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R&D IN SWEDISH MULTINATIONAL CORPORATIONS

by

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R&D in Swedish Multinational Corporations

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Abstract

Using unique data on Swedish multinational corporations (MNCs) in manufacturing, this study investigates several dimensions relating to industrial R&D. The development in the latter half of the 1980s is emphasized. Between 1978 and 1990 R&D intensity of the Swedish MNCs almost doubled from about 2 to 4 percent. It is further noted that growth in real R&D expenditures declined in the second half of the 1980s compared with the early 1980s. The statistical analysis supports the view that Swedish MNCs to a large extent base their international competitiveness, measured as foreign sales, on technological capabilities created through R&D activities. On the other hand, the analysis also indicates that more sales in foreign markets increases the rate of return on each R&D SEK spent, and, thus, induces more R&D expenditures. Finally, it is shown that the marginal productivity of R&D is positive, although this effect is statistically weak and seems to have decreased over time.

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1. Introduction

Multinational corporations (MNCs) account for an increasing share of the world's industrial R&D, and dominate in terms of aggregate manufacturing output and exports as well. In countries with small domestic markets, such as Sweden, the Netherlands and Switzerland, which are particularly dependent on foreign markets for their industrial output, MNCs play an even more pronounced role than in large economies like USA, Japan or Germany. When considering the stock of foreign direct investment (FDI), Sweden is the tenth largest originator in absolute terms in the world, and on the fifth place when FDI is related to GDP (UNTCT [1988]).

Relative to its size, the Swedish economy is also one of the most R&D intensive in the world. In 1989, the share of national R&D expenditures to GDP was 2.9% for Sweden and Switzerland, followed by United States and Japan with 2.7%, considering major R&D performing industrial countries (United Nations 1992). An overwhelming majority, almost 80%, of total Swedish R&D in the manufacturing sector was undertaken by MNCs in 1990. The same year, 52% of Swedish exports, 42% of industrial employment in Sweden and 40% of Swedish industrial production were attributed to these firms.

The present study investigates several dimensions relating to R&D in Swedish MNCs. The analysis is based on data covering practically all Swedish MNCs, and their foreign production affiliates, in the manufacturing industry between 1965 and 1990. The database has been collected by The Industrial Institute for Economic and Social Research (IUI).[1,2] The emphasis of the study is on the

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[1] A total sample of 110 MNCs originating in Sweden in the manufacturing sector is studied in 1990. These 110 firms are selected, on the basis that they have production abroad, out of a larger sample of all Swedish MNCs (320 firms) in manufacturing. The 110 MNCs with production abroad account for 91% of total sales, 88% of total number of employees and 89% of exports from Sweden for the sample of 320 firms. A MNC is here defined as a firm originating from Sweden with at least one majority owned affiliate abroad. Any firm with more than 50 employees and with industry classification SNI 3 (i.e. manufacturing industry) is included.

[2] The surveys cover the years 1965, 70, 74, 78, 86 and 1990, and the response frequency has mostly been above 90%. No information from 1965 is included in the present paper. Note that in numerous diagrams the year 1982 is included even though no survey was undertaken that year. The reason for this is to obtain an even four year scaling of the time axis. The observations of 1982 are calculated as a simple average of 1978 and 1986.

development in the latter half of the 1980s.

Section 2 presents some descriptive data on R&D in Swedish MNCs, surveying both firms' overall R&D and their foreign R&D. Swedish and foreign R&D intensities, the development over time of Swedish versus foreign R&D expenditures, and other related topics, are discussed. Section 3 analyzes statistically the simultaneous relationship between MNCs' R&D and their internationalization. It is here proposed that firms with a higher R&D intensity have a competitive advantage and will therefore be more international, in terms of foreign sales. At the same time, higher internationality should favor a higher rate of return on each R&D SEK spent, which speaks for more investments in R&D. Some descriptive data and correlations on R&D and internationalization are also presented. In section 4, the relationship between R&D and productivity is studied. First, by some descriptive observations and correlations, and second, by econometric estimation of the marginal productivity of R&D. It is expected that R&D exerts a positive impact on a firm's productivity growth. Finally, section 5 summarizes.

2. Descriptive data on R&D in Swedish MNCs

After establishing some facts regarding the characteristics of Swedish MNCs' overall R&D, this section investigates MNCs' R&D abroad.

2.1 Overall R&D

Swedish MNCs generally base competitiveness either on technology, created through, e.g., R&D activities within the firm, or on factors of production specific to Sweden, such as raw materials (Swedenborg [1979, 1982]). In the IUI-survey of Swedish multinationals 1990, only 20 out of 110 firms did not perform R&D at all. As can be seen in Table 2.1, such MNCs are small with respect to number of employees, and have only a limited share of their employees abroad, if compared with MNCs performing R&D.

Swedish MNCs spent almost 23 billion SEK on R&D in 1990, as shown in Table 2.2. About 83 percent, 19 billion SEK, was undertaken in Sweden, to be compared with 24.3 billion SEK for the whole Swedish manufacturing sector in 1990.[1] Swedish MNCs, thus, dominate activities in R&D in the home country. Two industries,[2] transports and electronics, together are responsible for more than 15

Table 2.1. ***Comparison of MNCs that perform R&D and those that have no R&D in 1990.***

Characteristics	Firms without R&D (n=20 MNCs)	Firms with R&D (n=90)
Average number of employees	278	7 339
Average share of employees abroad	27%	62%

[1] Source: NUTEK, Department of Policy Analysis, based on unpublished material from Finans statistiken (Finance statistics).

[2] The four main industries considered in this paper are *chemicals* (SNI 35), *basic* consisting of paper & pulp, paper products and iron & steel (SNI 34 and 37), *engineering* (SNI 38) *food, textiles and others* (SNI 31, 32, 33, 36 and 39). Usually, we will refer to the first three groups. Engineering, which is the most important industry (see Tables 2.2 and 2.5), is decomposed into *metal products* (SNI 381), *machinery* (SNI 382), *electrical machinery & electronics* (SNI 383), denoted "electronics" in the text, and *transport equipment* (SNI 384), denoted "transports".

billion SEK, or some 70 percent of total R&D expenditures in Swedish MNCs. There are also considerable R&D activities in the chemical industry, primarily in pharmaceuticals.

The 20 largest Swedish MNCs, with respect to turnover 1990, account for almost all aggregate R&D undertaken by the group of 110 MNCs, 97% of these firms R&D in Sweden, and about the same share of the R&D abroad. Even within the group of 20 MNCs we note a concentration of R&D activities. For example, four MNCs (group 1 in Table 2.6, Appendix 2) account for 72% of the 110 firms' aggregate R&D in Sweden. This implies that as much as 56% of overall R&D expenditures for the whole Swedish manufacturing sector in 1990 can be attributed to only four MNCs. From Table 2.6, we can also note that eight MNCs (groups 1 and 3) together undertake about 74% of the 110 firms' overall R&D abroad. Hence aggregate R&D is concentrated to a few large firms, especially with regards the R&D localized in Sweden.[3]

R&D in foreign affiliates is undertaken to any great extent only in electronics and machinery. Machinery is the only industry with more R&D abroad than in Sweden. Table 2.2 shows the relative weights for different industries when considering aggregate R&D-data. A similar distribution of shares for different

Table 2.2. ***R&D expenditures in 1990 for Swedish MNCs across industries (MSEK).***

Industry (No. of MNCs)	Total R&D	Swedish R&D	Foreign R&D
Basic (14)	1 376	1 034	342
Chemicals (17)	3 311	2 760	551
Food, textile, other (21)	81	71	10
Engineering (58)	17 990	14 925	3 065
Metal products (25)	872	687	185
Machinery (18)	1 511	713	798
Electronics (11)	6 070	4 524	1 546
Transports (4)	9 537	9 001	536
All MNCs (110)	22 758	18 790	3 968

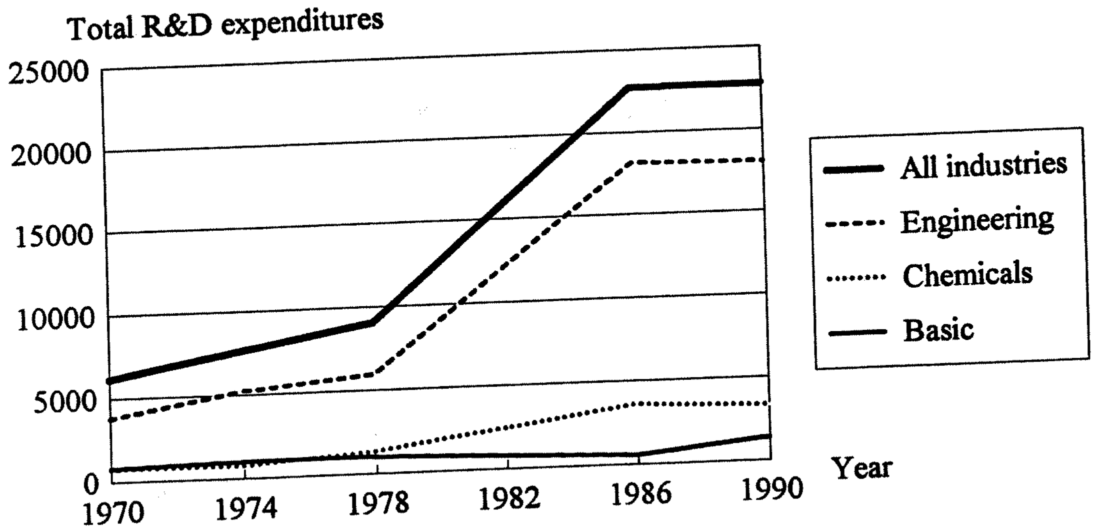
[3] Table 2.6 in Appendix 2, reports some further details on the 20 largest MNCs, and divide them into smaller groups. The same information regarding the remaining 90 firms (out of the overall 110) is provided in Table 2.7, Appendix 2. The 90 firms are here grouped according to their R&D intensity.

industries with respect to turnover, employees and value added, is given in Table 2.5 in Appendix 2.

Studying the trend in real R&D expenditures since 1970 in Figure 2.1, we observe a substantial increase between 1978-86. This was primarily explained by the development in engineering, which increased its R&D expenditures from about 6 to 18 billions SEK in constant prices. There was no growth between 1986-90, however.[4] R&D has grown continuously in chemicals between 1970-86, and declined slightly in the second half of the 1980s. The basic industry has throughout exhibited relatively low R&D expenditures.

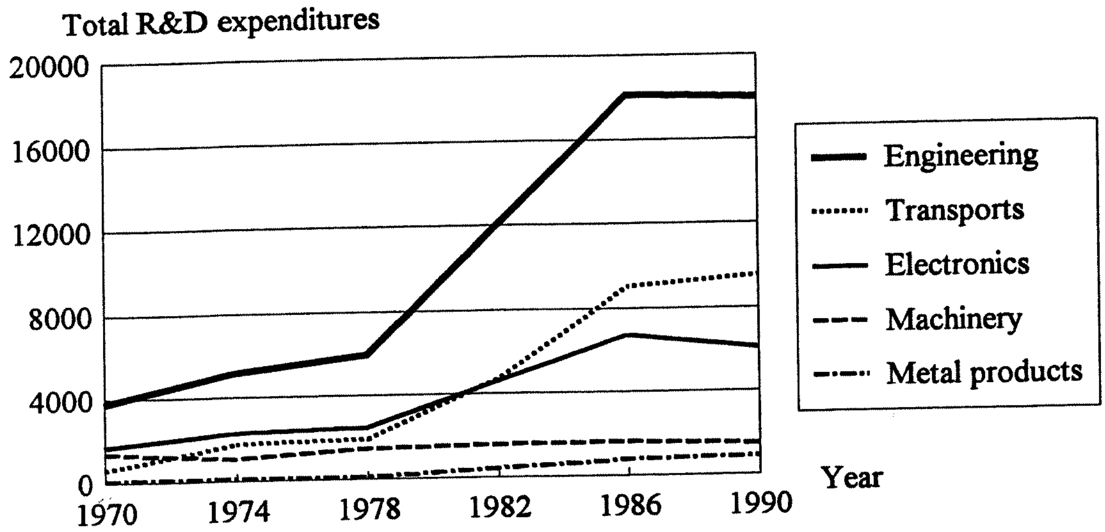
If we divide the engineering industry further, as in Figure 2.2, it is clear that the two most important R&D-groups, transports and electronics, are responsible for the large increases in R&D expenditures in engineering as a whole. It should also be noted that machinery has not had any growth in R&D at all during the whole 20-years period.

Figure 2.1. ***R&D expenditures for Swedish MNCs 1970-90. Constant 1990 prices (MSEK).***



[4] It should be noted that in Figures 2.1 and 2.2 the entire cross-section of MNCs is included each year. If instead constant groups of MNCs are followed over, e.g., the periods 1978-86 and 1986-90, we observe a rapid growth in the former period and a much slower growth in the latter period. Hence, the overall pattern over time does not change substantially when analyzing the cross-section or constant groups of MNCs.

