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**Working Paper**

## Industrial Transformation in Finland - From Factor Driven to Technology-Based Growth

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## Keskusteluaiheita - Discussion papers

No. 413

Synnöve Vuori - Pekka Ylä-Anttila

### **INDUSTRIAL TRANSFORMATION IN FINLAND - FROM FACTOR DRIVEN TO TECHNOLOGY-BASED GROWTH\***

- \* This paper is an extended version of the introductory chapter of the book "Mastering Technology Diffusion - The Finnish Experience", to be published by ETLA. The book is part of the larger project "Diffusion of Technology and Industrial Transformation in Finland", partly financed by TEKES (The Technology Development Centre). Assistance with data and editing tasks performed by Maarit Säynevirta is gratefully acknowledged.

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**ABSTRACT:** The paper is a descriptive analysis of the growth and transformation of Finnish industry over the past 100 - 150 years. It is shown that the industry grew initially on the basis of some fairly favourable factor conditions: timber, hydro-power and water ways used for transportation. The forest sector has remained by far the most important development block in the economy. However, while most of the technology in the sector were imported up to the early 1950s, Finland is in contrast today a leading supplier of paper machinery and related technologies worldwide. Since the 1950s the engineering industry has been clearly the fastest growing industrial sector. Still, Finland is more than any other industrial nation dependent on the forest industry: the value of forest industry exports per capita is twice as much as, for example, in Sweden and three times that of Canada. The overall growth performance of Finnish manufacturing has been quite strong by international standards up to the recession of the early 1990s. The growth of the last 10 - 20 years has been mainly technology driven: the manufacturing labour force has diminished drastically since the early 1980s and the contribution of capital to output growth has been much smaller than during the post-war period on average.

**KEY WORDS:** Industrial growth, technical change, technology diffusion, structural change

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## 1. FACTOR DRIVEN GROWTH - CATCHING UP

### Phases of growth

"What generates growth? Is it sustainable at high rates? Those questions stem from the deep feeling that growth is not an explicit, conscious, rational, and strategic process which can be centrally controlled. It is rather the result of decentralized, myopic, more or less locally strategic decisions of individuals and firms, in an environment characterized by uncertainty and affected by government policies and by both social and economic institutions." (Marcel Boyer, Canadian Journal of Economics, Nov. 1991)

The Finnish economy entered a period of rapid, industrialization-based growth in the 1860s. That was clearly later than in the leading countries undergoing the industrial revolution, but still rather early by global comparison. Finland belonged to that select group of countries which formed the economically progressive area of the world during the following century. At the onset of this phase of growth, however, Finland was lagging behind the core group of countries as a poor developing country. Finland's major - and only important - endowment of natural resources, forests, proved to be the decisive factor in the take-off phase of the whole economy.

Quick advancements in prosperity were made at the end of the 1800s thanks largely to the rapidly growing exports of forest products. The sawmill industry first grew up into a leading export industry having its main markets in the west, particularly in Britain. The pulp and paper industry instead exported mainly to the Russian markets, where it soon became a leading supplier with a market share of 20-25 % in the beginning of the 1900s. The first groundwood pulp mill had started production as early as in 1860. The first sulphate pulp mill was established in 1880 and sulphite mill in 1885. The adoption lags from the inventions of both the sulphate and sulphite methods to their application in Finland was fairly short. It was the technological advantage over the Russian producers which created the competitive edge in the Russian markets - the main raw material of Russian paper mills was rags still in the beginning of the 1900s. Moving from the mechanical to the chemical pulp industry is a good example of efficient transfer and diffusion of technological knowledge in Finland. This was part of the forest industry expansion which opened the road to rapid industrial growth that has continued until now.

The Finnish economy grew initially on the basis of some fairly favourable factor conditions: timber, hydro-power and water ways used for transportation. So, inspite of the important role of the adoption of technical innovations, the first growth phase could be characterized as factor-driven. Porter (1990) distinguishes between four stages of economic development: factor driven, investment driven, innovation driven and wealth driven. One can not distinguish these phases as separate periods of industrial development. Rather, and especially in the case of Finland, they are overlapping stages during which, however, the relative importance of different growth generating factors has varied. Following this idea one could say that it was in the 1930s and in the post World War II era when the Finnish industry entered the phase of investment driven development. A growing part of the investment goods were produced domestically in the 1920s and 1930s, especially those for the forest industries. Gradually, in the 1950-60s parts of the investment goods industries developed into important export branches, and by the mid-70s the total volume of investment goods exports surpassed that of the imports - a significant milestone in the Finnish industrial history.

