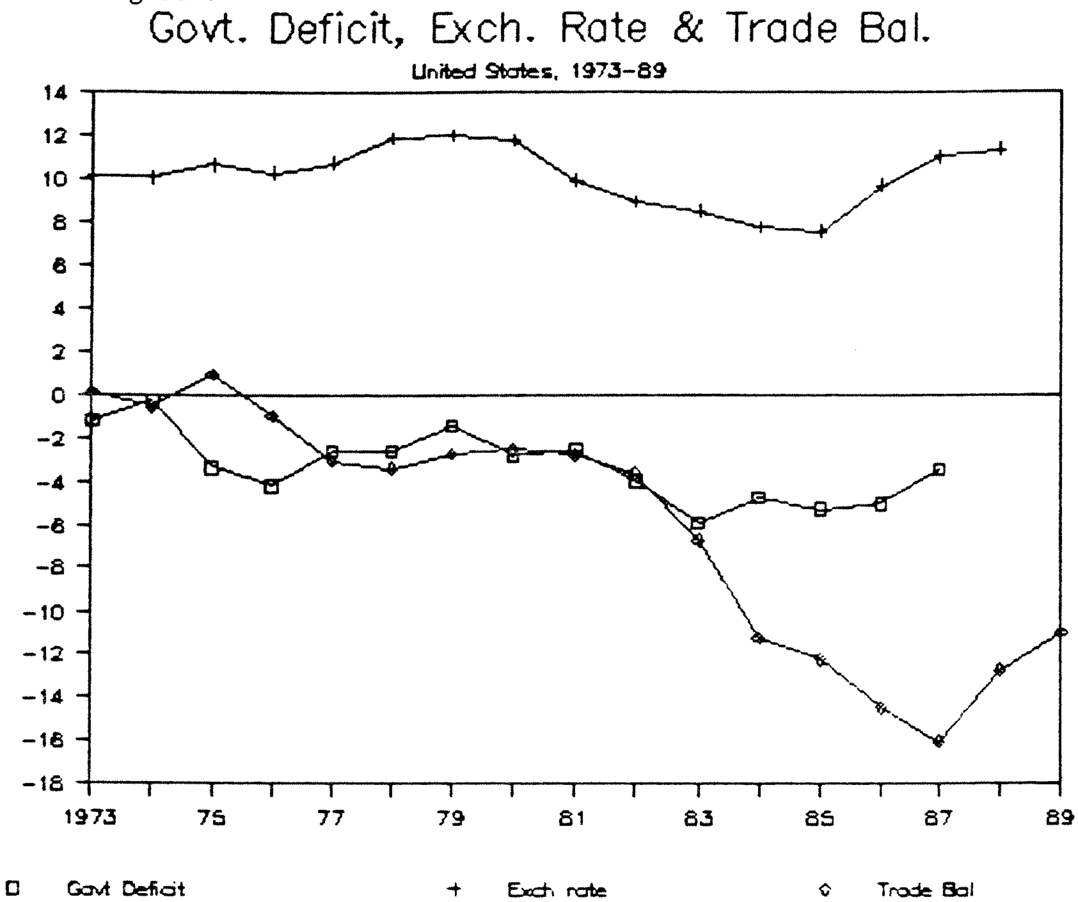
Source: IMF, International Financial Statistics Yearbook, 1988.

Figure 6 Government Deficit and the Reciprocal of the Real Effective Exchange Rate. Sweden, 1975-87.



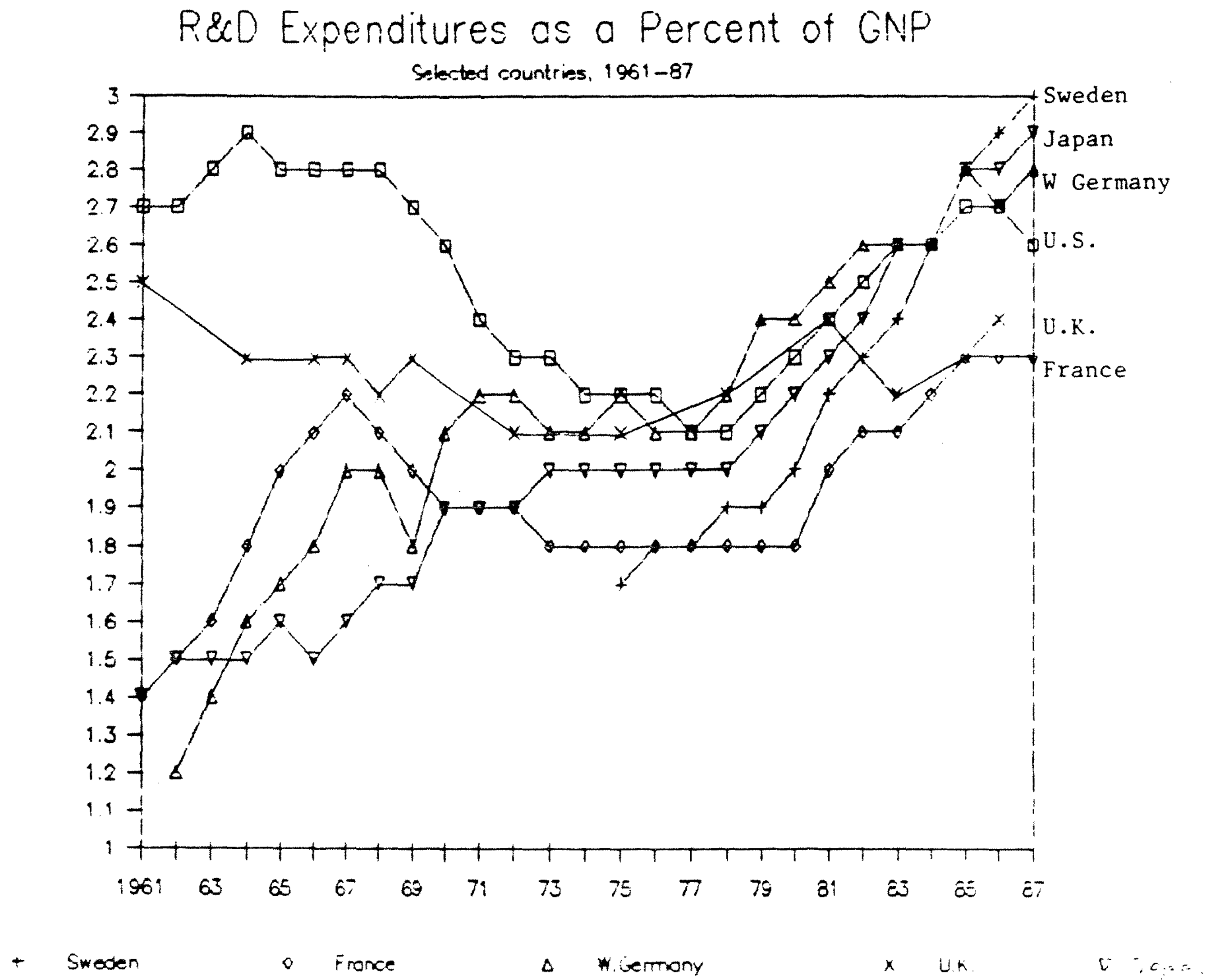
Source: IMF, International Financial Statistics Yearbook, 1988.