Figure 2.2. ***Total R&D expenditures in engineering (SNI 38) 1970-90. Constant 1990 prices (MSEK).***



Comparing R&D expenditures with some measures of firm size yields a measure of R&D intensity. Two different alternatives of R&D intensity are available: R&D divided by sales or by value added. As in the vast majority of studies investigating the economics of R&D, sales is used as a deflator since it is more stable over time

Figure 2.3. ***Total R&D-intensity (Total R&D/Total production) for Swedish MNCs 1970-90. Percent. Discrete points in time.***

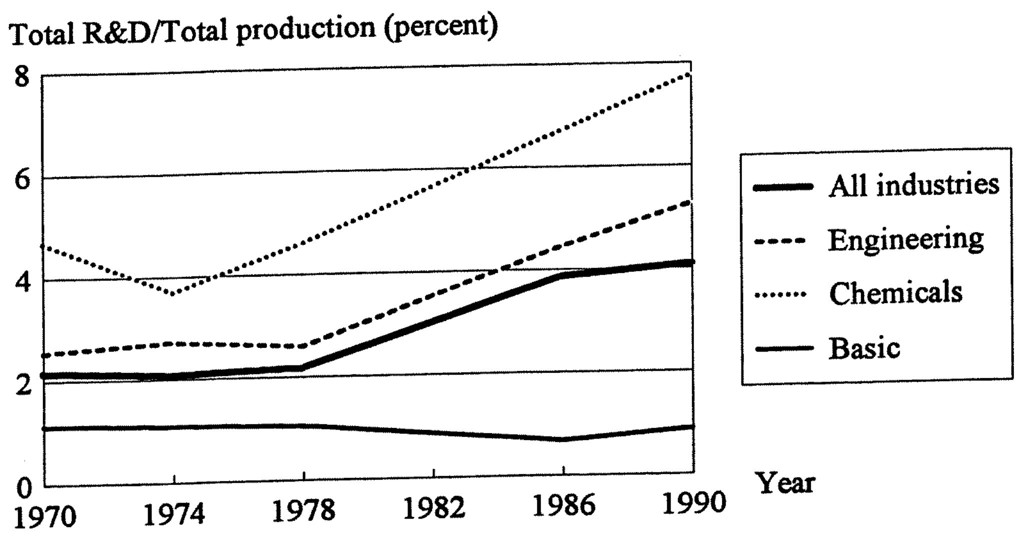
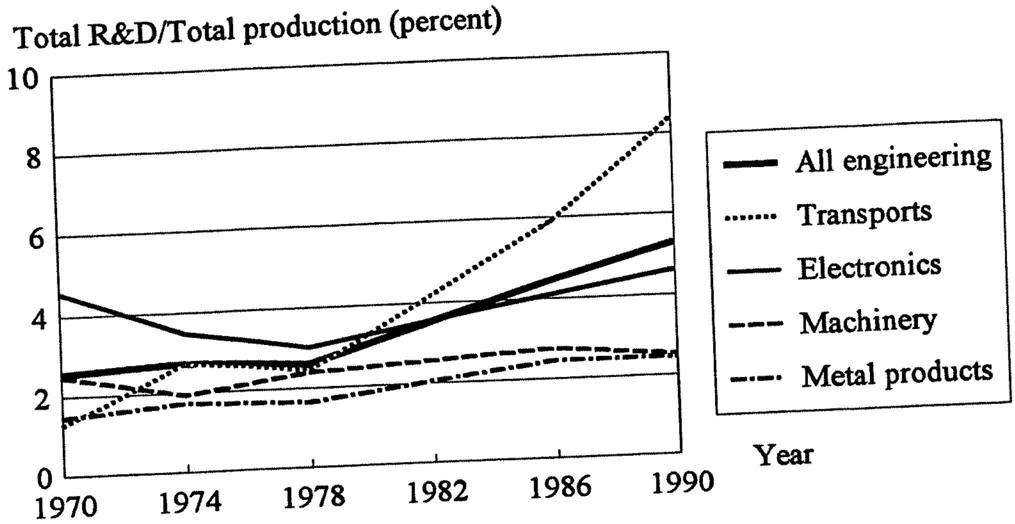


Figure 2.4. ***Total R&D-intensity (Total R&D/Total production) for Swedish MNCs in engineering (SNI 38) 1970-90. Percent. Discrete points in time.***

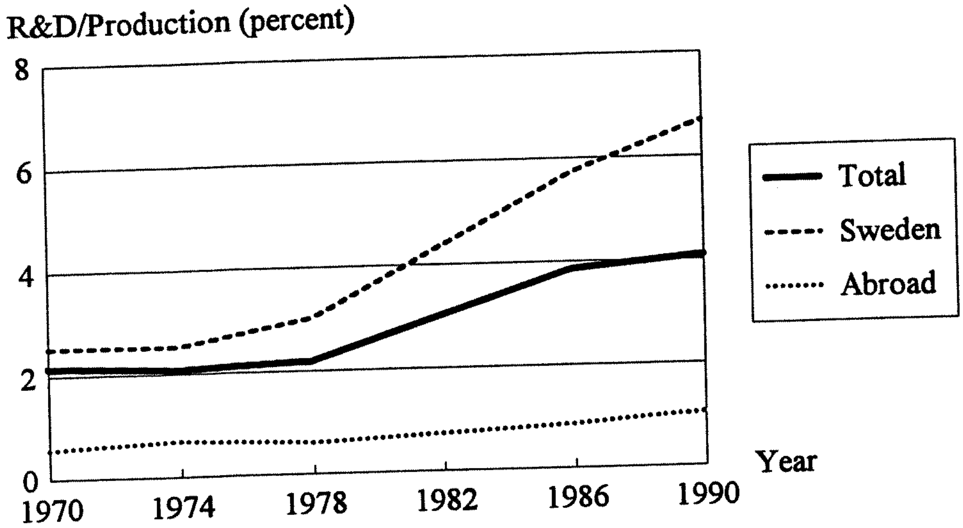


than value added. The latter variable is more dependent on business cycles, since it partly consists of profits. As shown in Figure 2.3, total R&D intensity has increased from about 2 to 4 percent for all firms during the last 20 years, primarily between 1978 and 1986. The R&D intensity in the basic industry has been on a low level throughout the period, about 1 percent. It is also worth noting that the chemical industry has had the highest intensity over time. It is only challenged by the transport industry in 1990 (more than 8 percent in Figure 2.4).

If we split the MNCs' total R&D intensity into a Swedish and a foreign part, we note from Figure 2.5, that the Swedish intensity was almost 6 percent in 1986 and 7 percent in 1990.[5] The foreign R&D intensity was considerably lower, it increased slowly from roughly 0.5 to 1 percent over the period 1970-90. It is obvious that the large increase in total R&D intensity 1978-86 can be explained by the increase in the Swedish parts. Swedish R&D-intensities for different industries (see Figures 2.12 and 2.13 in Appendix 2) are, in fact, very similar to the total intensities

[5] This could be compared with the R&D intensity in foreign-owned affiliates located in Sweden, which was 1.8 and 3 percent, for the same years (Riksbanken [1992]). The last two figures must anyway be regarded as relatively high, since the corresponding R&D-intensity in Swedish-owned affiliates abroad has never exceeded 1 percent (Figure 2.5).

Figure 2.5. ***Total, Swedish and foreign R&D-intensity for Swedish MNCs 1970-90. Percent. Discrete points in time.***

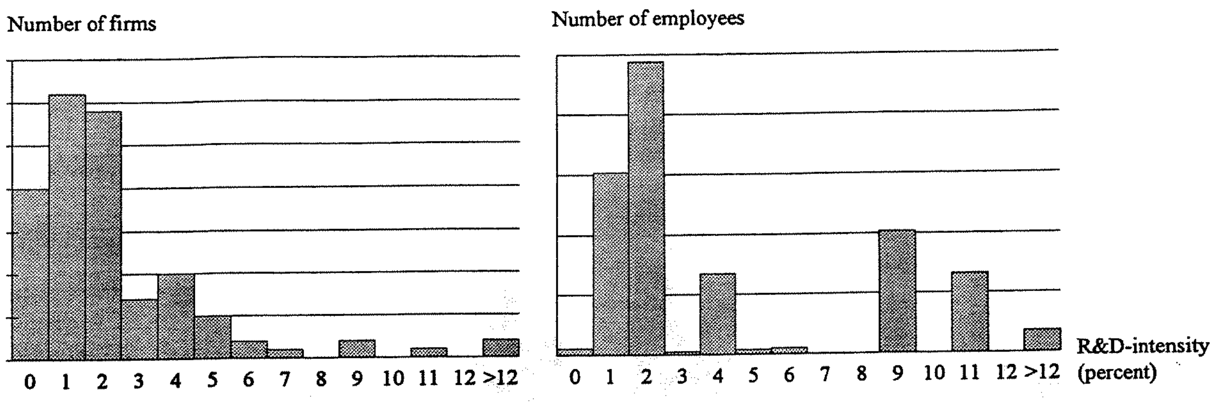


shown in Figures 2.3 and 2.4, although the former are on a higher level. Chemicals have the highest foreign R&D intensity of all industries, as shown in Figure 2.14 in Appendix 2. The intensity was as high as 2 percent in 1990, to be compared with about 1% for the second highest, engineering. Basic industry exhibits a lower R&D intensity in this case as well.

The distribution of the number of MNCs in different R&D intensity groups is shown in Figure 2.6.a. This should be studied carefully, since the average R&D intensity for various industries, reported in Figures 2.3-2.5 above, tells us little about the individual firms. The individual MNCs may diverge considerably from the average. As many as 80 of the 110 firms have an intensity of 2 percent or less, and for only 13 firms does the intensity exceed 4 percent. Again, firms without R&D tend to be very small, as seen from Table 2.1. One may suspect that the few firms with high R&D intensity are more important than shown in Figure 2.6.a.

When substituting the number of MNCs for the number of employees in MNCs with a certain R&D-intensity on the vertical axis in Figure 2.6.b, the pattern changes radically. The group of firms with no R&D almost disappears and some groups with high R&D-intensities obtain a larger weight. The distribution takes rather a bimodal character with two groups of firms. One group has an R&D

Figures 2.6.a and 2.6.b. ***Distribution of Swedish MNCs according to R&D intensity groups in 1990. Number of MNCs and number of employees.***



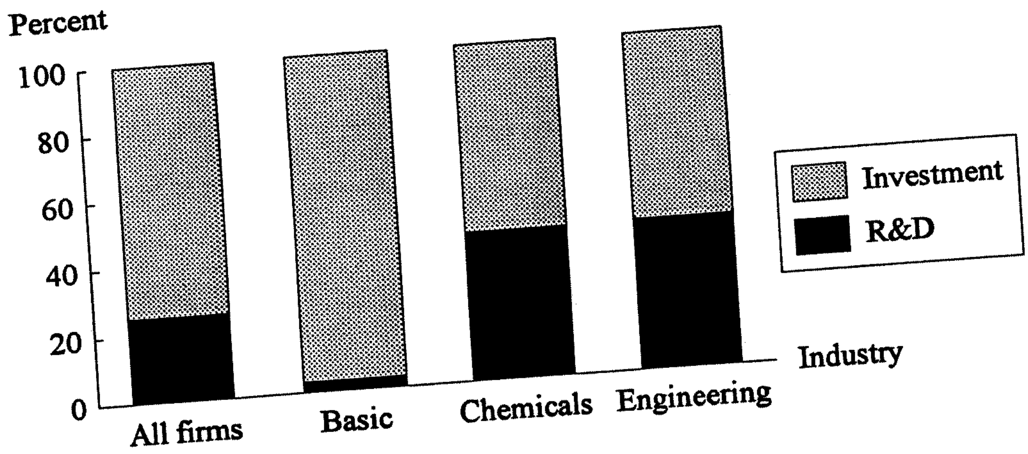
Note: In order not to reveal information on individual MNCs the vertical axes are not scaled with respect to number of firms or number of employees. The intervals of R&D-intensity on the horizontal axis are the following: Group 0 has 0% R&D of total production, group 1 has an R&D-intensity between 0-1%, group 2 has an R&D-intensity between 1-2%, etc.

intensity between 0-2% and the other one has a remarkably high R&D intensity. Similar distributions for chemicals, metal products and machinery are depicted in Figures 2.16-2.21 in Appendix 2. Not surprisingly, the spread in R&D intensity is especially notable in chemicals (Figures 2.16 and 2.17), partly due to the industry's heterogenous nature, consisting of firms producing pharmaceuticals, petroleum, plastic and rubber products.

If we consider R&D expenditures as an investment in addition to traditional physical investments,[6] and relate R&D to this measure of "total investments", we obtain an indication of R&D's relative importance in terms of long term investments. For all firms in 1990, more than 20 percent of all investments were in R&D, as noted from Figure 2.7. The share was more than 40 percent in engineering and chemicals, which is in line with the proposition that firms in these industries compete with technology and new products. The share was, however, only a few percent in the basic industry, explained by the high capital intensity in this industry.

[6] Physical investments are here defined as investments in real estate, tools and equipment.

Figure 2.7. ***R&D and physical investments for Swedish MNCs in 1990. Percent of total investments.***



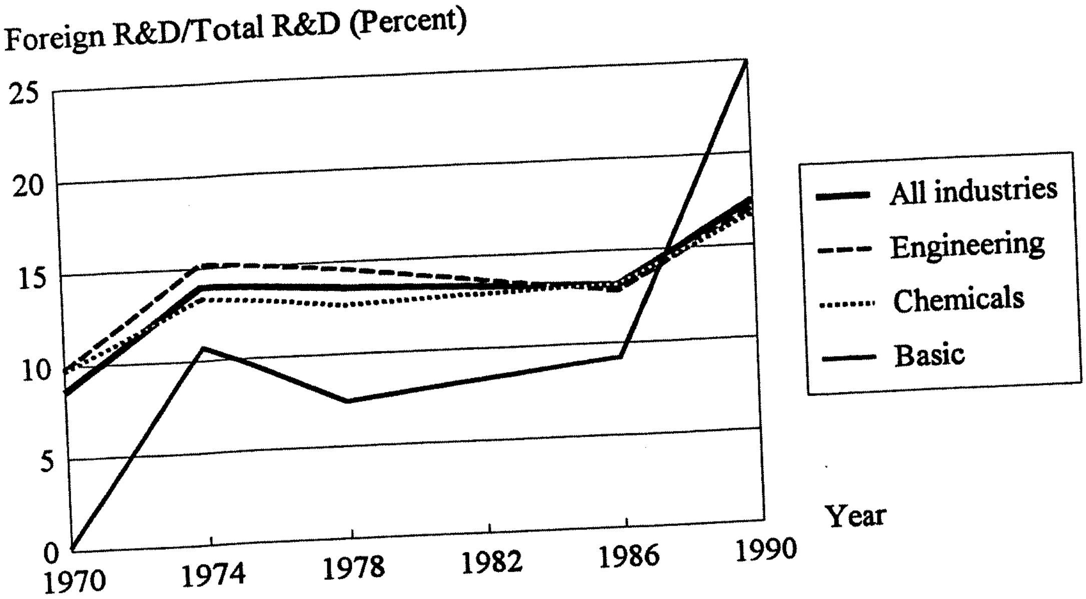
2.2. Foreign R&D

MNCs have historically performed the major part of their R&D in the home countries. In recent time, however, there have been a marked growth in the internationalization of R&D activities. The increasing importance of economies of scope, shorter product cycles and rapid obsolescence, is pointed out as factors that require closer interaction with local customers. This applies to the localization of production as well as R&D (United Nations [1992]).

R&D undertaken abroad by Swedish MNCs has changed considerably both in character and magnitude over the past 20 years. In the 1970s, the major part of foreign R&D was directed towards adaptation of products and processes developed in Sweden for local use, while in the 1980s there was a shift towards more long term and general applicable R&D in the foreign affiliates. A similar trend was observed in other industrial countries (United Nations [1992]). In 1990 more than half of foreign R&D by Swedish MNCs was directed towards development of new products and processes (Norgren [1993]). Today some major Swedish MNCs have even located entire R&D laboratories outside Sweden.

Most R&D by Swedish MNCs still takes place in Sweden. Figure 2.8 shows the development 1970-90 of R&D undertaken abroad as percentage of total R&D.