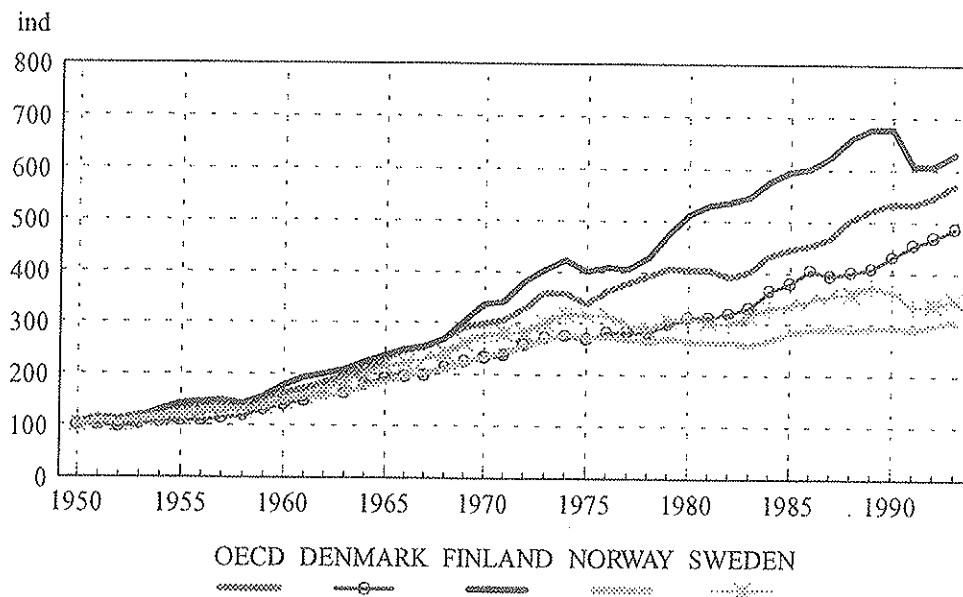
High investment rates have prevailed in Finnish manufacturing until recently, but from the mid-70s the technological change and innovative activity have played a major role in industrial growth and transformation (see next section). To some extent the developments of the 1980s could also be characterized as wealth driven. During the wealth-driven phase economic activity is based on the past accumulated wealth and incentives for new industrial investment and innovative activity are few. Part of the economic and industrial growth in Finland in the 1980s has proved hollow and unsustainable when judged from today's perspective.

All in all, the initial industrialization and the subsequent growth process of Finnish industry are a good example of the interactions of several growth generating factors. Favourable factor conditions are not sufficient. In order to achieve sustained growth, adoption of new innovations and the local and international division of labour are needed. Growth that is not based on increasing productivity derived from technological progress is unsustainable; one could call it windfall growth. Division of labour, in turn, implies specialization which is not possible without well-functioning markets and institutions. Regarding this, in the early industrialization phase an array of important decisions were made: decisions based on economic liberalism freed the markets,

firms adopted new technical and social innovations, economic and social institutions - like education and transportation systems - were enhanced. Later, capital formation was supported by strongly growth-oriented economic and industrial policies, and deepening of the division of labour was enhanced by decisions to take part in international free trade arrangements.

Analogously, the problems of the late 1980s are partly attributable to poor functioning of some basic growth factors: the economy has fostered rigidities and business branches sheltered from competition, the growth rate of technological progress was curbed towards the end of the 1980s and an increasing share of economic resources were used outside the industrial sector. During the overheating phase of the economy in the late 1980s the foundations of technological accumulation were undermined by short-sightedness on the part of many firms and policy makers. This, the collapse of the major export market in the former Soviet Union, and the lack of competition in a large part of the economy with the subsequent cost overshooting, were behind the downturn in the long growth rate of the Finnish industry.