Figure 7



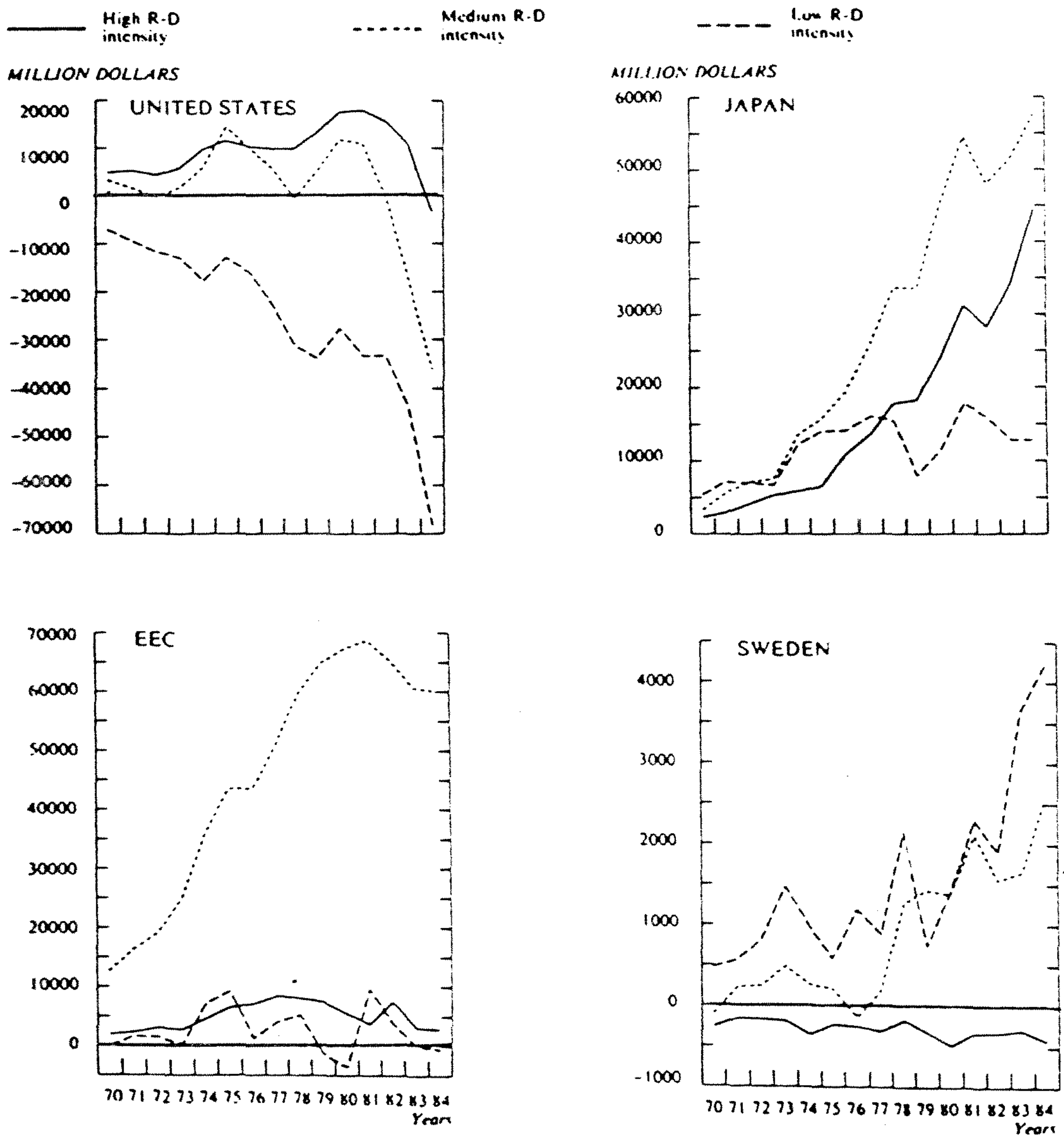
Sources: Trade Balance: IMF, International Financial Statistics Yearbook, 1988.
1988 data: Survey of Current Business, February 1989
1989 data: (First and Second Quarter at annual rates): Federal Reserve Bank of Cleveland, Economic Trends, October 1989, p. 18
Exchange Rate: Economic Report of the President, 1989, p. 431
Government Deficit: IMF, International Financial Statistics Yearbook 1988