Figure 2.8. ***Share of R&D abroad for Swedish MNCs 1970-90. Percent. Discrete points in time.***

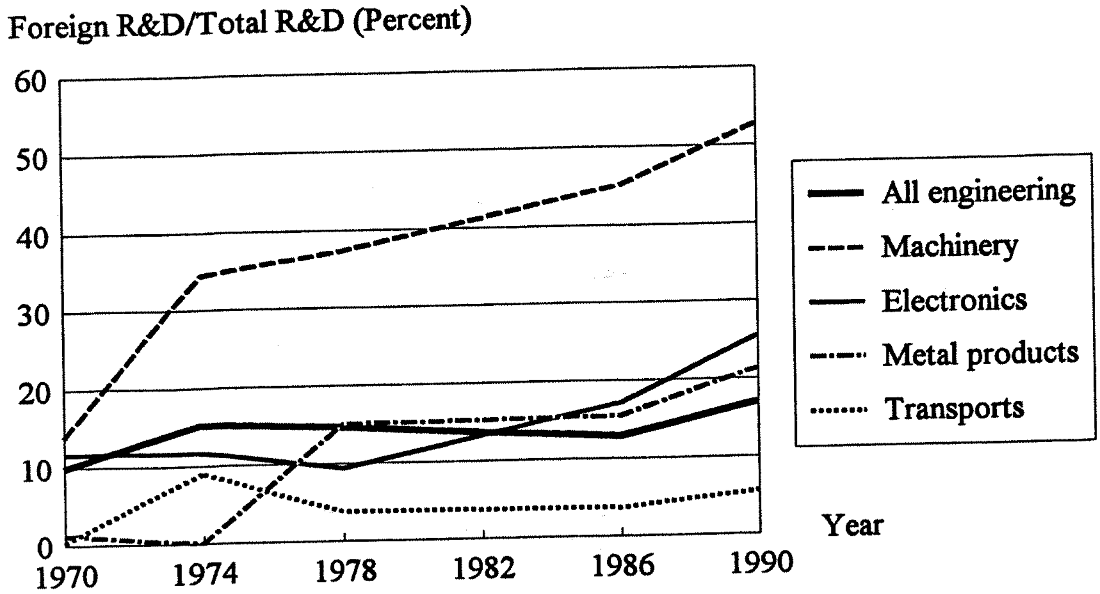


Considering all manufacturing industries, we note that in the first half of the 1970s the share increased from approximately 8 to 14 percent. Thereafter it remained on that level, or even decreased slightly until 1986. In the second half of the 1980s, we note a dramatic jump in the share of R&D undertaken abroad, from around 13 to 17 percent of total R&D. As a comparison, the share of foreign to total R&D by US multinationals in manufacturing increased from 6 percent in 1970 (Mansfield et al [1979a]), to around 10 percent in 1989 (United Nations [1992]), hence, considerable lower than in the Swedish firms.

The engineering industry, constituting the major part of the manufacturing industry in Sweden in terms of R&D (see Table 2.1), was slightly above the share for all manufacturing industries, while chemicals was slightly below the total figure for most of the period 1970-90. There have been large changes in the basic industry, partly depending on the low level of R&D expenditures in absolute terms in this industry. A modest change in foreign R&D will, thus, cause a large change in the share. The drastic increase between 1986-90 can partly be attributed to the large foreign acquisitions during this period in the paper & pulp industry.

Within the engineering industry (Figure 2.9), especially machinery and electronics have increased their ratio of foreign to total R&D over the past 20

Figure 2.9. ***Share of R&D abroad for Swedish MNCs in engineering (SNI 38) 1970-90. Percent. Discrete points in time.***



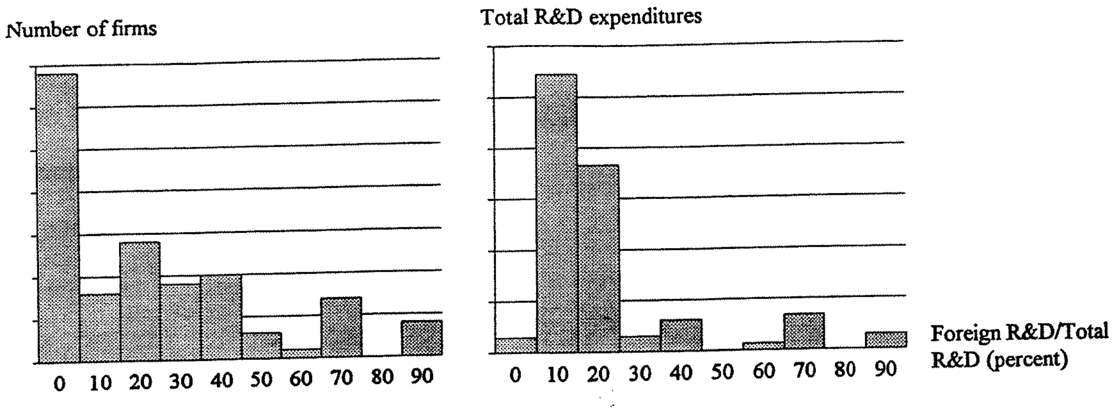
years. The transport industry exhibited the lowest ratio, 5% in 1990. Transports have, however, the largest weight according to Table 2.2, which explains the modest increase for engineering on the whole. Machinery has throughout the studied period been on a higher level relative to the other parts of engineering. In 1970, it had around 15% of its R&D abroad, not far from the corresponding figure for electronics, while machinery had more than 50% of its R&D abroad 1990. In electronics, foreign affiliates accounted for 25% of total R&D the same year.

As an alternative measure of internationalization of R&D, Figures 2.10.a and 2.10.b, illustrate the distribution of MNCs in terms of the share of R&D undertaken abroad. Two different measures of size are used on the vertical axis: (a) number of firms and (b) total R&D expenditures.[7] The distributions in Figures 2.10.a-b are reported only for all manufacturing industries.[8] Looking at the distribution of the number of MNCs, irrespective of size, we note from Figure 2.10.a that the 90 MNCs performing R&D, underlying the cross section 1990 average share of foreign to total

[7] In order to isolate for total R&D expenditures, which the R&D share is weighted with.

[8] In case of the distribution of number of MNCs, there are too few observations to analyze the distribution within each industry, without revealing the characteristics of individual MNCs.

Figures 2.10.a and 2.10.b. ***Distribution of Swedish MNCs according to the share of R&D undertaken abroad in 1990. Number of firms and R&D expenditures.***



Note: In order not to reveal information on individual MNCs the vertical axes are not scaled with respect to number of firms and R&D expenditures, respectively. Number of observations equals 90. The intervals of share of R&D abroad on the horizontal axis are the following: Group 0 has no R&D abroad, Group 10 has 0-10% of R&D abroad, Group 20 has 10-20% of R&D abroad, etc.

R&D which equals 17.4%, are spread around this average considerably.[9] 34 MNCs had no foreign R&D at all, and four MNCs have more than 80% of R&D abroad. In between we have 44 firms with less than 50% of R&D abroad, and 8 firms with more than 50 but less than 80% abroad.

When taking account of total R&D expenditures of the MNCs in each group, measured on the vertical axis, a different pattern emerges. R&D activities are small in the category "no foreign R&D" contrary to the number of MNC distribution figure. Most R&D expenditures are found in the 0-10% and 10-20% groups, and the 80-90% group contains as much R&D as the "no foreign R&D" group. Thus, it is important to take into account the denominator when trying to obtain a more detailed view of what is behind the average figure of a ratio for all firms.

In Table 2.3 below, the 1990 population of 110 Swedish MNCs in the manufacturing industry is divided into five different groups with respect to foreign

[9] As noted earlier, out of the total population of 110 MNCs 1990, considering all manufacturing industries, 20 have no R&D at all. The overall average fraction of foreign to total R&D of 17.4% is, however, the same for the group of R&D performers (90 firms) and all MNCs (110 firms).

R&D activities,[10] the first group in the table, "no R&D", is included as a reference case. Let us consider what differences prevail in certain key characteristics among the five groups of MNCs.[11]

In terms of total number of employees, it is obvious that the higher the share of R&D abroad, the larger the number of employees. Furthermore, MNCs with R&D abroad are on average almost seven times larger than MNCs with R&D only in Sweden. It can also be noted that, within the group of foreign R&D performers, MNCs with more than 50% of their R&D outside Sweden are more than twice as large as the foreign R&D performers with less than 50% of R&D abroad. The same pattern can, as expected, also be observed for the share of employees abroad. The higher the share of R&D abroad, the more international firms are. We note that the foreign R&D performers have almost 65% of employees abroad, to be compared with approximately 35% for MNCs that have R&D only in Sweden, and 27% of employees abroad in the group with no R&D at all. Furthermore, MNCs performing R&D abroad have large R&D expenditures and high R&D intensity.

Table 2.3. ***Characteristics of MNCs with different shares of R&D abroad.***

Characteristics	MNCs with				
	No R&D (n=20 MNCs)	Only R&D in Sweden (n=34)	Foreign R&D (n=56)	<50% of R&D abroad (n=44)	>50% of R&D abroad (n=12)
Average number of employees	278	1 566	10 844	9 203	19 028
Average percent of employees abroad	27	36	64	53	82
Average R&D expenditures (MSEK)	0	17	396	488	182
Average R&D intensity (percent)	0	1.0	4.5	5.5	1.7

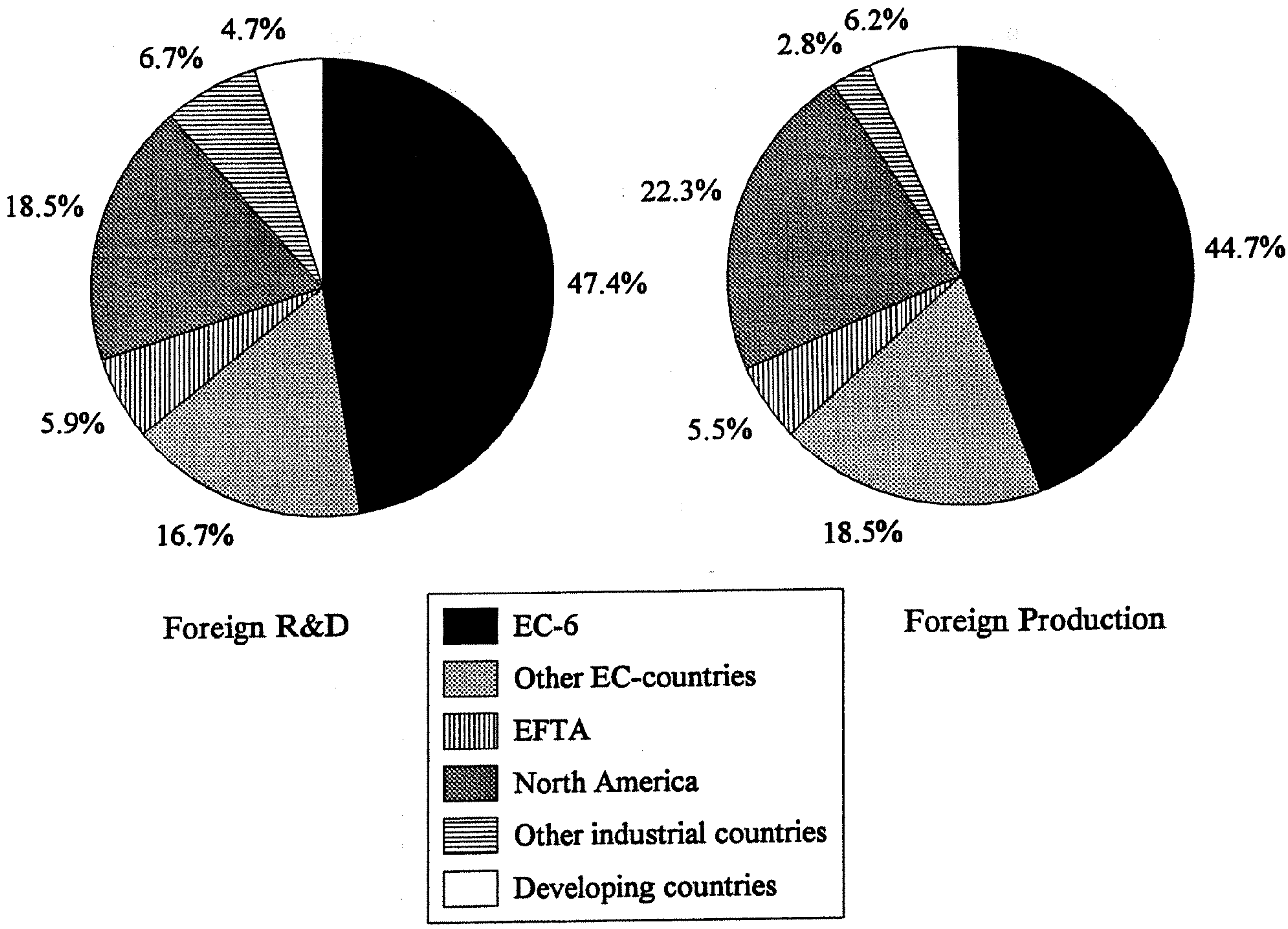
[10] Note that the last two groups sum up to the third group.

[11] See also Table 2.1 in section 2.1 where the groups "without R&D" and "with R&D" are compared in the same fashion.

This is especially the case for the group of MNCs with less than 50 percent of R&D abroad.

The geographical distribution of Swedish MNCs' foreign R&D in 1990 as well as the same distribution for production are shown in Figures 2.11.a and b. The geographical distribution of foreign R&D turns out to match that of foreign production. This is especially the case for the European countries. For example, almost half of foreign R&D was undertaken in EC-6,[12] which is in line with the share of foreign production. The correspondence is the worst for "Developing countries" and "Other industrial countries".[13] It is also possible to evaluate if a

Figures 2.11.a and 2.11.b. ***Distribution of foreign R&D and foreign production across regions in 1990. Percent.***



[12] The group EC-6 includes Germany, France, Italy, the Netherlands, Belgium and Luxembourg.

[13] The group of "Other industrial countries" includes Australia, New Zealand, Japan and South Africa.

region has a relatively high or low R&D intensity. The higher the share of foreign R&D relative to the share of foreign production, the higher the R&D-intensity. The intensity is highest in "Other industrial countries", while it is relatively low in "Developing countries" and North America.

In 1990, at least 60% of the MNCs' overall foreign R&D was undertaken in manufacturing affiliates abroad, i.e. in conjunction with production.[14] The remaining part took place either in sales and services affiliates, or in foreign affiliates specifically dealing in R&D. The affiliates classified as "R&D laboratories" were, however, small and few in number, and had only 388 employees in 1990.

In Table 2.8 in Appendix 2, the R&D undertaken in the foreign manufacturing affiliates is reported by country/region and industry for 1990. In the basic industry, foreign R&D was almost entirely located in the EC countries, notably Germany and United Kingdom. MNCs in chemicals perform most of their foreign R&D in the USA followed by Germany and France. In engineering, foreign R&D was more equally distributed across regions, although the affiliates in Germany, the USA and Belgium accounted for the major part.

[14] Foreign R&D accounted for 4.0 billions SEK in 1990 (Table 2.2), while 2.4 billions SEK were undertaken in foreign manufacturing affiliates (Table 2.8, Appendix 2). There are some missing values in the latter figure, however, meaning that the percentage of 60% is underestimated. According to another source, over 90% of all "foreign R&D units" were connected to manufacturing affiliates in 1991 (Interview with Robert Nobel, Institute for International Business, Stockholm School of Economics, 1993-12-29).