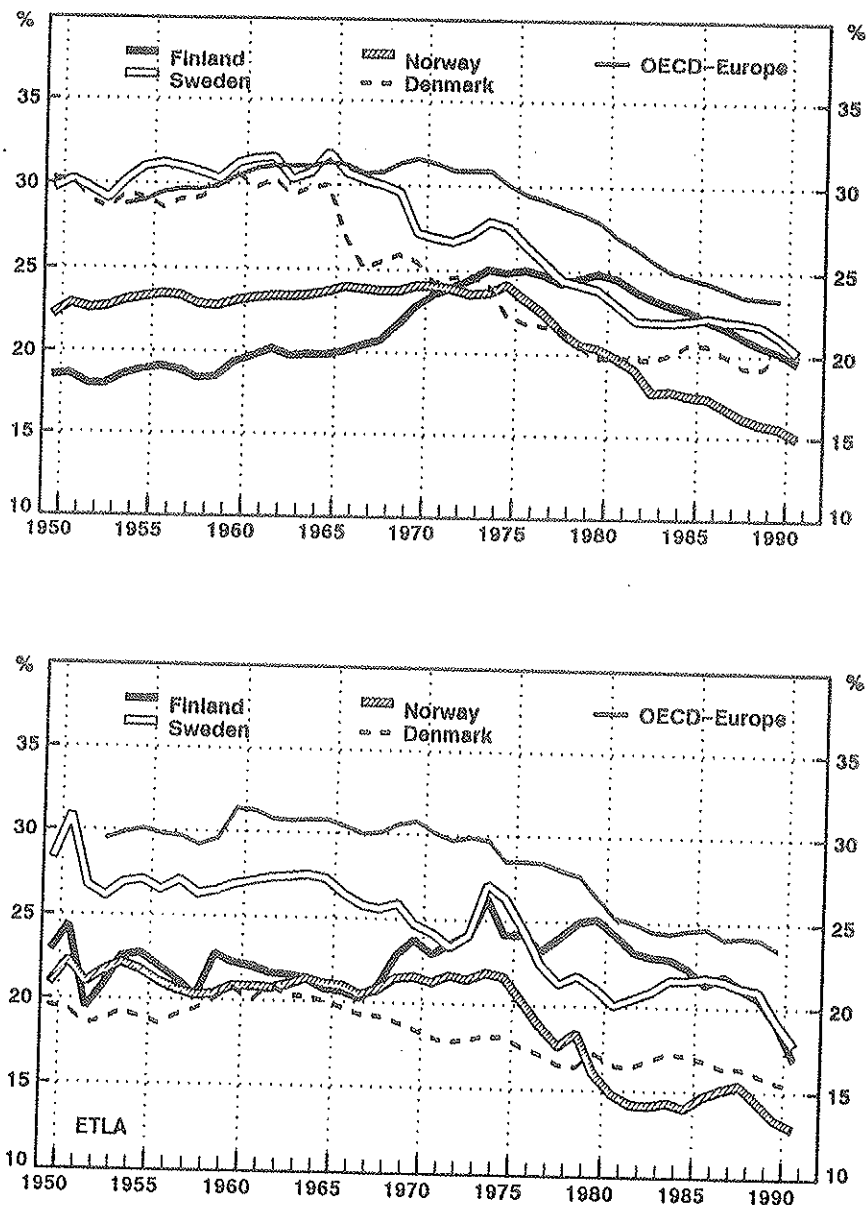
Figure 1. Volume of manufacturing output in the Nordic countries and in the OECD (1950 = 100)



### Finnish manufacturing in an international perspective

Since the late 1800s the manufacturing industry has been a growth engine of the economy. The growth rate of manufacturing output has been on average about 1.5 times that of the total economy during this century. Growth has been swift also internationally speaking. This holds for the 1920s and 1930s, but especially for a period starting from the late 1960s (see Figure 1.). However, due to the late start in the industrialization process the share of manufacturing industry has not attained the level of "old" industrial nations (see Figure 2.).

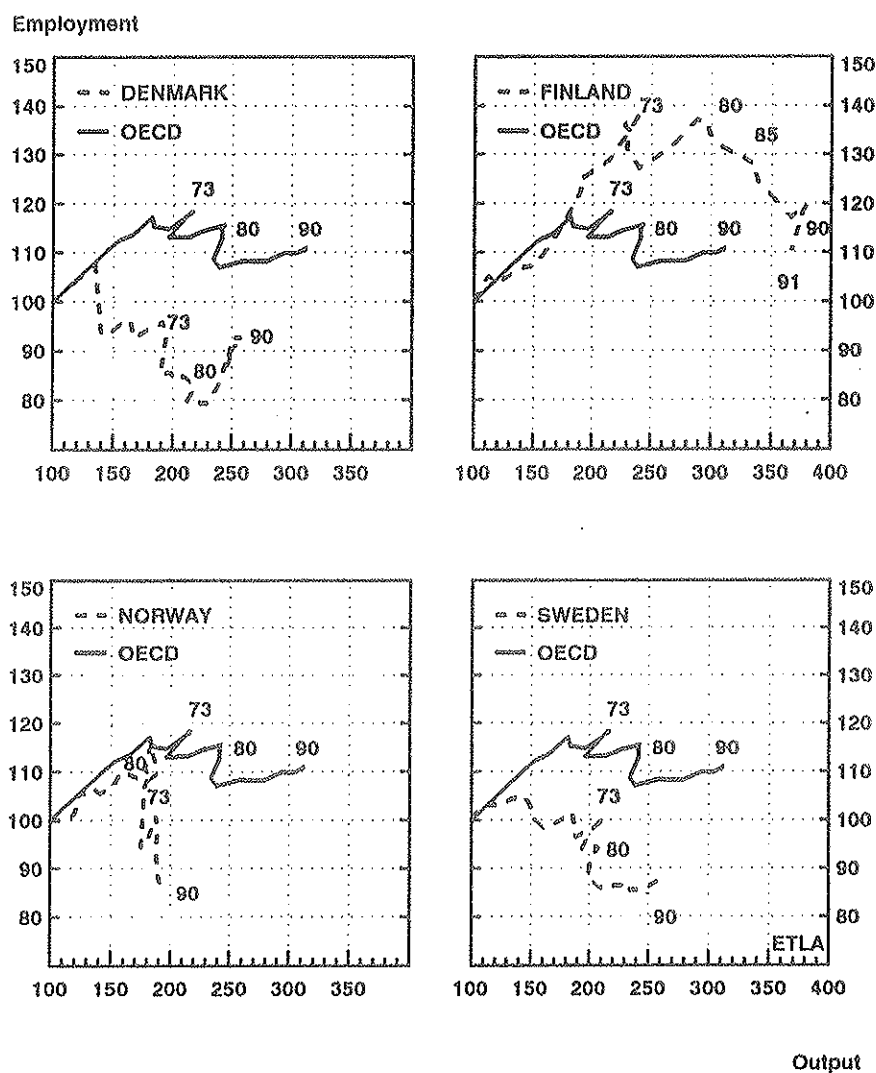
Figure 2. Share of manufacturing in total employment and output in selected countries, 1950 - 90, %.