Figure 8



Sources: OECD/DSTI, STI Indicators Newsletter, No. 11, 1988
NSF, International Science and Technology Data Update: 1988 Special Report, NSF 89-307, p. 6

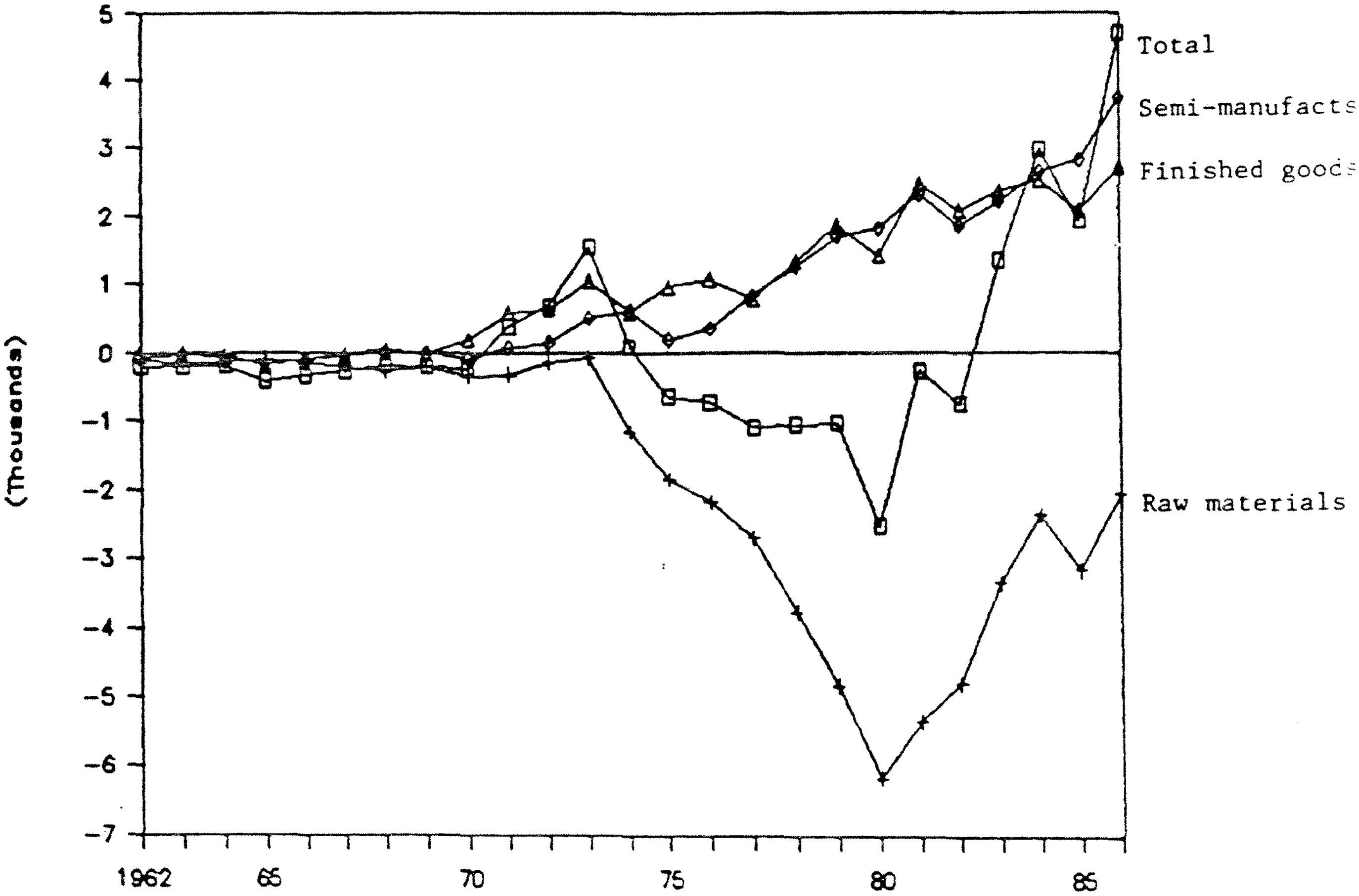
Figure 9 Trade Balance of Manufacturing Industries: United States, Sweden, Japan, and EEC, 1970-1984



Source: <u>OECD Science and Technology Indicators, No. 2, R&D, Invention and Competitiveness</u>. Paris: OECD, 1986

Figure 10 A. Swedish Merchandise Net Exports, 1962-1986.