3. R&D and internationalization

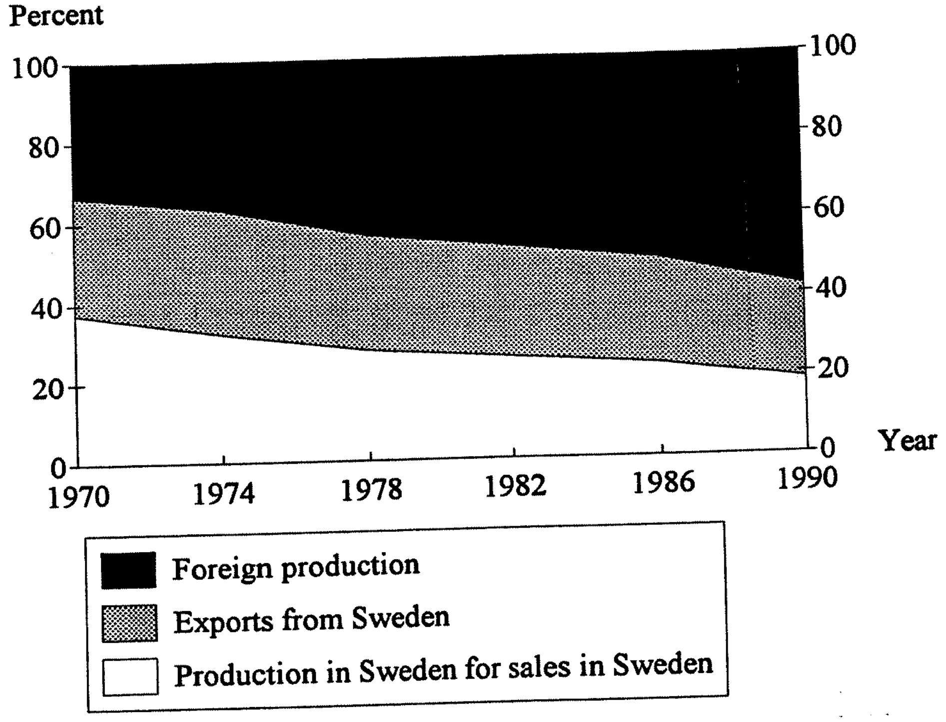
In this chapter, we analyze R&D in relation to the MNCs' degree of internationalization, measured in terms of foreign sales but also decomposed in exports and foreign production. In section 3.1, we first present some background data on Swedish MNCs' internationalization. Theoretical and empirical literature regarding R&D and internationalization is discussed in section 3.2. Descriptive statistics and results from correlation analysis on the subject are then provided in section 3.3, and an econometric model is set up in section 3.4 to test the relationships between R&D and internationalization. It is proposed that R&D will make firms more competitive internationally, leading to increased foreign activities. At the same time, a presence in foreign markets will itself induce more R&D spending. The results of the econometric analysis are presented in section 3.5.

3.1 The internationalization of Swedish firms

Swedish industrial firms have had manufacturing affiliates abroad since the early 1900s. It was not until the 1980s, however, that the internationalization increased substantially (Andersson [1992]). In the beginning of the 1980s, foreign direct investment (FDI) of Swedish MNCs was primarily directed towards North America, with its considerable size and market growth. After the decision to deepen the European integration in the mid 1980s, the flow of FDI shifted towards the EC. The cause of this massive flow can be found in a combination of Sweden's domestic problems, especially the increased labor costs, and the political uncertainty about Sweden's future association with the EC (Braunerhjelm [1990], Andersson & Fredriksson [1993]). The EC-countries constitute the dominating market for Swedish MNCs with 53 percent of foreign sales in the EC-countries in 1990.

The internationalization of Swedish MNCs is illustrated in Figure 3.1. Production in Sweden relative to total production has decreased continuously from 67 percent in 1970 to only 42 percent in 1990. In particular, the sales on the Swedish market have diminished - from 38 percent of total sales in 1970 to 19 percent in 1990. It can also be noted that the share of exports from Sweden in total

Figure 3.1. ***Distribution of the Swedish MNCs' production and sales in Sweden and abroad 1970-90. Discrete points in time. Percent.***



sales has declined from 30 to 23 percent during this period. In Figure 3.2, the development is shown for different industries between 1986 and 1990. Firms in the

Figure 3.2. ***Distribution of the Swedish MNCs' production and sales in Sweden and abroad across industries 1986 and 1990. Discrete points in time. Percent.***

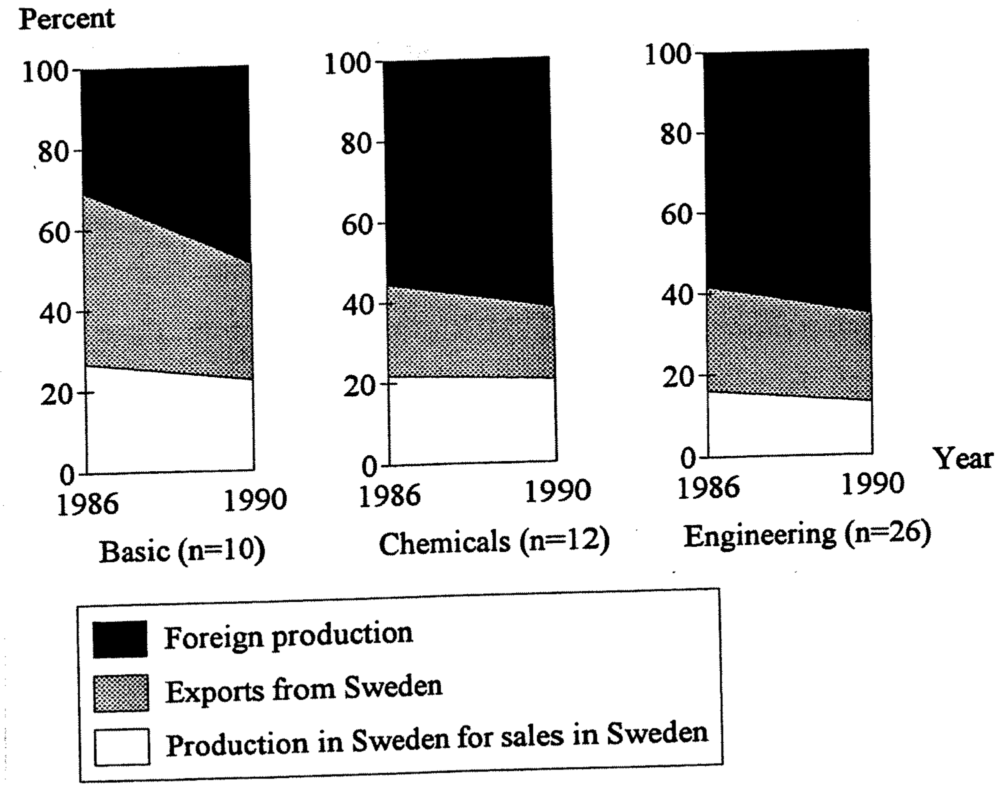
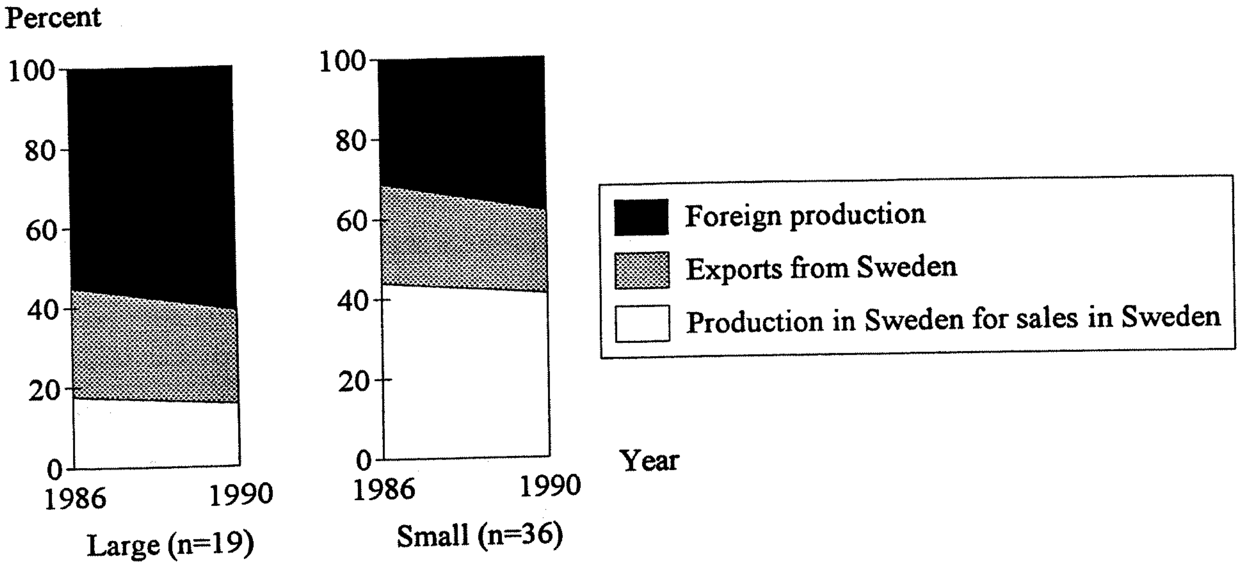


Figure 3.3. ***Distribution of the Swedish MNCs' production and sales in Sweden and abroad for large and small firms 1986 and 1990. Discrete points in time. Percent.***



basic industry have increased their share of foreign production from 31 to 49 percent, primarily due to large acquisitions in the paper & pulp industry in the EC during this period. The pattern for chemicals and engineering is similar. Both had about 60 percent of their production located abroad in 1990, although the engineering industry remains more dependent on Swedish exports. However, differences appear when the population of MNCs is divided into "Large" and "Small" firms[1], as shown in Figure 3.3. "Large firms" had as much as 61 percent of their production abroad in 1990 and 84 percent of their sales on foreign markets, indicating that they have become less dependent on the Swedish market. The corresponding figures are considerable lower for the group of "Small firms", 38 and 59 percent, respectively. It is interesting to note, however, that the trend 1986-90 is similar for the two groups, in the sense that they have both become more oriented towards foreign markets.

[1] The group of "Large firms" are taken from the 20 largest MNCs in 1990 with respect to total turnover in Table 2.6, Appendix 2. 19 of these firms could be followed between 1986-90. All firms in this group have a long experience of activities abroad. The remaining MNCs make up the group of "Small firms".

3.2 Theoretical framework

The possession of an oligopolistic advantage at home is required before a firm is able to penetrate foreign markets (Caves [1971], Dunning [1973]). Such advantages are considered necessary to offset the excessive costs of setting up and operating affiliates across geographical, cultural or legal boundaries. The oligopolistic advantages increase the concentration in the market and can be derived from factors which create barriers to entry for new competitors, e.g. superior technology, high initial capital costs and product differentiation, etc (Lall [1980]).

In particular, firms develop new, and improve existing, products and processes by spending resources on R&D.[2] By doing so they may obtain a technologically based competitive edge vis-à-vis their competitors.[3] The advantage makes it possible to increase foreign market shares. Several empirical studies have supported such a causal relationship, for example Swedenborg [1982], using Swedish data, and Lall [1980] and Kravis & Lipsey [1992], analyzing U.S. data.

If a firm is able to earn rents in foreign markets, the R&D-created knowledge will be utilized more extensively and, due to the public good character of R&D, increase the rate of return to each SEK spent on R&D.[4] Thus, more funds will be available for R&D activities (Pugel [1985]). This is especially the case if goods with a high R&D content make up a greater proportion of foreign sales than domestic sales. Foreign markets will then offer a higher return on R&D than domestic sales (Hughes [1985]). Foreign sales may contain relatively more R&D because R&D is necessary to overcome barriers to entry into foreign markets as discussed above. This means that R&D and foreign sales should reinforce each other in a simultaneous manner (Caves [1982], Mansfield et. al. [1979]). Hughes [1985], using U.K data, took the simultaneity between R&D and exports into account and found that R&D exerted a positive, significant impact on exports. A

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[2] A large share of R&D undertaken by MNCs uses existing technologies to create new, or imitate competitors', products (a good example is the automobile industry).

[3] An alternative is to buy technology, e.g. through licensing.

[4] The public good character arises since the technology created by R&D can be utilized in the whole organization of the MNC.

study on U.S. MNCs by Hirschey [1981] tested the causal relationship between R&D and foreign sales in both directions with a simultaneous method, but found only a significant impact of foreign sales on R&D expenditures.

Sales on foreign markets can be undertaken either through exports from the home country or by production in foreign affiliates. The theory does not say whether R&D activities determine the choice between exports and foreign production, however. According to the product cycle theory (Vernon [1966]), the choice between exports and foreign production depends on the historical phase of the product. R&D used for new products and processes will, primarily, result in exports from the home country, while R&D used for improving existing products and processes tends to favor foreign production.[5] Thus, R&D should be decomposed when investigating the separate effects of R&D on exports and foreign production.

3.3 Descriptive statistics and correlations

Some empirical observations about R&D and foreign operations in Swedish MNCs are provided in this section. Figure 3.4 shows changes over time and levels of firms' intensity to export and to produce abroad for groups of MNCs with different R&D-intensities.[6] The MNCs in a given group are studied over the period 1986-90.[7] The export share of total production has declined between 1986 and 1990, irrespective of R&D-intensity. The decline is the largest for firms without R&D. All groups except the one without R&D have increased their share of foreign production. These four groups also have their intensity to produce abroad on a higher level. The third diagram summarizes the first and second, verifying that the share of

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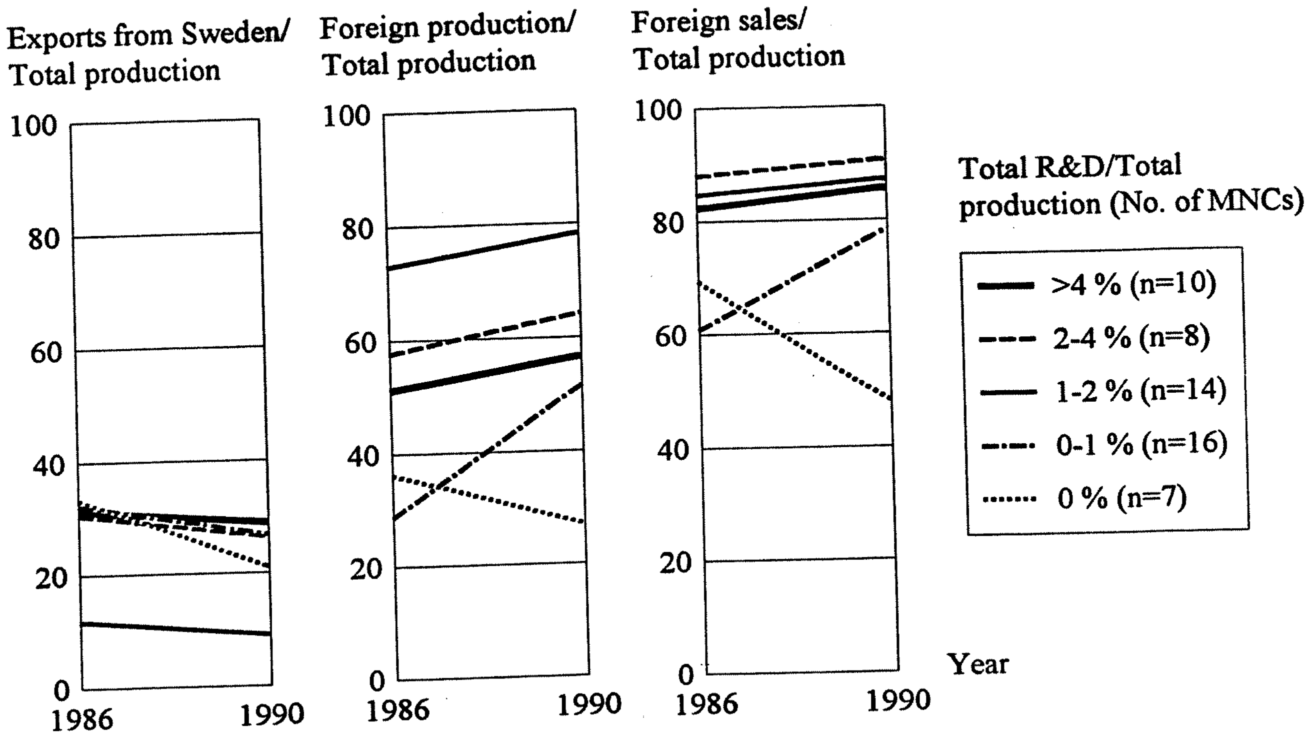
[5] In a product's introductory phase, the innovative firm tends to export. In a later phase when demand is higher, competitive firms are stimulated to imitate the product. The innovative firm will respond to the increased competition and defend its market share by, e.g., serving foreign markets through local production.