Finland, in a way, changed simultaneously from an agricultural society into both an industrial and a service society. Indeed, the growth pattern of Finnish industry has been different from the average OECD pattern or from that of the other Nordic economies. The Finnish manufacturing production grew rapidly also after the recession of the mid-1970s when in most other industrialized nations the process of deindustrialization started, part of manufacturing capacity was scrapped and the manufacturing labour force declined rapidly. The international "crisis" industries of the late 1970s - such as steel, shipbuilding, and textile and clothing - fared comparatively well in Finland up to the late 1980s.

Figure 3. Employment and output in manufacturing in selected countries (1960=100)



Manufacturing employment in Finland remained on a rising trend up to the early 1980s but has fallen since then quite dramatically. Thus, as regards employment Finnish manufacturing entered a phase of structural change similar to that which other European OECD countries experienced in the 1970s about 10 to 15 years later (see Vuori - Ylä-Anttila 1987). There are several factors behind this "delayed structural change". First, the supply of the labour force from the large primary sector was abundant from the 1950s to the 1970s - about 50 % of total labour force was still engaged in primary production in the beginning of the 1950s. Secondly, the investment ratio in Finnish manufacturing has been notably higher than in the industrialized countries as a whole. Thirdly, the high level of investment activity has been associated with efficient transfer of technology and the development of Finnish manufacturing firms' own applications. Facilitating this has been the relatively high level of education and training of the labour force. Hence, the growth of Finnish manufacturing output up to the late 1970s was still to a large degree extensive growth based on an increase in the volume of inputs, while in other west European countries many mature industries were in decline.

Since the latter half of the 1970s the growth of manufacturing output has been very rapid in international comparison - with the exception of the recent recession during which the output has fallen much more than in any other industrial country. The growth has no longer, however, been based to any significant extent on an increase in the volume of labour and capital inputs, but on the growth of total factor productivity. In that respect the growth process has been similar to that in other industrial countries. However, the manufacturing productivity growth was in Finland up to the turn of the decade much faster than in most other nations. This can be explained by fast growth in R&D expenditure and the rapid capital accumulation of the 1970s and early 1980s which has affected productivity via technological embodiment effects. The age structure of the capital stock in Finnish manufacturing, and particularly in certain branches, is still rather favourable in an international comparison.

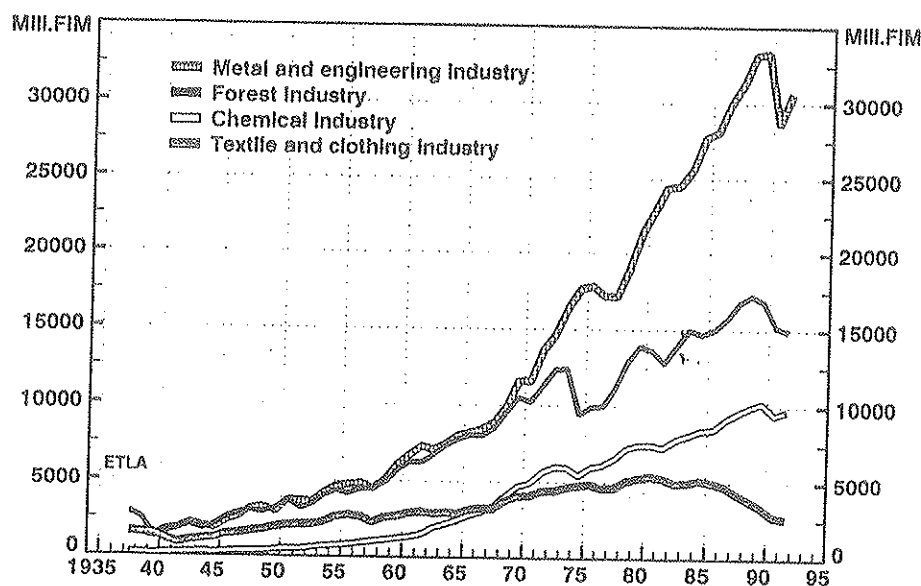
It can be argued that rapid advancement in well-being induced by industrialization and rapid expansion of manufacturing has been a significant endeavour spurred by economic nationalism. This process has, in many respects come to a crossroads. The firms have rapidly internationalized their operations and the significance of nation states in decision making is declining. Further

internationalization of business will heavily impinge on the industrial organization and pattern of technological change. The role of foreign companies, which until recently has been quite small, will probably become more important especially in the areas where large R&D expenditures and world-wide marketing efforts are needed. On the other hand, the Finnish firms have increasingly been becoming more international and the national base of operations has lost much its importance. The national industrial or economic policies have a much narrower scope than in the past.