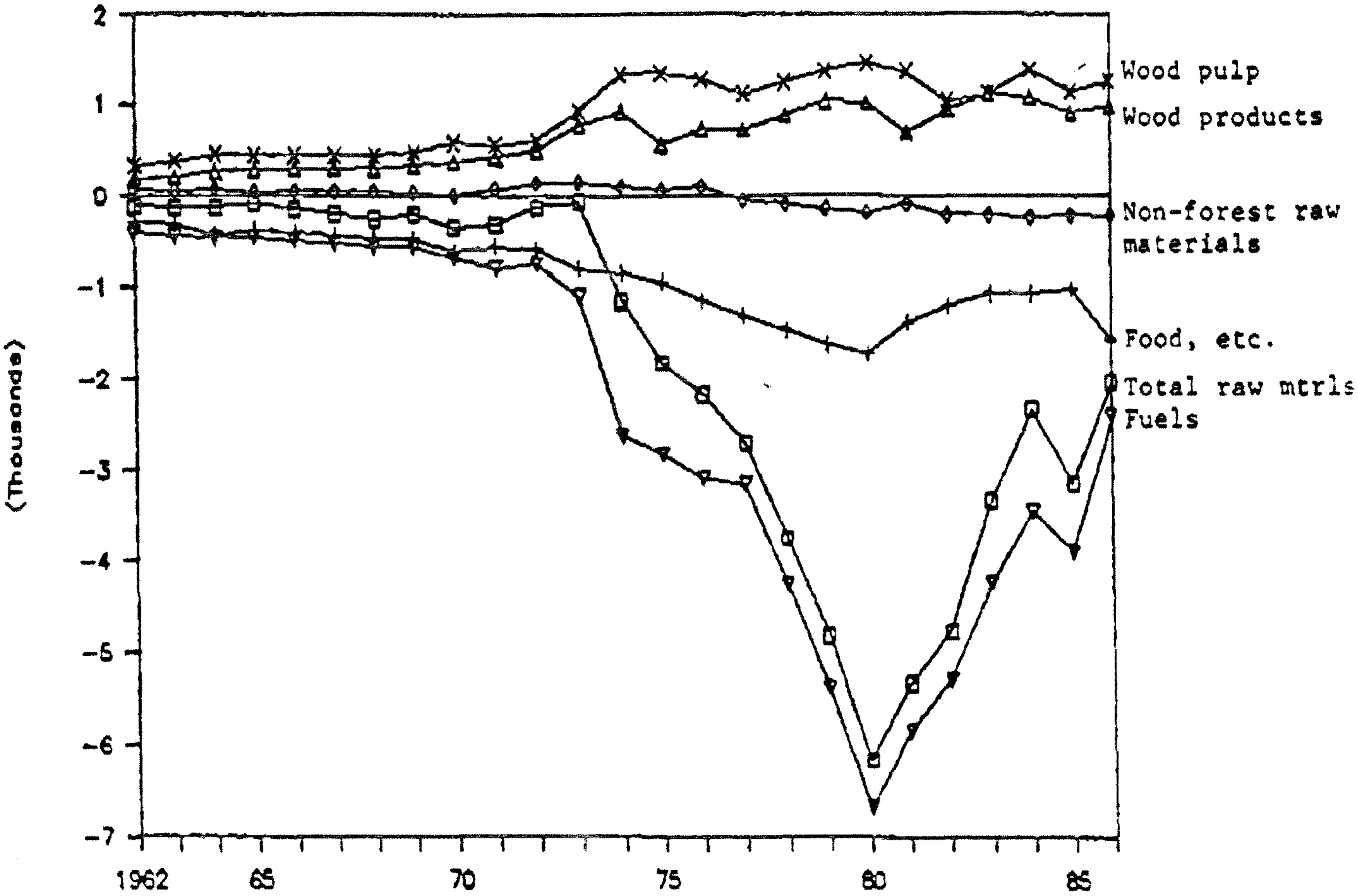
Million U.S. Dollars, current prices



Source: U.N. Yearbook of International Trade Statistics, various issues.

Figure 10 B. Swedish Raw Material Net Exports, 1962-1986.