[6] The firm's R&D-intensity is calculated as total R&D divided by total sales. This is the standard measure of technological intensity (Caves [1982]).

[7] According to their R&D intensity in 1990.

Figure 3.4. ***Exports, foreign production and foreign sales for groups of Swedish MNCs with different R&D-intensities 1986 and 1990. Percent.***



The groups were classified according to the MNCs' R&D-intensity in 1990. The same firms were followed between 1986 and 1990.

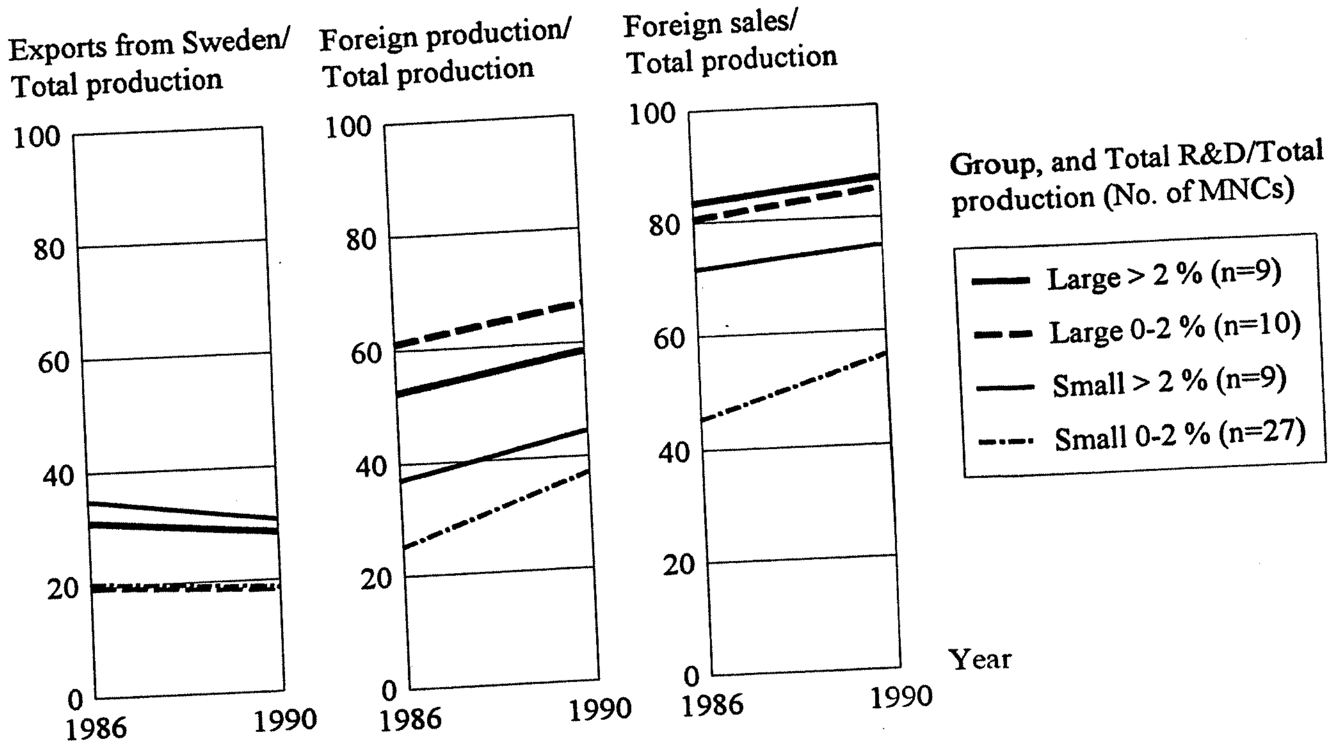
foreign sales[8] has decreased only for MNCs without R&D. Thus, R&D seems to be of major importance for a firm's internationalization process.[9] It is also interesting to note that the ranking of foreign sales is almost in line with the R&D-intensities. Firms not performing R&D appear to have a disadvantage when it comes to international expansion.

When dividing the sample of MNCs in groups of "Large" and "Small" firms in Figure 3.5 (as in section 3.1), some interesting observations can be made. Again, firms with high R&D-intensity, both "Large" and "Small", have a higher intensity to export from Sweden. Large firms have a higher intensity to produce abroad, irrespective of R&D-intensity. This is also the case when considering the share of

[8] Foreign sales = Exports from Sweden + foreign production. Total production equals total sales.

[9] This large decrease is not due to aggregation problems. By following each individual firm in this group between 1986-90, it can be shown that almost all of them have decreased their share of foreign sales.

Figure 3.5. ***Exports, foreign production and foreign sales for large and small MNCs with different R&D-intensities 1986 and 1990. Percent.***



The groups were classified according to the MNCs' R&D-intensity in 1990. The same firms were followed between 1986 and 1990.

foreign sales in the third diagram.

By estimating Pearson correlation coefficients for the variables analyzed above, it is possible to measure if there exists a linear relationship between R&D and the internationalization variables, and if so, how strong this relationship is.[10] It should be noted that such an analysis relates to the firm-level in contrast to the aggregates of firm groups used in the figures above.

As Table 3.1 shows, the correlations are all positive between R&D and foreign operations and significant at the 1%-level. Thus, we can say with 99 percent confidence that a positive linear relationship exists. To summarize the results in this section, we conclude that both descriptive data and correlations speak for a positive relationship between R&D and foreign sales. The relationship also holds when foreign sales are decomposed into exports from Sweden and foreign production.

[10] The higher the absolute value of the coefficient, ranging between -1 and +1, the stronger the relationship. The significance of the estimated coefficient tells at which level of confidence we can reject the hypothesis that the true coefficient equals zero, i.e that no linear relationship exists.

Table 3.1. ***Correlations between R&D-intensity and foreign operations in 1990.***

Pearson correlation coefficients	Exports from Sweden / Total production	Foreign production / Total production	Foreign sales / Total production
Total R&D / Total production	0.254 ***	0.346 ***	0.407 ***

Note: Number of observations: 109. ***, ** and * indicate significance at 1, 5 and 10 percent, respectively.

3.4 Regression analysis and hypotheses for empirical testing

Neither descriptive statistics nor correlations can tell us anything about possible *causal* relationships between R&D and foreign operations.[11] In order to investigate the causality stipulated by the economic theory in section 3.2 we have to use regression analysis. This statistical estimation technique makes it possible to test what will happen to a variable, A (the dependent variable), on the margin, if we change the value of another variable, B (the explanatory variable), by a small number - given the values of the other explanatory variables, C, D, E, etc, included in the model. Provided that the model is specified correctly, it is, consequently, possible to test the causal effect of, for example, a firm's R&D expenditures on foreign sales, controlling for firm size, industry category and other factors.

There are two main (endogenous) variables in the regression analysis. The firm's foreign sales, FS, and total R&D expenditures, RD. These variables are divided by total sales of the firm, TS, in order to control for firm size. The intensities FS/TS and RD/TS are, thus, the main variables. According to the discussion in section 3.2 and the descriptive statistics and correlations in section 3.3, a positive relationship is expected between internationalization and R&D.[12] The

[11] Even if there is a significant positive correlation between variables A and B, this is no evidence for causality. The positive correlation may be due to a "third" variable C, which affects both A and B in a positive direction.

[12] There are two reasons why we did not decompose foreign sales into exports and foreign production in the regression analysis. First, the theoretical discussion in section 3.2 indicated that such an analysis would require R&D to be decomposed in a research and a development part. Second,

regression analysis is carried out on the pooled 1986 and 1990 cross-sections of MNCs.[13]

In the following, we present the other explanatory variables in the model, their definitions and their expected impact on the dependent variables. Table 3.2 below summarizes the explanatory variables included in each equation. The signs (+ or -) show the expected impact on the dependent variable.

According to the theory of oligopolistic advantages (section 3.2), high initial capital costs, HIC, is a factor that limits competition, since it makes it costly for new firms to enter the market. HIC gives, therefore, a competitive advantage for the firms already in the market and it is expected to exert a positive impact on FS/TS. HIC is measured as the average plant (net production) of the MNC's foreign affiliates.[14] It is, however, not expected that HIC exerts any effect on RD/TS, but these two variables are instead regarded as independent of each other.[15]

Several empirical observations about Swedish MNCs indicate that large firms tend to locate a larger share of their sales and production abroad when expanding (see e.g. Figure 3.5). Size by itself does not confer a distinct firm-specific advantage, but is rather a product of different oligopolistic advantages, e.g. scale economies, technological skills, etc. Firm size is instead included in equation (1) due to the limited size of the Swedish home market, implying that large firms should locate a large share of their sales on foreign markets. The size of the firm is measured as total sales, TS, and is, thus, expected to have a positive effect on FS/TS. Furthermore, it has earlier been argued that there is a positive relationship between firm size and R&D intensity (see e.g. Caves [1982]). It is meant that large firms

regression analysis, undertaken by the authors, that included exports as well as foreign production resulted in multicollinearity. This is a common problem in models where several variables are correlated with each other.

[13] A complete description of the model specification can be found in Appendix 3.

[14] This definition is made under the assumption that each affiliate operates at the optimal level of scale.

[15] There are no empirical evidence for any relationship between HIC and RD/TS, which both are oligopolistic advantages. For example, firms operating in the basic industry often have high initial capital requirements to their large plants, but very low R&D intensity. On the other hand, firms in chemicals have high R&D intensity and small plants.

Table 3.2. ***Explanatory variables included in each equation and the expected impact on the dependent variable.***

Dependent variable		FS/TS	RD/TS
Explanatory variables	Label	Equation (1)	Equation (2)
RD/TS	Total R&D / Total sales	+	
FS/TS	Foreign sales / Total sales		+
TS	Total sales	+	
HIC	High initial costs	+	
CONC	Concentration		+
π	Profit margin		+

have a higher rate of return to each SEK spent on R&D, due to the public goods character of R&D. According to the theoretical discussion in section 3.2, however, foreign sales should contain more R&D than domestic sales in order to overcome barriers to entry in foreign markets. This means that it is the internationality of the firm, and not firm size by itself, which offers higher rate of return on R&D.[16]

Firms operating in oligopolistic industries are more inclined to compete with other strategies than price, including advertising, product differentiation and above all R&D activities. The concentration, CONC, is measured as the world market share of the four largest firms of the MNC's largest division. A positive effect of CONC on R&D intensity is expected. CONC is not included in equation (1), however, since it is regarded more as an outcome of various oligopolistic advantages than a cause of such advantages.

A higher profit implies a greater ability to raise internal funds for R&D investments. The profit variable, π, is defined as operating income before depreciation divided by total assets. We expect this variable to exert a positive impact on firms' R&D intensity.

Except TS, all explanatory variables included in equation (1) are related to

[16] It has also been argued that large firms have greater possibilities to raise external funds for R&D. This capacity is rather related to the solidity and profitability of the firm and not to the size.

oligopolistic advantages. The explanatory variables in equation (2), on the other hand, are more related to market structure and the possibilities to raise funds for R&D. Finally, we control for different industry categories and time periods, which may affect the level of FS/TS and RD/TS.[17]

Since the two dependent variables are also included as explanatory variables, we have to estimate equations (1) and (2) simultaneously. This implies that while we, for example, estimate the effect of RD/TS on FS/TS, we simultaneously take into account that FS/TS affects RD/TS. Equations (1) and (2) are also estimated separately in order to compare the results with the simultaneous approach. For each explanatory variable in the respective equations, one parameter is estimated. The sign of the parameter shows if the impact on the dependent variable is positive or negative.[18]

3.5 Results of the estimations

The results of the simultaneous estimation are provided in Table 3.3 below. As expected, the effect of an increase in RD/TS on FS/TS is positive and we can with 99 percent confidence say that the estimated parameter differs from zero. This strongly supports the hypothesis that R&D expenditures create competitive advantages on foreign markets. Furthermore, an increase in FS/TS exerts a positive impact on RD/TS, but the parameter is only significant at the 10%-level. Thus, there is only weak evidence that increased foreign operations induce higher R&D investments.

The marginal effect of an increase in RD on FS can be interpreted directly from the values of the estimated parameter in Table 3.4, since both main variables

[17] This is done by assigning an additive time dummy for 1986 and additive dummies for different industries: food, textile, chemical, basic, machinery, electronics and transport.

[18] The significance of the estimated regression parameter tells at which confidence level we can reject the hypothesis that the true parameter value equals zero. Usually, one claims that this confidence should be at least 95 percent (or, in other words, significant on the 5%-level). On the other hand, the strength of the causal effect should be evaluated from the elasticities, which can be obtained by scaling the parameter estimate with the means of the dependent and explanatory variables.

Table 3.3. ***Results of simultaneous estimations.***

Dependent variable	FS/TS	RD/TS
Explanatory variables	Equation (1)	Equation (2)
RD/TS	+ ***	
FS/TS		+ *
TS	+	
HIC	+ *	
CONC		+ *
π		+

Note: ***, ** and * indicate significance at 1, 5 and 10 percent level respectively. The values of the estimated parameters are shown in Appendix 3, Table 3.6.

are divided by the same variable, TS.[19] An increase in RD by 1 SEK causes FS to increase by 6.32 SEK. On the other hand, an increase in FS by 1 SEK induces RD to increase by 0.045 SEK. By calculating the elasticities, it is possible to evaluate the effect of a 1 percent change in RD on FS. The elasticity between RD/TS and FS/TS is 0.22, implying that a 1 percent increase in RD causes FS to increase with 0.22 percent. In a similar way, the elasticity between FS/TS and RD/TS is 1.31 percent.

Considering the marginal effects across industries, we notice that engineering and chemicals have the largest effects and the highest significance in both equations (1) and (2). The marginal effects for the basic industry are, in fact, never significant, meaning that we can not tell if there is any relationship between RD and FS in this industry at all. When studying the elasticities, the pattern is the same in equation (1). The elasticity is as high as 0.4 in chemicals compared to 0.1 in the basic industry. There are some changes compared to the marginal effects in equation (2), however. The basic industry has a larger elasticity than both chemical and engineering industries, explained by the low average of RD/TS in the basic industry.

Turning to the other explanatory variables included in the model, the size

[19] It is not possible to evaluate the parameter for FS/TS in equation (2) in a similar way, since this equation is estimated by means of the Tobit method.