### Structural changes by industries

Despite major changes in the structure of manufacturing final output (see Figure 4.) the forest based industries have remained the core of the Finnish industrial system. Many new industries have emerged as spin-offs from the forest sector or as forest-related new businesses. The forest sector forms by far the most important development block in the Finnish economy.

Figure 4. Manufacturing output by industries (Value added at 1985 prices)



While most of the forest industry machinery were imported still in the 1950s, Finland is now a leading supplier of paper machines in the world. The first Finnish paper machine to be exported was delivered just after the war, in 1948, but the first paper board machine for the domestic market had been built already in 1905 (under a US licence). Hence, a long period of domestic user-producers interactions preceded the start of the export-led growth of the paper machine industry.

In addition, such industries as industrial electronics, logging equipment, parts of the chemical industries and finally forest-related consulting services have developed basically from the knowledge accumulated in the forest industries. Today, about one fifth of total production of the metal and engineering industry is directly accounted for by forest industry-related products. In exports this share is even a bit higher.

It could be argued that most of the internationally successful engineering products with high world market shares have linkages to forestry or the forest industry. Among them are process control electronics, forestry tractors, boilers for pulp factories etc. The most important are, of course, large systems comprising design and planning, machinery, and training and education services for the entire production lines or paper mills. As shown in Raumolin's article (Raumolin, 1992) Finland has during this century developed from an object of technology transfer to an important international supplier of forest industry technologies.

Another important resource-based development block in the Finnish industry is a complex grown out of the mining sector. The mineral resources of the country have been quite small (with the exception of copper and nickel and some non-metallic minerals) and the basic metal industry nowadays uses mainly imported minerals. Mining and metal industry equipment has nevertheless developed into important product groups within the engineering industry. Their share in the total production of the branch is certainly smaller than that of the forest industry machinery. Nevertheless, some of them (like flash smelting technology and crushing equipment) have gained leading positions in the world market and the internationalization of operations has gone far particularly in these products: clearly more than half of the sales in mining related products is generated by foreign subsidiaries (cf. Airaksinen 1991, see also Raumolin, 1992).

Taking a more conventional look at structural changes in manufacturing one can observe that the metal and engineering industries took the dominant position in the Finnish industrial structure as late as in the 1970s (see Figure 4.). By that time also the chemical industries had grown into a significant sector in the economy. The share of the forest industry in total manufacturing output in 1992 is less than 20 %, while the corresponding share of the metal and engineering sector is close to double of this. In the beginning of the 1950s both of these industries had a share of around 25 %. Chemical industries were practically non-existing before the war, but today hold a share of over 10 % in total manufacturing output. The chemical industries emerged mainly as a result of conscious industrial policies: two of the largest companies in the branch are state owned and established in nationally strategic fields - oil refining and production of fertilizers.

Rapid growth in the metal and engineering industries started already in the 1930s when the domestic pulp and paper industry as well as agriculture rapidly increased their investment demand. The growth got a new impetus after the war, first in the form of war reparations and later as normal trade with the Soviet Union. This trade proved to be important for the further expansion of the engineering industry. At its peak the share of the Soviet market of the total exports of the branch was as much as 50 % (in 1983). This high share proved to entail a large risk as evidenced by the drastic drop of output in the beginning of the 1990s. The drop was, however, only partly due to the collapse of the Russian market, since by the turn of the decade the share of this market in total exports had diminished already down to 20 %. Anyway, the Russian market as well as the markets of the other Nordic countries served as stepping stones for expansion and globalization of new branches within the engineering industries. Among these new branches the most important are industrial electronics and automation, medical electronics and instruments, and telecommunication equipment.

The electronics industry as a whole has been growing at an annual rate of 15-20 % from the beginning of the 1970s. Parts of this industry relates to the forest sector and some parts also to mining, but there are significant branches without any linkages to established or resource-based industries. These industries have developed on the basis of created factors, i.e. knowledge capital, rather than having their origin in inherited factor endowments. No doubt, the metal and engi-

neering industry as a whole went through a significant within-industry structural change in the 1980s which shifted the production towards knowledge-intensive goods and fast growing markets (see Ylä-Anttila 1991 and the next section).