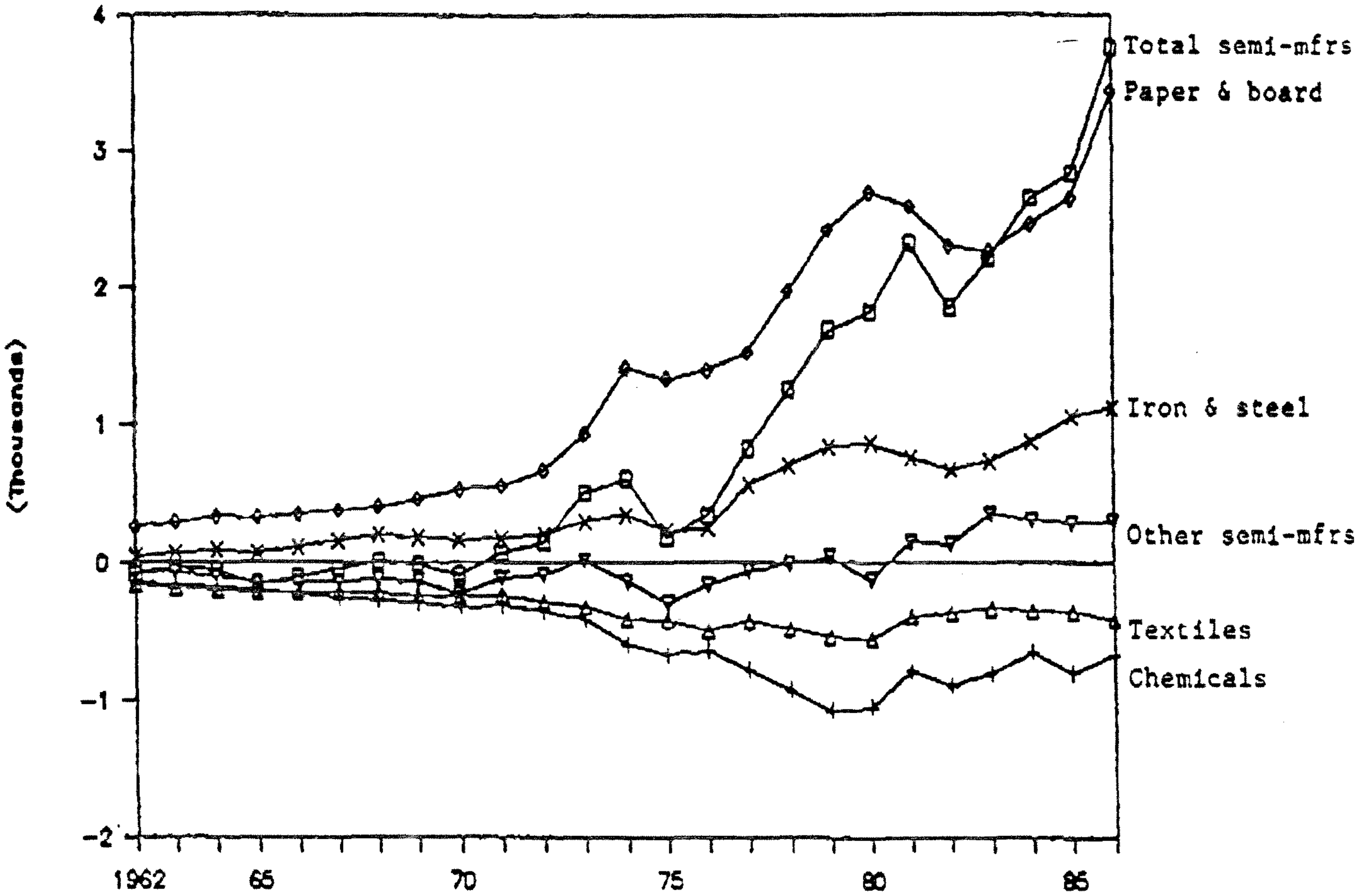
Million U.S. Dollars, current prices



Source: U.N. Yearbook of International Trade Statistics, various issues.

Figure 10 C. Swedish Net Exports of Semi-Manufactures, 1962-1986

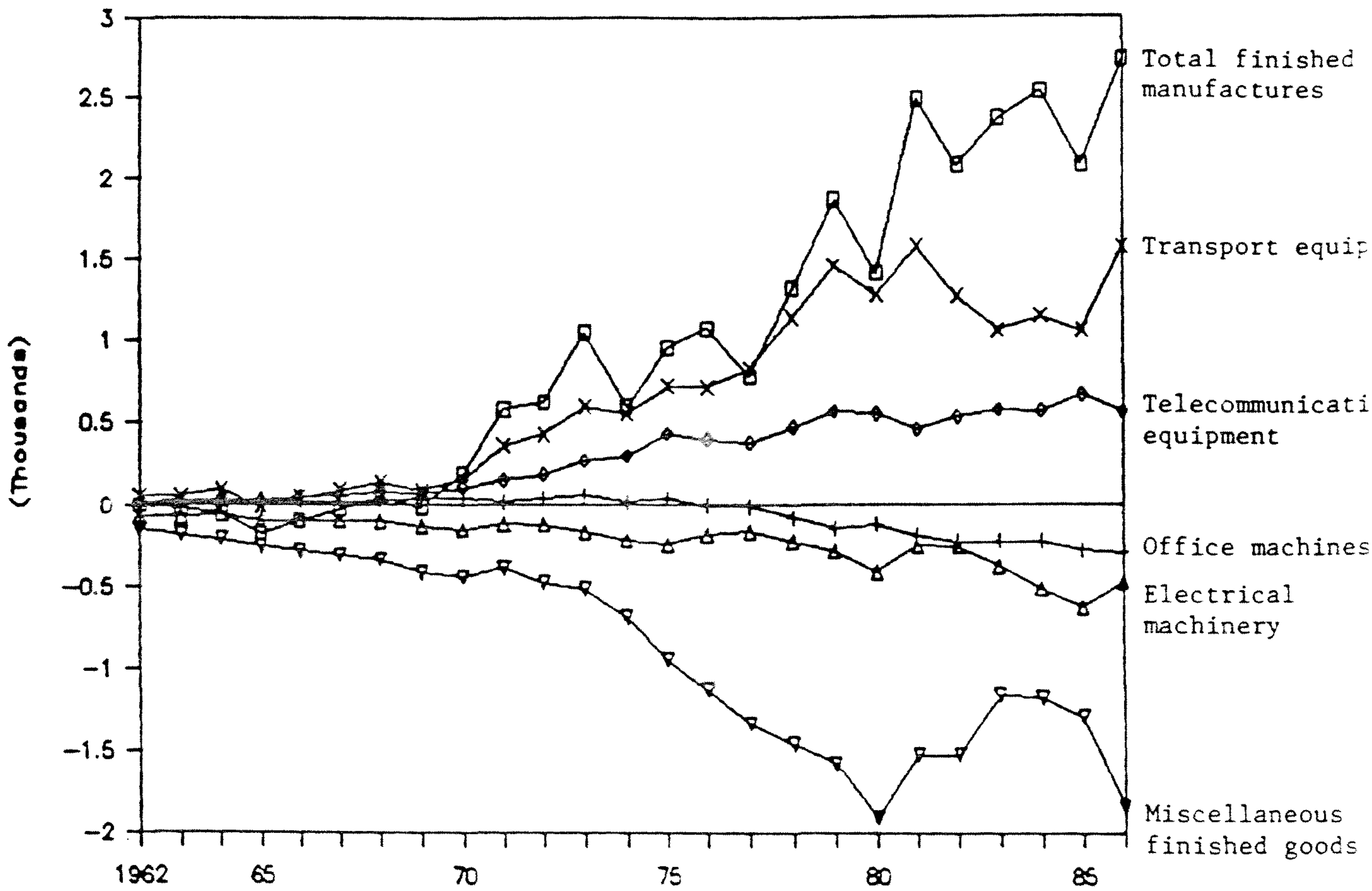
Million U.S. Dollars, current prices



Source: U.N. Yearbook of International Trade Statistics, various issues.