Table 3.4. ***Marginal effects and elasticities across industries for the main variables.***

Dependent variable		FS/TS		RD/TS	
Explanatory variables		Equation (1)		Equation (2)	
		Marginal effect	Elasticity	Marginal effect	Elasticity
RD/TS	All industries	6.32 ***	0.22	---	---
	Engineering	6.10 ***	0.21	---	---
	Chemicals	7.17 ***	0.40	---	---
	Basic	5.37	0.10	---	---
	Other industries	6.93 **	0.10	---	---
FS/TS	All industries	---	---	0.045 *	1.31
	Engineering	---	---	0.048 *	1.37
	Chemicals	---	---	0.062 *	1.12
	Basic	---	---	0.028	1.51
	Other industries	---	---	0.039	2.80

Note: ***, ** and * indicate significance at 1, 5 and 10 percent, respectively. Marginal effects and elasticities have only been calculated for the main variables. The marginal effect equals the parameter value in equation (1). For a more detailed information about the industry values see Table 3.8 in Appendix 3.

of the firm, TS, has a positive effect on the intensity to sell abroad, but the parameter is not significant. The variable measuring high initial capital costs, HIC, has the expected positive impact on FS/TS and the parameter is significant at the 10%-level. This gives some support to the view that high initial costs limit entry by new firms and give an advantage to firms already established in the market. The concentration ratio, CONC, exerts a significant positive impact on RD/TS, which is in line with the hypothesis that an oligopolistic market structure favors competition by other strategies than pricing. The profit variable, π, is not significant in the simultaneous model.

The results of separate OLS and Tobit estimations, provided in Table 3.5, indicate similar results for the key variables as the simultaneous estimations. The signs of the parameters are the same, but the significance levels are stronger. This

Table 3.5. ***Results of separate estimations.***

Dependent variable	FS/TS	RD/TS
Explanatory variables	Equation (1)	Equation (2)
RD/TS	+ ***	
FS/TS		+ **
TS	+ ***	
HIC	+ ***	
CONC		+ ***
π		+

Note: ***, ** and * indicate significance at 1, 5 and 10 percent level respectively. The values of the estimated parameters are provided in Appendix 3, Table 3.7.

is the case for TS and HIC in equation (1), and for FS/TS and CONC in equation (2). These estimations are, however, biased and inconsistent.

To summarize section 3, studying the internationalization process in the latter part of the 1980s, we find strong support for the general hypothesis of a positive relationship between R&D and foreign sales, considering descriptive statistics and correlation analysis.

Estimation of a simultaneous regression model verifies the presence of causal linkages between R&D and internationalization, holding, e.g., firm size, scale economies, industry category and market structure constant. The results indicate that R&D exerts a positive impact on firms' sales on foreign markets. At the same time, firms' foreign sales induced more R&D investments, although this relationship is weaker.

4. R&D and productivity

This section deals with the relationship between R&D and productivity in Swedish multinationals. Since MNCs, in Sweden as well as in other countries, dominate industrial R&D, it is important to assess the economic role of these firms' research and development activities. We will here evaluate if R&D expenditures exert a positive impact on firms' productivity, i.e. productive efficiency, as proposed by e.g. Griliches [1979]. The empirical literature in the field generally supports the view that R&D does exert a positive effect on productivity. For example, Badulescu [1992] finds evidence of such a relationship at the industry level in Swedish manufacturing 1963-81, and Lichtenberg and Siegel [1991] in the case of US firms 1972-85. Mairesse and Sassenou [1991] in their review of a number of econometric studies at the firm level, come to the same result.

This chapter is organized as follows. First, some descriptive statistics for labor productivity (LP) are provided, and correlations between R&D intensity and LP undertaken. Second, regression analysis is performed to estimate the marginal productivity of R&D.

4.1. Labor productivity and R&D

Figure 4.1. illustrates the development of labor productivity (LP)[1] in constant prices over the period 1974-90, for the MNCs Swedish and foreign operations respectively. Labor productivity for different industries is shown in figure 4.2.[2]

From Figure 4.1 we note that the MNCs' overall labor productivity have increased continuously since 1974. LP was higher in Sweden than in the foreign

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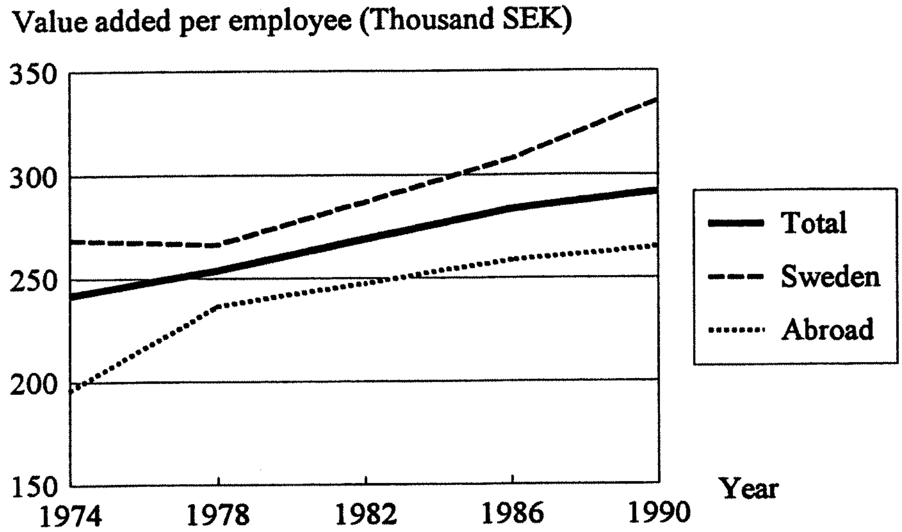
[1] Labor productivity is here measured as value added per employee. Value added, in turn, is measured as wage costs + operating profits before depreciation and financial items.

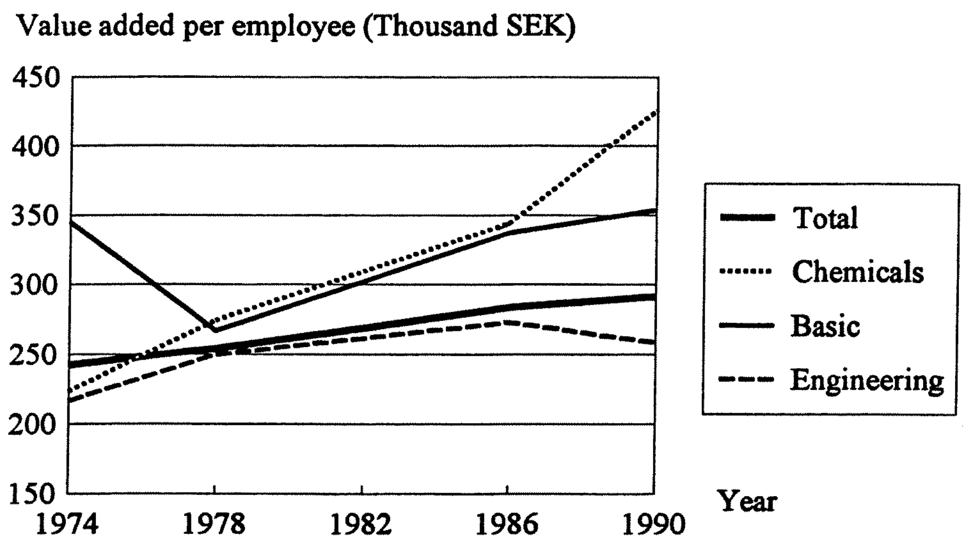
[2] Note that the entire cross section of MNCs is included each year in Figures 4.1 and 4.2, implying that a slightly different group of MNCs is followed over time. The overall pattern, however, remains roughly the same as in Figures 4.1 and 4.2, when analyzing constant groups of MNCs over each of the time periods 74/78, 78/86 and 86/90. It should be pointed out in this context that time series analysis of individual MNCs may be difficult, since firms change over time as a result of mergers, acquisitions and other restructuring. However, when studying averages based on large numbers of firms, as in the present paper, changes in individual firms should not alter the overall pattern over time considerably.

Figure 4.1. ***Labor productivity in Sweden and the foreign parts of Swedish MNCs 1974-90 (Thousand SEK). Constant 1990 prices.***



parts of the MNCs over the whole studied period. In Figure 4.2 it can be observed that from 1978 and onwards the chemical industry had the highest labor productivity, followed by basic and engineering. Chemicals showed a rapid LP growth in the 1986-90 period, relative to earlier periods, and basic industries a

Figure 4.2. ***Labor productivity in Swedish MNCs across industries 1974-90 (Thousand SEK). Constant 1990 prices.***



slower, but still positive, growth in 1986-90. It is noteworthy that the engineering industry exhibited a decline in labor productivity in the latter half of the 1980s. This pattern does not change if instead analyzing a constant group of MNCs over each period.

To answer the question how LP in the Swedish and foreign operations of a MNC are related, correlation analysis was undertaken. First, analyzing the cross section of all MNCs 1990, it can be observed that the level of labor productivity in the Swedish and foreign parts of the MNCs are positively related to each other.[3] When the same analysis was undertaken for Swedish and foreign LP growth rates 1986-90, no statistically significant results were obtained, however. The fact that the growth rates were not correlated, is in line with the diverging development between the MNCs' Swedish and foreign parts in the same period, illustrated in Figure 4.1.

Correlations between R&D intensity and LP, which are given in Table 4.1, indicate a positive relationship on the whole. However, the relationship was

Table 4.1. ***Correlation coefficients between R&D intensity and labor productivity in 1986 and 1990.***

Industry	Correlations between R&D intensity and labor productivity	
	1986	1990
All industries	0.30 *** (n=100)	0.20 ** (n=106)
Basic	0.75 *** (n=13)	0.40 (n=14)
Chemicals	0.47 ** (n=19)	0.26 (n=16)
Engineering	0.22 (n=44)	0.19 (n=58)

Note: ***, ** and * indicate significance at the 1, 5 and 10 percent level respectively. Number of observations in parentheses.

[3] The Pearson correlation coefficient equals 0.36 and is significant at the 1% level, for the 1990 cross section of MNCs (n=107).

stronger in 1986 than 1990, both for all industries and for the basic and chemical industries separately.[4] No significant correlations were obtained in the engineering industry either year. It can further be noted that, in 1986, the relationship was the strongest in basic, followed by the chemical industry. None of the correlations for separate industries 1990 were significant.

4.2. Marginal productivity of R&D

In this subsection we estimate the marginal productivity of R&D in Swedish MNCs, considering the two four-year periods 1974-78 and 1986-90. The starting point for the analysis is the conventional Cobb-Douglas production function relating output to input factors of production, with R&D included as a third production factor, in addition to the traditional factors, physical capital and labor. The econometric model is derived in appendix 4, which also presents the complete statistical results.

Summarizing the regression results relating to R&D, the following can be noted from Table 4.2. The marginal productivity of R&D is positive and significant, at the 10% level, analyzing all industries and including both time periods. Separate regressions for the two periods, suggest that the marginal productivity was higher in 1974-78 compared with 1986-90, although the estimation for the latter period was not significant. When analyzing basic, chemical and engineering separately, no statistically significant results were obtained.

Table 4.2. ***Marginal productivity of R&D in Swedish MNCs in the periods 1974-78 and 1986-90***

	Marginal productivity of R&D		
	1974-78 and 1986-90 pooled	1974-78	1986-90
All industries	1.08 *	1.96 *	0.95

Note: * indicates significance at the 10 percent level. The values of the other estimated parameters are provided in appendix 4. Constant 1990 prices are used in the analysis.

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[4] For all industries in terms of the estimated Pearson correlation coefficient and the significance level.

5. Summary

The present study investigates a number of dimensions relating to R&D in Swedish multinational corporations (MNCs) in manufacturing. The analysis is based on a unique data base collected by IUI, which covers the period 1965-90. The development in the latter half of the 1980s is emphasized.

Multinationals performed almost 80% of aggregate Swedish manufacturing sector R&D in 1990, and dominated in manufacturing output and exports as well. Most R&D was undertaken by MNCs in the transport and electronics industries, about 70% of the total for the MNCs' in 1990. Over 80% of the MNCs did perform R&D at this point in time. These firms are substantially larger and more internationally oriented on average compared with the MNCs that do not undertake R&D. The growth in real R&D expenditures has been clearly positive over the period 1970-86, but declined drastically thereafter. Between 1978 and 1986 we note a rapid growth in expenditures, but no growth at all in 1986-90. Chemicals and engineering, in particular, have exhibited slower growth in the latter period.

Average R&D intensity (R&D/sales) for all industries has doubled from 2 to around 4% between 1978 and 1990. Most of that increase is attributed to the 1978-86 period. As with the growth in R&D expenditures, the intensity did not change much in the second half of the 1980s. Chemicals exhibited the highest intensity throughout the period 1970-90, followed by engineering. In 1990, their intensities were about 8 and 5%, respectively. At the same time, the basic industry had an intensity of roughly 1%. Within the engineering industry, transports had an intensity of over 8% and electronics about 4.5%. The intensity in the rest of engineering has been considerably lower in the 1980s, just slightly above 2%.

The R&D intensity has been substantially higher in the Swedish parts of the MNCs relative to the foreign affiliates in the last two decades. As of 1990, the Swedish R&D intensity was almost 7%, while that of foreign affiliates was only 1%. This divergence has increased over time, especially during the 1980s. The Swedish intensity more than doubled while the foreign mostly stayed below the 1% level. Finally, we observe a considerable variation in the average when MNCs are classified in accordance with R&D intensity groups. A few MNCs have intensity exceeding 12%.

The major part of the MNCs' R&D is still undertaken in Sweden. The share of total R&D undertaken in foreign affiliates increased significantly in the second half of the 1980s, however, from a level of 13-14 % in 1974-86 to over 17% in 1990. Both the chemical and engineering industries closely followed that pattern over time. The machinery industry is the only industry with more than half of R&D located abroad as of 1990. Electronics is second with 25% abroad. Transports, finally, the largest R&D performer in absolute terms, has the lowest share of R&D abroad, only 4-5% in the 1980s. Dividing firms in groups according to percentage of R&D abroad, reveals large variations among Swedish MNCs. Several firms had more than 90% of R&D abroad in 1990. Almost 65% of the MNCs' foreign R&D was undertaken in the EC-countries, and slightly less than 20% in North America as of 1990.

Statistical analysis of the relationship between R&D intensity and degree of internationalization, measured as foreign sales, produces strong evidence of a positive two-way relation. When estimating a simultaneous regression model, it is concluded that MNCs with higher R&D intensity are more successful in foreign markets. On the other hand, the analysis also indicates that a more international MNC tends to perform more R&D. It is argued that a MNC with a relatively large share of sales in foreign markets, can obtain a higher rate of return on each SEK spent on R&D. Hence, internationalization in turn induces more R&D expenditures. Descriptive statistics and correlation of these issues, support the regression analysis.

Finally, the study investigates productivity dimension of R&D. Correlations between R&D intensity and labor productivity on the whole indicate that there exists a positive relationship. The correlations were, however, statistically stronger in 1986 than 1990. With respect to different industries, the relationship was the strongest in basic followed by chemicals as of 1986. When the marginal productivity of R&D was estimated by regression analysis, with the periods 1974-78 and 1986-90 pooled together, marginal productivity turned out to be positive. Statistically, the result is rather weak since it is only significant at the 10% level. Analyzing these two periods separately, we note that the relationship was weaker in the latter period, suggesting a decline in the marginal productivity of R&D in the 1980s.