The forest industries, too, have experienced a substantial internal structural change during the past few decades. The trend has been towards more refined forms of products. Sawn wood and pulp account only for 20 % of the total exports of forest products, while the share was about 40 % in the beginning of the 1970s. The change was especially pronounced in the paper industry during the 1980s (cf. Ray, 1992). While the market share of the Finnish producers in the total European consumption of paper and board remained at about 6-7 % over the decade, the share of high value added printing and writing paper rose from 6 % in 1980 to 14 % in 1990 (Lammi 1992). Compared to, for example, the Swedish paper industry, which is the main competitor of Finnish companies, the value added content of products is very high (see Ylä-Anttila 1991).

Does all this upgrading of products and expansion of emerging high-tech industries mean that the industrial and technological base of the economy has decisively improved and the competitiveness is sound in the light of the future market prospects? The answer is only partly affirmative.

First, the rapid growth of the electronics industry has been slowing down since the turn of the decade. Furthermore, it seems that many of the new business operations focused on in electronics and industrial automation have proved to be unprofitable and companies are selling them off, in many cases to foreign larger firms. There has been a tendency to concentrate on core businesses to free up scarce resources (often management resources) to better run the basic activities of the firm (see Ylä-Anttila and Lovio 1990, cf. also Kajaste et al. 1992). The strategy of expanding into new rapidly growing industries seems to have failed in part and major restructurings are going on both at the corporate and industry level. One explanation for the difficulties seems to stem from too small resources for research and development. That is a general problem of small countries: huge development costs in nearly all high tech branches will make it hard for small countries and firms to keep up with technical advances. That poses a major challenge for the whole national innovation system.

Secondly, the rapid growth of the forest industry's investment in modern production capacities and more advanced products has also had its drawbacks which are clearly appearing during the recession: the companies have run into severe financial problems due to high leverage ratios and the consequently burdensome interest payments. Continuously high investment ratios have guaranteed high technological competitiveness - the productive equipment is relatively new and the average size of paper and board machines is the largest in the world, about 25 % larger than, e.g., in Sweden or Canada. This type of productive structure is technically efficient but, on the other hand, inflexible and vulnerable when the demand fluctuations are large.

Profitability in the capital-intensive forest industry is, to a large extent, determined by the rate of capacity utilization (see Ylä-Anttila 1985). A major problem during the first half of the 1990s will be the overcapacity in precisely the product groups where the Finnish producers have been strong, i.e., in printing and writing paper (see Lammi 1992). That, together with extremely high capital costs, suggests no immediate improvement in profitability. Previously, the problems with finances and profitability were solved through devaluations of the Finnish markka. When that option is now ruled out, the way out of the current dilemma has to include major structural changes in the production system and industrial organization. Since world trade in forest products typically experiences larger volume and price changes than other industrial goods, these structural changes have to increase flexibilities in the whole forest sector and become a permanent part of the industrial system. More flexibility is needed in both labour and timber markets as well as in internal organizations of firms. A prerequisite for this is a broader change in the entire socio-economic system.

An additional, and from a national point of view, very important question will be the utilization of forest resources. Most of the global paper capacity in the 1990s will be based on recycled raw material. That means that demand for wood will decrease and prices probably go further down. The majority of new paper mills will be established close to areas of large consumption (see Kajaste 1991). It is still unclear what kind of role the former backbone of the economy will have in the Finnish industrial structure. The utilization rate of the forest resources will probably diminish substantially in the future, which will have far-reaching consequences for the economy and the society as a whole. The industrial growth which started with the expansion of the forest

industries is now in a turning point which is, from historical a perspective, comparable to the initial period of industrialization or the post-war periods and the depression of the 1930s. Nevertheless, forest industries will have a major role in the ongoing restructuring process. Finland is still, after remarkable changes in the structure of industrial output, more dependent on the forest sector than any other industrial economy. About 40 % of total export earnings comes from that sector, the value of forest industry exports per capita is around 2000 USD, which is twice as much as, e.g., in Sweden and three times that of Canada.

## 2. FROM EXTENSIVE TO TECHNOLOGY-BASED GROWTH

### Industrial growth and productivity

By international standards, industrial growth in Finland has been rapid in the post-war period. This growth has been almost continuous, two notable exceptions being the mid-1970s and the beginning of the 1990s. Within this period, however, there has been a marked change in the character of growth: the earlier years were characterised by extensive growth, based mainly on increased use of the basic inputs, labour and capital. In contrast, since the early 1970s growth has been of a more intensive kind, based on factors such as more efficient use of inputs, better organization and technological advance. In other words, much more than before, the growth in total factor productivity (TFP) has contributed to the growth of industrial production.