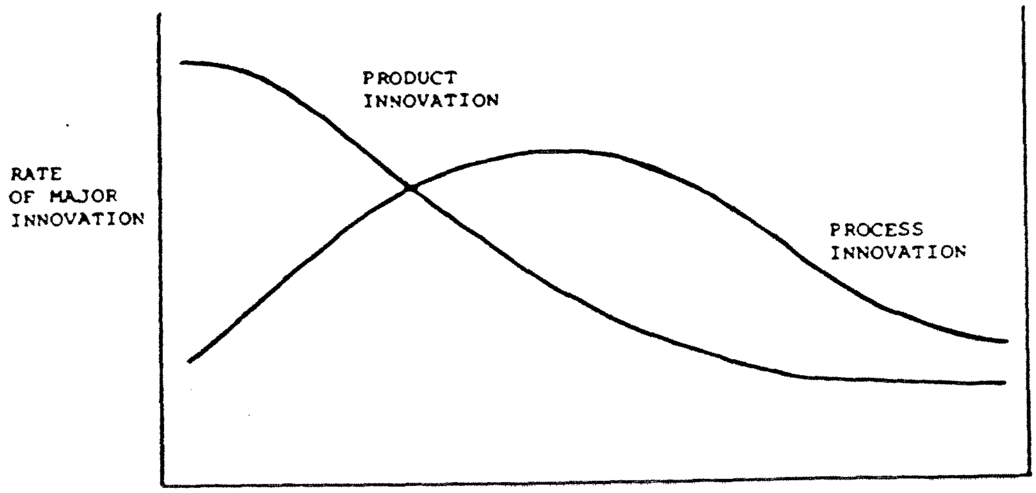
Figure 10 D. Swedish Net Exports of Finished Manufactured Products, 1962-1986.

Million U.S. Dollars, current prices



Source: U.N. Yearbook of International Trade Statistics, various issues.

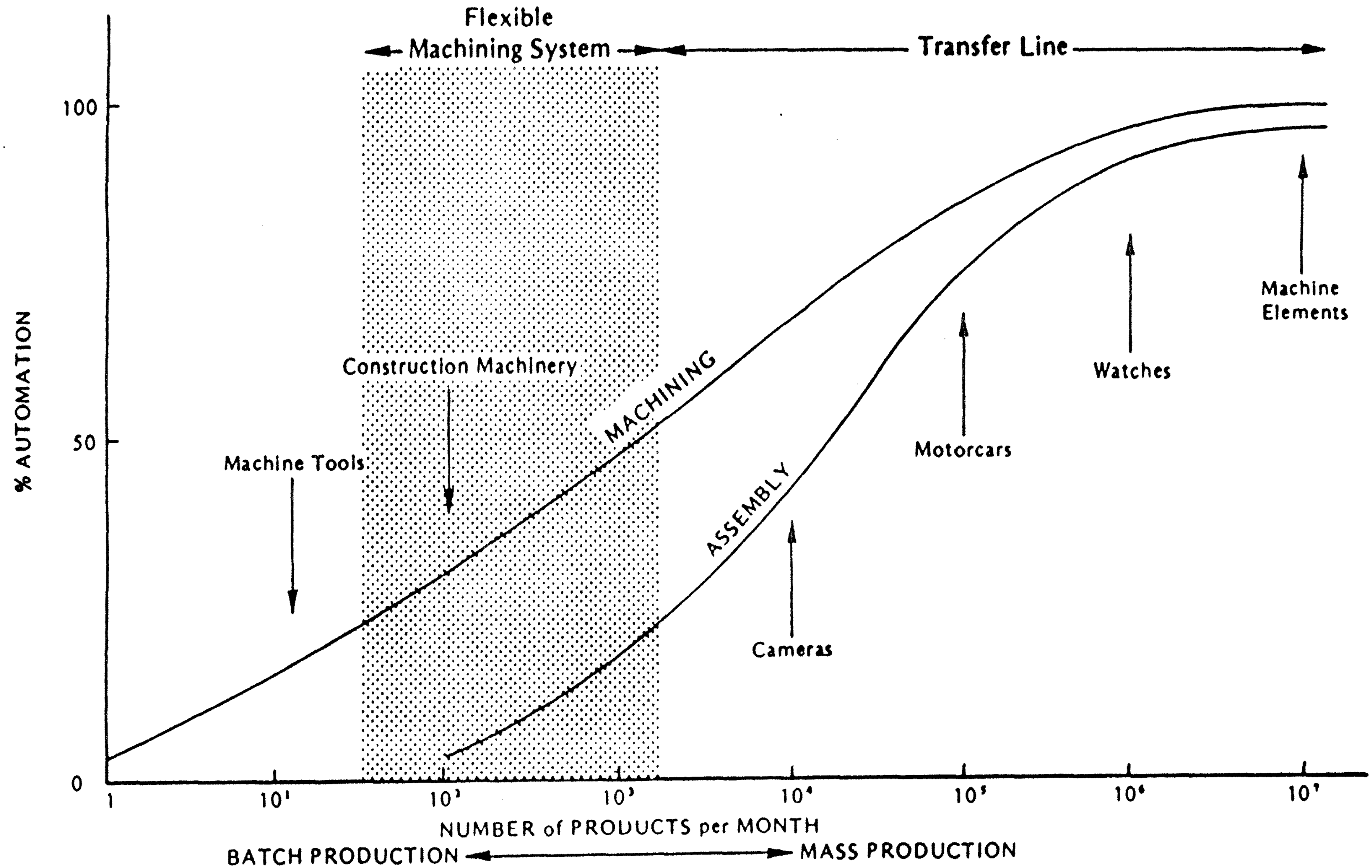
Figure 11 A Model for the Dynamics of Process Innovation in Industry