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Appendix 2

Table 2.5. ***Share of aggregated turnover, employees and value added for different industries in 1990. Percent.***

Industry	Number of MNCs	Percent of total		
		Turnover	Employees	Value added
Basic	14	31.4	24.3	29.7
Chemicals	17	7.3	6.4	7.2
Food, textile, other	21	3.1	2.2	2.4
Engineering	58	58.2	67.1	60.7
Metal products	25	6.1	7.0	8.0
Machinery	18	10.2	13.2	12.6
Electronics	11	22.5	32.0	25.7
Transports	4	19.4	14.9	14.4
Total	110	100.0	100.0	100.0

Table 2.6. ***20 largest MNCs 1990 with respect to turnover out of the 110 (MSEK).***

Variables	All 20	Group 1	Group 2	Group 3	Group 4	Group 5
Swedish R&D	18 198	13 619	2 480	955	319	825
Foreign R&D	3 836	1 442	516	1 511	33	334
Swedish production	248 707	100 630	10 505	30 200	38 888	68 484
Foreign production	363 407	134 632	13 953	117 957	21 485	75 380
Swedish employment	236 918	107 053	9 554	40 702	29 875	49 734
Foreign employment	393 034	87 059	12 710	193 273	24 979	75 013
Swedish value added	63 921	22 014	5 328	11 791	6 253	18 535
Foreign value added	90 706	16 382	5 591	41 310	6 336	21 087
Swedish exports	144 801	68 547	6 328	14 883	10 752	44 291
Foreign sales	494 482	193 856	20 174	129 781	31 956	118 715
Swedish Investment	17 107	7 036	1 431	1 264	1 150	6 226
Foreign Investment	22 021	4 669	821	6 662	1 492	8 377

Note: Group 1 includes firms in engineering with large part of the operations in Sweden and substantial R&D expenditures: Ericsson, Saab-Scania, Sandvik and Volvo. Group 2 includes firms in the pharmaceutical and medical industries: Astra, Gambro and Kabi Pharmacia. Group 3 includes firms in engineering with large part of operations abroad: Alfa Laval, Electrolux, ESAB and SKF. Group 4 includes other large firms: AGA, PLM, SSAB and Trelleborg. Group 5 includes firms in the paper & pulp industry: ASSI, Korsnäs, MoDo, SCA and Stora.

Table 2.7. ***The other 90 MNCs 1990 grouped according to R&D intensity.***

Variables	All 90	R&D intensity (number of firms)			
		0% (n=20)	0-2% (n=50)	2-4% (n=13)	>4% (n=7)
Swedish R&D Foreign R&D	592 132	0 0	337 76	154 16	101 39
Swedish production Foreign production	41 132 24 444	4 206 1 255	31 749 18 523	3 806 2 638	1 375 2 028
Swedish employment Foreign employment	38 834 22 939	4 093 1 476	28 426 16 627	4 495 2 095	1 820 2 741
Swedish value added Foreign value added	12 204 6 249	1 274 276	9 005 4 539	1 451 699	475 736
Swedish exports Foreign sales	15 318 39 139	1 080 2 204	11 209 29 355	2 130 4 708	898 2 872
Swedish investment Foreign investment	2 436 2 234	330 151	1 760 1 296	303 681	43 106

Table 2.8. ***Distribution of foreign R&D in manufacturing affiliates across country/ region and industries in 1990 (MSEK).***

Country / region	All industries	Basic	Chemicals	Engineering	Other
Belgium France Italy The Netherlands Germany Great Britain Denmark Other EC-countries	236 155 180 137 421 222 56 122	12 26 33 14 50 43 2 15	0 56 21 10 63 0 4 0	224 71 127 112 307 179 47 107	0 1 0 1 2 0 3 0
EFTA	141	10	9	118	4
USA Canada	406 35	0 0	112 35	294 0	0 0
Japan Other industrialized countries	16 143	0 0	4 4	12 139	0 0
Developing countries	113	0	1	112	0
All regions	2384	205	319	1849	11

Figure 2.12. ***Swedish R&D-intensity (Swedish R&D/Swedish production) for Swedish MNCs 1970-90. Percent. Discrete points in time.***

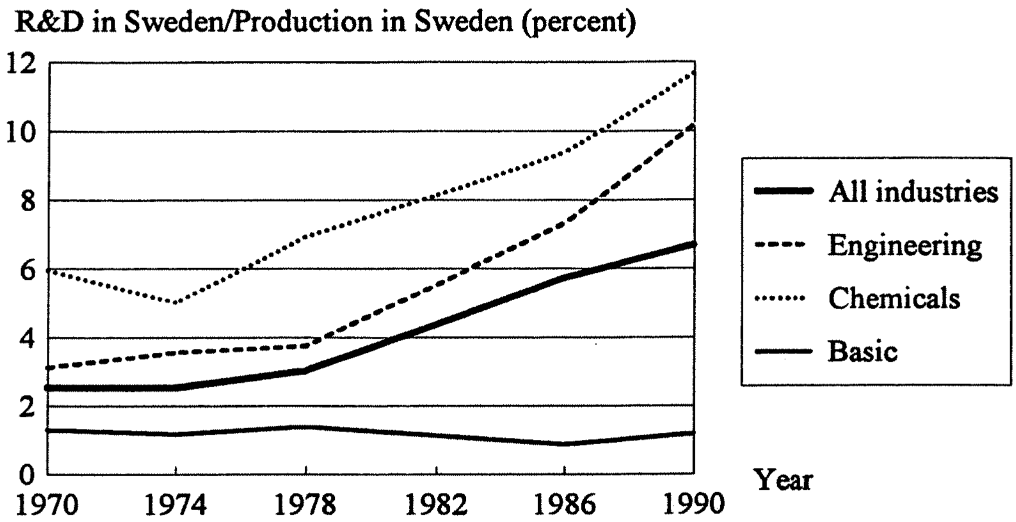


Figure 2.13. ***Swedish R&D-intensity (Swedish R&D/Swedish production) for Swedish MNCs in engineering (SNI 38) 1970-90. Percent. Discrete points in time.***

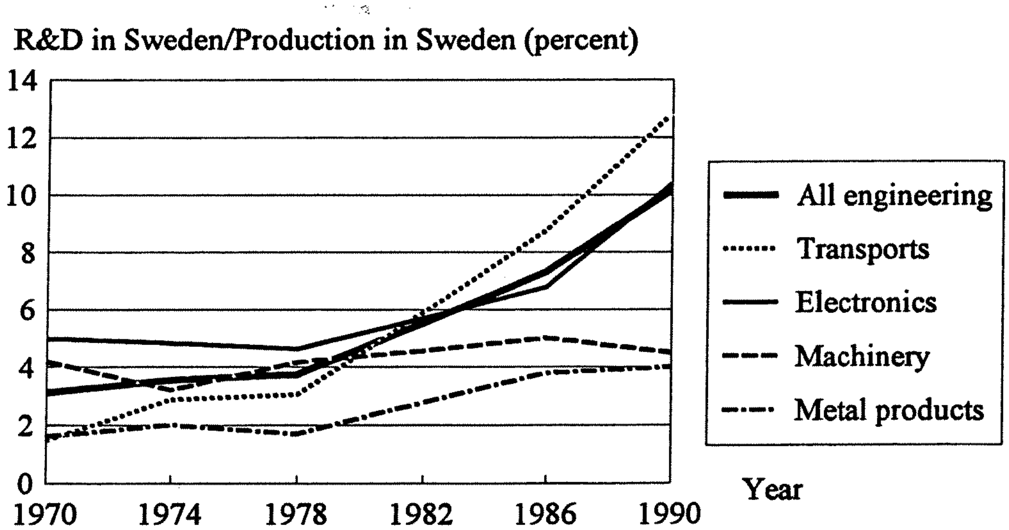


Figure 2.14. ***Foreign R&D-intensity (Foreign R&D/Foreign production) for Swedish MNCs 1970-90. Percent. Discrete points in time.***

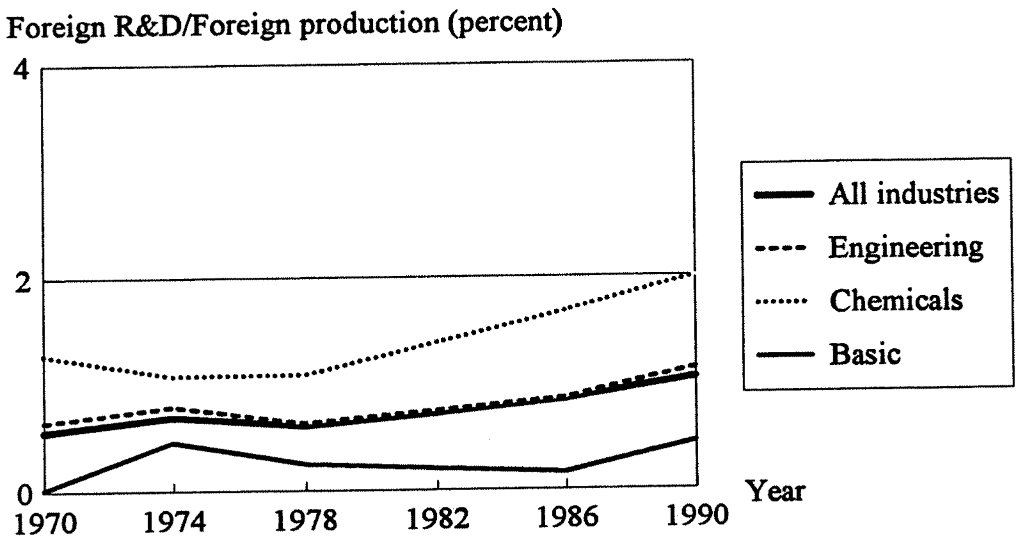
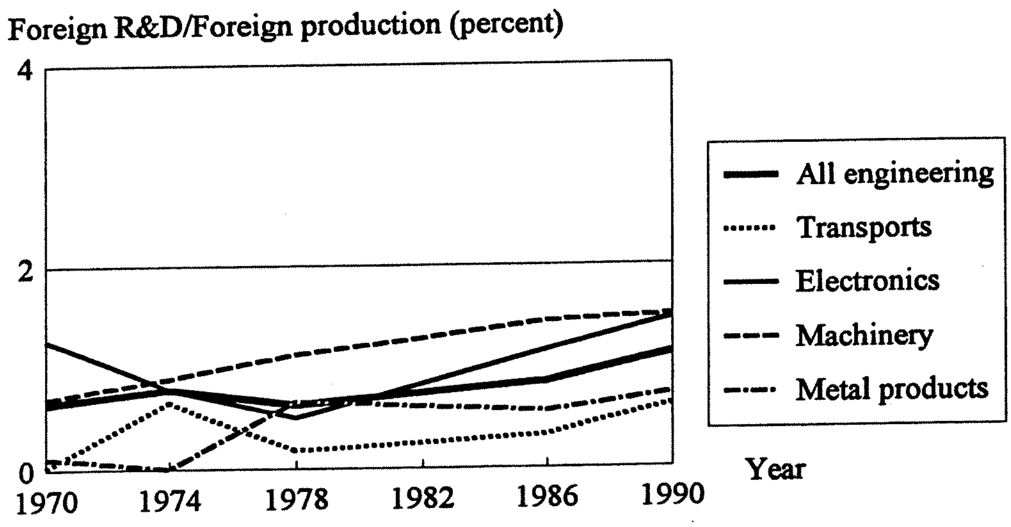
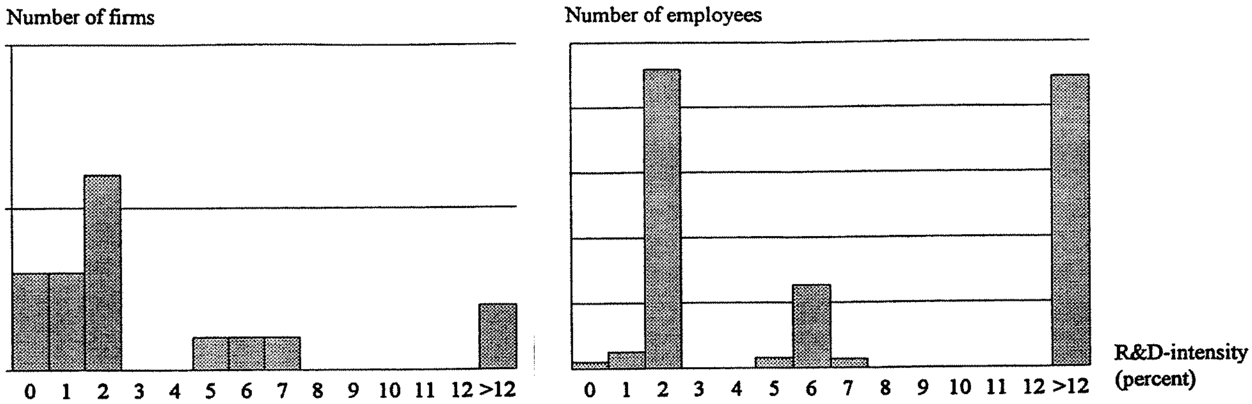


Figure 2.15. ***Foreign R&D-intensity (Foreign R&D/Foreign production) for Swedish MNCs in engineering (SNI 38) 1970-90. Percent. Discrete points in time.***

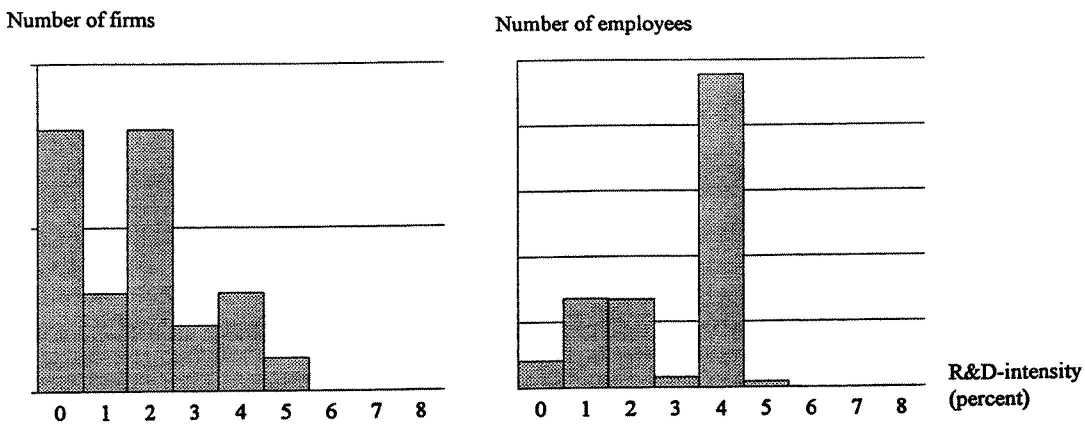


Figures 2.16 and 2.17. ***Distribution of Swedish MNCs in chemical industry according to R&D-intensity groups in 1990. Number of firms and number of employees.***



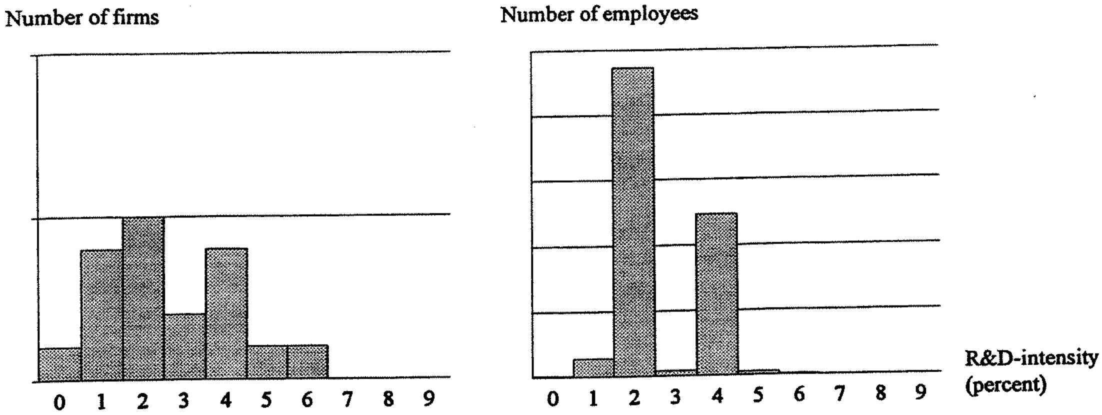
Note: Explanation of intervals of R&D-intensity see note to Figure 2.6.