Indeed, the contribution of TFP to output growth in manufacturing was about 56 percent on average in the period 1960 to 1973, whereas it increased to as much as 94 percent in the post-1973 period (Table 1). However, there are large variations both between industries in both of these periods and between these periods for each industry. For instance, the average growth contribution of TFP in the chemical industries only increased from 39 percent to 66 percent



between the periods, whereas in the wood industry it grew from 88 percent to 460percent. At the same time there was a marked slowdown in the average yearly growth rates of output for both industries, just as in total manufacturing.

The rate of growth of both total factor productivity and labour productivity in the business sector as a whole was clearly higher in Finland in the 1980s than in most other OECD countries (Table 2). In addition, the slowdown of productivity growth when compared with the 1960s and early 1970s has not been as strong as generally in other industrialized countries. The factors behind this slowdown are, however, probably partly the same for Finland as those having been suggested for the industrialized countries in general: the effect of large changes in energy and raw material prices, slowing capital accumulation, lower expenditure on R&D, demographic change affecting the average skill level of the labour force, and diminished possibilities for "catching up" since the 1950s and 1960s (OECD,1991).

Table 1. Growth of manufacturing output in Finland and contributions of labour and capital input and total factor productivity (TFP), average annual changes, percent.

1960-1973	Output growth	Contribution of labour	Contribution of capital	Contribution of TFP
Food manufacturing	5,1	0,8	1,8	2,5
Textile, wearing apparel and leather industries	3,9	-0,8	1,0	3,7
Wood industry	4,1	-0,6	1,1	3,6
Furniture industry	7,0	1,0	2,7	3,3
Pulp and paper industry	7,0	0,7	2,2	4,1
Printing and publishing	4,3	1,6	2,2	0,5
Chemical industries	13,2	2,4	5,6	5,2
Non-metallic mineral products	10,4	1,2	3,2	6,0
Basic metal industry	10,4	2,4	3,5	4,5
Metal products and engineering industries	6,7	1,4	1,7	3,6
Other manufacturing	7,0	-1,2	1,3	6,9
Total manufacturing	6,6	0,7	2,2	3,7

1973-1990	Output growth	Contribution of labour	Contribution of capital	Contribution of TFP
Food manufacturing	2,2	-0,9	0,9	2,2
Textile, wearing apparel and leather industries	-1,6	-3,9	0,1	2,2
Wood industry	0,5	-2,4	0,6	2,3
Furniture industry	2,7	-0,9	0,9	2,7
Pulp and paper industry	2,3	-1,1	1,2	2,2
Printing and publishing	4,1	0,3	2,6	1,2
Chemical industries	3,2	-0,5	1,6	2,1
Non-metallic mineral products	2,7	-0,7	1,2	2,2
Basic metal industry	5,2	-0,4	0,9	4,7
Metal products and engineering industries	4,9	-0,3	1,4	3,8
Other manufacturing	3,1	-1,2	1,3	3,0
Total manufacturing	3,1	-0,9	1,1	2,9

Source: National accounts and calculations made at ETLA.

Table 2. Productivity in the business sector in selected countries, average annual changes, percent

Country	Total factor productivity			Labour productivity		
	1963-73	1973-79	1979-90	1963-73	1973-79	1979-90
United States	1.6	-0.4	0.3	2.2	0	0.7
Japan	5.9	1.4	2.0	8.6	2.9	3.0
Germany	2.7	1.8	0.8	4.6	3.1	1.6
United Kingdom	2.3	0.6	1.6	3.6	1.6	2.1
Denmark	2.8	1.2	1.3	4.3	2.6	2.1
Sweden	2.7	0.3	0.9	4.1	1.5	1.7
Finland	3.2	1.5	2.5	4.9	3.2	3.6
OECD Europe	3.3	1.4	1.3	5.0	2.7	2.0
OECD	2.8	0.5	0.9	4.1	1.4	1.5