Predominant type of innovation	Frequent major changes in products	Major process changes required by rising volume	Incremental for product and process, with cumulative improvement in productivity and quality
Competitive emphasis on	Functional product performance	Product variation	Cost reduction
Innovation stimulated by	Information on users' needs and users' technical inputs	Opportunities created by expanding internal technical capability	Pressure to reduce cost and improve quality
Product line	Diverse, often including custom designs	Includes at least one product design stable enough to have significant production volume	Mostly undifferentiated standard products
Production processes	Flexible and inefficient; major changes easily accomodated	Becoming more rigid, with changes occuring in major steps	Efficient, capital-intensive, and rigid; cost of change is high
Equipment	General-purpose, requiring highly skilled labor	Some subprocesses automated, creating "islands of automation"	Special-purpose, mostly automatic with labor tasks mainly monitoring and control
Materials	**Inputs are limited to generally-available materials**	**Specialized materials may be demanded from some suppliers**	**Specialized materials will be demanded; if not available, vertical integration will be extensive**
Plant	**Small-scale, located near user or source of technology**	**General-purpose with specialized sections**	**Large-scale, highly specific to particular products**

Source: J.M. Utterback, "The Dynamics of Product and Process Innovation in Industry," Ch. 2 in C.T. Hill and J.M. Utterback (eds.), Technological Innovation for a Dynamic Economy. New York: Pergamon Press, 1979, pp. 44-45.

Figure 12 Automation versus Volume.



Source: American Machinist (November 1981): 208.

Table 1

Shares of OECD Manufacturing Exports, 1970-1984
(adjusted for intra-EEC trade flows)

	High R&D			Medium R&D			Low R&D		
	1970	1980	1984	1970	1980	1984	1970	1980	1984
U.S.	35.4	30.5	31.2	26.0	22.5	20.5	16.1	15.0	14.3
Japan	15.0	21.3	28.8	10.1	17.1	21.5	15.7	13.7	15.5
EEC	33.0	33.4	26.1	40.1	39.4	33.9	34.4	37.9	34.8
Sweden	3.0	2.7	2.2	3.6	3.3	3.1	5.9	5.2	5.1
Sum of above	86.4	87.9	88.3	79.8	82.3	79.0	72.1	71.8	69.7
OECD	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0

Source: OECD, Science and Technology Indicators, No. 2, R&D, Invention and Competitiveness. Paris: OECD, 1986.

U.S.			0.88			0.79			0.89
Japan			1.92			2.13			0.99
EEC			0.79			0.85			1.01
Sweden			0.73			0.86			0.86

Table 2

Apparent Comparative Advantage of Manufacturing Industry, 1970-1984
OECD average = 100

	High R&D			Medium R&D			Low R&D		
	1970	1980	1984	1970	1980	1984	1970	1980	1984
U.S.	158	156	156	109	106	98	63	64	64
Japan	123	141	147	78	105	101	114	75	68
EEC	93	93	82	105	101	99	97	102	114
Sweden	37	43	34	62	86	83	165	143	157

Source: OECD, Science and Technology Indicators, No. 2, R&D, Invention and Competitiveness. Paris: OECD, 1986. Table 2.21.

Table 3

	R&D expenditure/output OECD (1980)	US (1980)	US (1985)	Sweden (1983)
High R&D Intensity	11.4	8.8		9.4
Aerospace	22.7	13.7	17.5	5.3
Computers	17.5	12.0		10.1
Electronics - components	10.4	7.9	9.1	11.0
Drugs and medicine	8.7	6.2	8.4	20.2
Instruments	4.8	7.5	10.3	6.0
Electrical machinery	4.4	6.3	7.8	6.5
Medium R&D Intensity	1.7	2.5		2.9
Motor vehicles	2.7	4.9	3.7	5.0
Chemicals	2.3	2.8	3.7	2.2
Other manuf. industries	1.8	0.4		
Non-electrical machinery	1.6	2.3		2.2
Rubber, plastics	1.2	2.2	3.0	0.3
Non-ferrous metals	1.0	0.7	1.6	0.6
Low R&D Intensity	0.5	0.7		0.6
Stone, clay, glass	0.9	1.4		0.8
Food, drink	0.8	0.4		0.3
Shipbuilding	0.6	0.6		1.1
Petroleum refineries	0.6	0.6		0.3
Ferrous metals	0.6	0.7		2.0
Fabricated metal products	0.4	1.4	1.4	0.7
Paper, printing	0.3	1.0		0.7
Wood, cork, furniture	0.3	0.8	0.6	0.1
Textiles, footwear, leather	0.2	0.4		0.2
Total manufacturing		3.0	4.2	2.2

Sources:

NSF, National Patterns of Science and Technology Resources: 1987, Surveys of Science Resources Series, NSF 88-305, Tables B-25 and B-28.

OECD, Science and Technology Indicators, No. 2, R&D, Invention and Competitiveness, OECD, Paris, 1986, Table 40.

Swedish Central Bureau of Statistics, Industri 1983, Stockholm 1985; and special printouts made available by the Bureau (as cited in Jacobsson, S., "R&D and International Competitiveness in Industry," Department of Industrial Management, Chalmers University of Technology, mimeo,