Figures 2.18 and 2.19. ***Distribution of Swedish MNCs in metal products industry according to R&D-intensity groups in 1990. Number of firms and number of employees.***



Note: Explanation of intervals of R&D-intensity see note to Figure 2.6.

Figures 2.20 and 2.21. ***Distribution of Swedish MNCs in machinery industry according to R&D-intensity groups in 1990. Number of firms and number of employees.***



Note: Explanation of intervals of R&D-intensity see note to Figure 2.6.

Appendix 3.

Econometric method and results.

Our main variables are firm f's total R&D expenditures at time t, RD_{ft}, and foreign sales FS_{ft}.[1] These variables are weighted with total sales of the firm, TS_{ft}, in order to isolate for firm size and to obtain the intensities. The intensities RD/TS and FS/TS are treated as endogenous in the model, since it is expected that they affect and reinforce each other, i.e. simultaneity is present. The hypothesis of no simultaneity was tested using a Hausman test (Hausman [1978]).[2] This hypothesis was, however, clearly rejected. The simultaneous method, used to estimate the interactions between R&D and foreign activities of the firms, is a variant of 2SLS with limited endogenous variables outlined in Nelson & Olson [1978], and is specified as:

$$\frac{FS_{ft}}{TS_{ft}} = \beta_0 + \beta_1 \frac{RD_{ft}^*}{TS_{ft}} + \beta_2 TS_{ft} + \beta_3 SC_{ft} + \epsilon_{ft} , \qquad (1)$$

$$\frac{RD_{ft}^*}{TS_{ft}} = \gamma_0 + \gamma_1 \frac{FS_{ft}}{TS_{ft}} + \gamma_2 CONC_{ft} + \gamma_3 \pi_{ft} + \mu_{ft} , \qquad (2a)$$

---

[1] FS was also decomposed into exports from the home country, EXP, and foreign production, FQ, in order to evaluate the separate effects of foreign activities on R&D and vice versa. The experiments were undertaken in the same way as in the text, but with three equations instead of two (Equation (1) was estimated twice with EXP/TS and FQ/TS, respectively, as dependent variables.). The results were not satisfactory, however, since multicollinearity arose in equation (2) in the second stage of 2SLS.

[2] To implement the Hausman test, first estimate the reduced form of equation (2) by Tobit, retrieve the fitted values from this regression and denote them (rd/ts). Next estimate by OLS the expanded regression equation:

$$(FS/TS)_{ft} = \beta_0 + \beta_1 (RD/TS)_{ft} + \beta_2 TS_{ft} + \beta_3 SC_{ft} + \beta_4 (rd/ts)_{ft} + \epsilon_{ft} , \qquad (1')$$

where (rd/ts) is an added regressor. The null hypothesis that no simultaneity is present (that (RD/TS) and ϵ are uncorrelated in large samples) then reduces to a test of the simple hypothesis that $\beta_4 = 0$, which can easily be tested by a T-test.

$$\frac{RD_{ft}}{TS_{ft}} = \begin{cases} \frac{RD_{ft}^*}{TS_{ft}} & if \ \frac{RD_{ft}^*}{TS_{ft}} > 0 \\ 0 & if \ \frac{RD_{ft}^*}{TS_{ft}} \leq 0 \end{cases} . \tag{2b}$$

In the first stage of 2SLS, instruments are created for the endogenous variables. This is accomplished by regressing each endogenous variable on all exogenous variables in the system. In the second stage, the predicted values of FS/TS and RD/TS are substituted for the corresponding RHS variables.

OLS is the appropriate statistical technique to estimate the reduced and structural forms of equation (1). The second endogenous variable, RD/TS, is, however, characterized by some concentration of zeroes (about 18%), i.e. the firms with no R&D expenditures. When estimating equation (2) in the first and second stage of 2SLS, the Tobit method is used. The latent variable, $(RD/TS)^*$, can be interpreted as an index of R&D-intensity, of which FS/TS will be a function.

All residuals are assumed to have the desired properties: $\mu \sim N(0,\sigma_\mu^2)$ and $\epsilon \sim N(0,\sigma_\epsilon^2)$; $E(\mu_{ft}\mu_{gt})=0$ and $E(\epsilon_{ft}\epsilon_{gt})=0$ for $f \neq g$.[3] However, $E(\mu_{ft}\epsilon_{ft}) \neq 0$, since simultaneity is present. The simultaneous Tobit method yields consistent parameter estimates, but the standard errors of the parameter estimates are underestimated. In order to avoid this, the asymptotic variance-covariance-matrix is derived and the standard errors are recalculated according to Amemiya [1979].

We also estimate equations (1) and (2) without taking the simultaneity into account in order to compare the results with the 2SLS-estimations. This is accomplished by regressing the second stage of 2SLS only, i.e. without using any instruments. One has to remember that such estimation techniques will yield inconsistent parameter estimates.

The interpretation of the parameters of the endogenous variables, β_1 and γ_1 can be done in two different ways. First, they show the effect of one intensity on another. Second, they show the direct effect of e.g. R&D on foreign sales, since

[3] It should be noted that $E(\mu_{fs}\mu_{ft}) \neq 0$ and $E(\epsilon_{fs}\epsilon_{ft}) \neq 0$ for $s \neq t$. A firm which, e.g., has a high R&D-intensity in time s, is also expected to have a high R&D-intensity in time t. This will, however, not yield inconsistent parameter estimates.

both endogenous variables are weighted with the same variable, TS, which can be taken as given. The parameters in equation (1) are marginal effects. The estimate of γ_1 in the Tobit equation may not be interpreted as a marginal effect, however, Rather, it is a combination of the marginal effect on the R&D-intensity and the effect on the probability that the firm will have any R&D at all (McDonald and Moffitt [1980]).

The elasticities are also calculated in order to make the interpretation of the estimated parameters more easy. The percentage effect of an 1 percent increase in R&D on foreign sales is the elasticity:[4]

$$e\,(RD,\,FS) = \beta_1 \frac{RD/TS}{FS/TS}\,, \tag{3}$$

where β_1 is the estimated parameter, or the marginal effect $\delta(FS/TS)/\delta(RD/TS)$, and RD/TS and FS/TS are calculated for the means of the sample. When calculating the elasticities for the parameters in equation (2), we may not use the parameter estimate directly, but derive the marginal effect according to McDonald and Moffitt [1980].[5]

[4] There are no statistical problems to calculate the elasticities. There may be some interpretation problems, however, since the elasticities are calculated for the reduced forms of the endogenous variables.

[5] The marginal effect of FS on RD, $\delta(RD/TS)/\delta(FS/TS)$, simply equals $F(z)\gamma_1$, where F(z) is the cumulative normal distribution and $z=X'\gamma/\sigma_\mu$. X is a vector of explanatory variables and γ is the vector of estimated Tobit parameters. The z is calculated around the means of X.

Table 3.6. ***Results of simultaneous estimations.***

Method	Simultaneous Tobit	
Dependent variable	FS/TS	RD/TS
Explanatory variables	Equation (1)	Equation (2)
RD/TS	6.32 *** (1.52)	---
FS/TS	---	0.061 * (0.034)
TS	2.72 E-9 (1.88 E-9)	---
SC	4.12 E-7 * (2.31 E-7)	---
CONC	---	2.69 E-4 * (1.48 E-4)
Π	---	0.037 (0.027)
Adjusted R^2	0.35	---
F-value	8.75	---
Log-likelihood ratio	---	95.68
Number of observations	160	160
Left-censored obs.	---	26

Note: ***, ** and * indicate significance at 1, 5 and 10 percent level respectively. Standard errors in parentheses. Intercepts and dummies for time and industries are not shown.

Table 3.7. ***Results of non-simultaneous estimations.***

Method	OLS	Tobit
Dependent variable	FS/TS	RD/TS
Explanatory variables	Equation (1)	Equation (2)
RD/TS	2.151 *** (0.694)	---
FS/TS	---	0.026 ** (0.011)
TS	5.67 E-9 *** (1.61 E-9)	---
SC	6.20 E-7 *** (2.22 E-7)	---
CONC	---	3.42 E-4 *** (9.11 E-5)
Π	---	0.033 (0.025)
Adjusted R^2	0.29	---
F-value	6.79	---
Log-likelihood ratio	---	106.78
Number of observations	160	160
Left-censored obs.	---	26

Note: ***, ** and * indicate significance at 1, 5 and 10 percent level respectively. Standard errors in parentheses. Intercepts and dummies for time and industries are not shown.

Table 3.8. ***Estimation of interaction dummies for different industries. Reference industry=Engineering.***

	Equation (1)		Equation (2)	
Dependent variable	FS/TS		RD/TS	
Interaction dummies	Estimates	Std. errors	Estimates	Std. errors
RD/TS	6.10 ***	1.51	---	---
(RD/TS)*Chemical	1.07	2.94	---	---
(RD/TS)*Basic	-0.73	4.32	---	---
(RD/TS)*Other	0.82	3.58	---	---
FS/TS	---	---	0.0631 *	0.0376
(FS/TS)*Chemical	---	---	0.0186	0.0497
(FS/TS)*Basic	---	---	-0.0195	0.0648
(FS/TS)*Other	---	---	-0.0123	0.0152
Recalculated values	β_1	Std. errors	γ_1	Std. errors
Engineering	6.10 ***	1.51	0.0631 *	0.0376
Chemical	7.17 ***	2.78	0.0817 *	0.0463
Basic	5.37	4.19	0.0436	0.0497
Other industries	6.93 **	3.34	0.0508	0.0447

Note: ***, ** and * indicate significance at 1, 5 and 10 percent level respectively. Exogenous variables, intercepts and dummies for time and industries are not shown.

Appendix 4

Econometric model and results

The econometric model that will be used to estimate the marginal productivity of R&D is derived below. A three factor Cobb-Douglas production function characterizes the technology of MNC i in time t,

$$Q_{it}=\phi e^{\lambda t}C_{it}^{\alpha}L_{it}^{\beta}K_{it}^{\gamma}e^{\varepsilon_{it}} \tag{1}$$

where Q is the MNCs' production measured as total sales, Φ a constant, λ the disembodied technical change, C the stock of physical capital (book value of equipment, machinery and buildings), L labor (average number of employees during the year in question), K the MNCs' knowledge stock generated by R&D activities in the MNC. α, β and γ are the elasticities relating to the three factors of production respectively and ε the error term. Taking logarithms of (1) yields;

$$q_{it}=\varphi+\lambda t+\alpha c_{it}+\beta l_{it}+\gamma k_{it}+\varepsilon_{it} \tag{2}$$

with lower case letters denoting logs. Taking first differences we obtain;

$$\Delta q_{it}=\lambda+\alpha\Delta c_{it}+\beta\Delta l_{it}+\gamma\Delta k_{it}+\Delta\varepsilon_{it} \tag{3}$$

where for example

$$\Delta q_{it}=q_{it}-q_{it-1}=\log\left(\frac{Q_{it}}{Q_{it-1}}\right) \tag{4}$$

which, for small variances, is practically equal to the growth of Q_{it}, i.e. $[(Q_{it}-Q_{it-1})/Q_{it-1}]$ or $[\Delta Q/Q_{it-1}]$, (Mairesse and Sassenou [1991]). Since our statistical material does not contain information on knowledge stocks, and due to the obstacles associated with the construction of a reliable knowledge stock measure (Griliches [1979]), the production function is transformed to enable utilization of our data on R&D expenditures instead of knowledge stocks. The approach follows that of Terleckyj [1974] and has been applied by scholars studying the relation between R&D and productivity growth at the firm and industry level. (For surveys see Mairesse and Sassenou [1991] and Griliches [1979]). The term $\gamma\Delta k$ in equation (3) is rewritten in the following way;

$$\gamma\Delta k = \left(\frac{\partial Q}{\partial K}\frac{K}{Q}\right)\Delta k = \left(\frac{\partial Q}{\partial K}\frac{K}{Q}\right)\left(\frac{\Delta K}{K}\right) = \left(\frac{\partial Q}{\partial K}\right)\left(\frac{R}{Q}\right) = \varrho\left(\frac{R}{Q}\right) \quad (5)$$

where R is the R&D expenditures in one year, R/Q the corresponding R&D intensity (R&D relative to sales) that year and ϱ the marginal productivity of R&D. Subscripts are left out for notational simplicity. It is, hence, assumed that K depreciates only marginally in one year, and that R approximates the flow of ΔK during that year. The R&D intensity is considered in *t-1* as suggested by e.g. Scherer (1982), i.e. the beginning of Δ which is the period *[(t-1)-t]*. The variables Δq, Δc and Δl in equation (3) denote the average yearly growth rates in log form (Δq and Δc in constant 1990 prices). Moving from a stock *(K)* to a flow *(R)* measure of knowledge in the MNC's production function, and utilizing (4) and (5), we can rewrite equation (3) as,

$$\Delta q_{it} = \lambda + \alpha\Delta c_{it} + \beta\Delta l_{it} + \varrho\left(\frac{R}{Q}\right)_{it-1} + \eta_{it} \quad (6)$$

which is the equation to be estimated by ordinary least squares (OLS) analysis. The parameter of main interest is ϱ, the marginal productivity of R&D. η_{it} is the new error term.

Fixed dummy variables for time periods and industries are included in order to take account of the difference in sales growth over time and in different industries, which is not the focus in the present section. The statistical results are provided in table 4.3. below.

Table 4.3. *Results from the estimations of marginal productivity of R&D.*

Explanatory variables	Dependent variable Δq: growth sales. All industries		
	1974-78 & 1986-90 pooled	1974-78	1986-90
Δc :growth capital	0.080 ** (0.035)	0.104 ** (0.045)	0.090 * (0.052)
Δl :growth labor	0.835 *** (0.058)	0.810 *** (0.084)	0.811 *** (0.076)
R/Q : marginal productivity of R&D	1.082 * (0.657)	1.961 * (0.999)	0.949 (0.837)
Adjusted R^2	0.79	0.74	0.86
F-value	49.52	25.60	37.14
Number of obs.	132	79	53

Note: ***, ** and * indicate significance at 1, 5 and 10% level respectively. Standard errors in parentheses. Intercept and fixed dummy variables for industries and time period are not shown.