Table 4

	Share of Mfg. Industry in OECD					
	U.S. (1970)	U.S. (1980)	U.S. 1980/70	Sweden (1970)	Sweden (1980)	Sweden 1980/70
High R&D Intensity						
Aerospace	80.9	60.6	0.75	1.0	1.5	1.50
Computers	52.3	48.6	0.93	2.1	1.2	0.57
Electronics - components	48.4	33.3	0.69	1.0	1.8	1.80
Drugs and medicine	41.6	33.2	0.80	0.7	1.0	1.43
Instruments	51.9	44.1	0.85	0.6	0.7	1.17
Electrical machinery	42.7	31.2	0.73	1.3	1.5	1.15
Medium R&D Intensity						
Motor vehicles	49.8	40.4	0.81	1.2	1.7	1.42
Chemicals	45.8	43.6	0.95	0.9	0.8	0.89
Other manuf. industries	54.3	40.0	0.74	0.6	0.7	1.17
Non-electrical machinery	46.1	38.1	0.83	1.7	1.9	1.12
Rubber, plastics	45.3	39.3	0.87	1.1	0.9	0.82
Non-ferrous metals	47.7	46.4	0.97	1.7	1.6	0.94
Low R&D Intensity						
Stone, clay, glass	38.7	31.0	0.80	1.6	1.3	0.81
Food, drink	46.7	40.0	0.86	1.5	1.3	0.87
Shipbuilding	34.1	39.6	1.16	4.9	3.8	0.78
Petroleum refineries	49.1	51.2	1.04	0.6	1.4	2.33
Ferrous metals	34.5	34.5	1.00	1.7	1.5	0.88
Fabricated metal products	45.4	42.6	0.94	1.7	1.7	1.00
Paper, printing	53.6	46.3	0.86	2.8	3.2	1.14
Wood, cork, furniture	40.7	34.2	0.84	3.5	3.8	1.09
Textiles, footwear, leather	44.0	37.2	0.85	0.8	0.6	0.75
Total manufacturing						

Table 5 United States Net Exports in Metalworking Industries (SIC 34-38), 1973 and 1983 (Current prices)

SIC Code	Industry	Net exports 1983 $ Billion (1)	Rank 1983 (2)	Net exports 1973 $ Billion (3)	Rank 1973 (4)
3720	Aircraft	6645.4	1	2896.5	1
3530	Construction machinery	5402.3	2	2543.9	2
3570	Office machines & computers	4807.9	3	1278.4	3
3721	Aircraft parts	3586.0	4	618.9	8
3510	Engines & turbines	3177.5	5	1244.8	4
3811	Engineering & scientific instruments	2563.9	6	768.0	5
3580	Refrigeration & merchandising machines	1202.3	7	554.4	10
3440	Fabricated structural metal products	1036.2	8	318.2	14
3560	General industrial machinery	915.5	9	580.1	9
3760	Guided missiles & space vehicles	902.1	10	101.9	25
3840	Medical instruments & supplies	817.6	11	224.7	17
3480	Ordnance & accessories nec	766.7	12	164.2	22
3690	Misc electric equipment & supplies	431.5	13	30.2	28
3620	Electrical industrial apparatus	361.9	14	291.4	15
3462	Forging, stamping & misc products	349.4	15	351.3	12
3531	Materials handling machinery	258.2	16	165.0	21
3743	Railroad equipment	253.1	17	182.2	20
3730	Ship & boat building & repair	235.6	18	127.3	23
3520	Farm & garden machinery	211.3	19	81.5	26
3610	Electrical distribution equipment	163.7	20	107.4	24
3752	Misc transport equipment	74.9	21	-754.0	36
3410	Metal cans, barrels, drums & pails	49.5	22	3.2	29
3640	Electric lighting & wiring equipment	-11.0	23	-7.4	30
3861	Photographic equipment & supplies	-66.9	24	375.6	11
3430	Plumbing & heating	-83.3	25	68.2	27
3832	Optical & ophthalmic instruments	-159.7	26	-133.5	33
3541	Other metalworking mach	-159.8	27	182.2	19
3540	Machine tools	-243.8	28	258.6	16
3420	Cutlery, hand tools, etc	-337.2	29	-19.7	31
3450	Screw machine products	-371.7	30	-132.3	32
3630	Household appliances	-661.6	31	-221.1	34
3672	Electronic components & accessories	-726.8	32	685.0	7
3710	Motor vehicles & supplies	-755.5	33	343.0	13
3552	Special industrial mach. & misc machines	-771.8	34	738.0	6
3660	Communication equipment	-836.6	35	213.0	18
3873	Watches, clocks, etc.	-968.1	36	-302.4	35
3650	Radio & TV receiving equipment	-5772.2	37	-1920.1	37
	SIC 34 - 38 Total	22286.3		12006.9	

Sources: U.S. Department of Commerce, Bureau of the Census, U.S. Exports (FT 610), 1973 and 1983 Annual Reports.

U.S. Department of Commerce, Bureau of the Census, U.S. Imports (FT 210), 1973 and 1983 Annual Reports.

Note: Data have been aggregated from the 8-digit level. See Appendix.

Table 6 Share of Numerically Controlled (NC) Machine Tools in Total Investment in Machine Tools in Japan, Sweden, the United Kingdom, and the United States, 1978-1984. (Percent, current prices)

Year	Japan	Sweden	United Kingdom	United States
1978	15.6	26.0	19.0	n.a.
1979	27.2	31.1	22.5	n.a.
1980	28.3	28.6	30.9	27.8
1981	29.3	30.6	44.9	30.2
1982	38.8	31.4	40.8	38.1
1983	47.5	55.0	54.6	43.8
1984	54.3	59.4	62.4	40.1

*) Refers to metal-cutting machine tools only; information on metal-forming machine tools is not available for Japan and unavailable for Sweden for 1978-1982.

<u>Source</u>: Jacobsson & Edquist (1988): 25.

Table 7 Number of Industrial Robots and Flexible Manufacturing Systems (FMS) in Various Countries, 1984.

(per 100,000 employees in engineering industries)

Country	Number of Robots	Number of FMS
Japan	1225.7	1.9
Sweden	701.1	5.5
Belgium	281.0	. .
Italy	271.6	. .
West Germany	161.7	0.6
United States	147.5	0.7
France	146.9	. .
United Kingdom	84.6	0.3

<u>Source</u>: C. Edquist and S. Jacobsson (1987)