Source: OECD Economic Outlook 50, OECD, Paris, December 1991

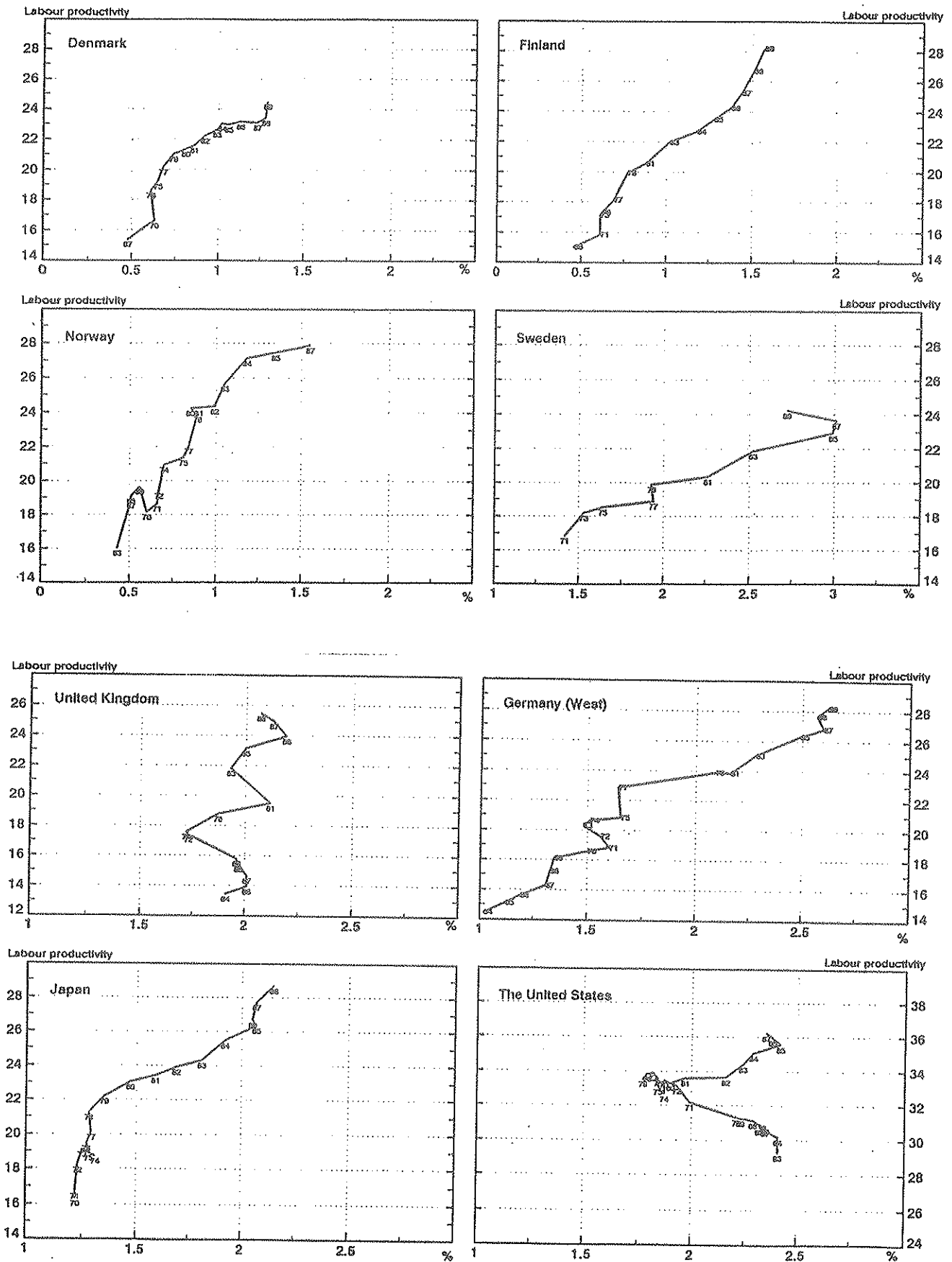
Studies on the effects of firms' own research and development activities on total factor productivity have in general produced the conclusion that, especially before the economic crises of the 1970s, the returns to R&D have been quite high, often in the range of 20-80 percent. Most of these results, however, have concerned the U.S. and other large countries. Similar analyses with Finnish, Swedish and Norwegian data have indicated that the returns to firms' own R&D are perhaps not as high in these countries as has been thought on the basis of previous research (see Vuori 1986 and 1991).

Thus, it has been argued that the role of firms' own R&D and that of technology diffusion may be different in small open economies such as Finland from the situation in larger countries that became industrialized earlier. Thus diffusion seems to be extremely important for the smaller countries, but can be achieved only by means of firms' own sufficient capabilities, which are partly built on their own research activities. The decisive role of diffusion could be an explanation for the fact that very strong empirical evidence on the positive impact of firms' own research on their productivity has not yet been found for the Nordic countries (see Vuori 1992).

Figure 5 illustrates how research intensity and labour productivity are related to each other in different countries. Some of the cases can be seen as examples of the catching-up phenomenon. Thus in countries which in the 1960s and 1970s were clearly lagging behind the United States, such as Germany and Japan, the development of both research intensity and productivity has been rapid. In countries where R&D expenditures were on a much lower level in the late sixties (Finland, Denmark and Norway), they have grown even more rapidly. In these cases, it seems that when the gap with respect to the leading countries is wide, a substantial increase in research efforts is needed for approaching the leaders' productivity levels, but after reaching a certain level of research intensity, productivity increases are mainly based on other factors.

Of the smaller countries, Sweden is again a different case: although research intensity was fairly high already in the early 1970s, it continued rising sharply, but nevertheless the gains in productivity were not as impressive. This is evidently connected with the Swedish model of internationalization, where multinational Swedish companies have largely kept their research activities in Sweden, despite the fact that a high share of their production has been shifted abroad.

Figure 5. R&amp;D intensity and labour productivity in selected countries



R&D intensity = Business enterprise R&D (BERD) in relation to value added

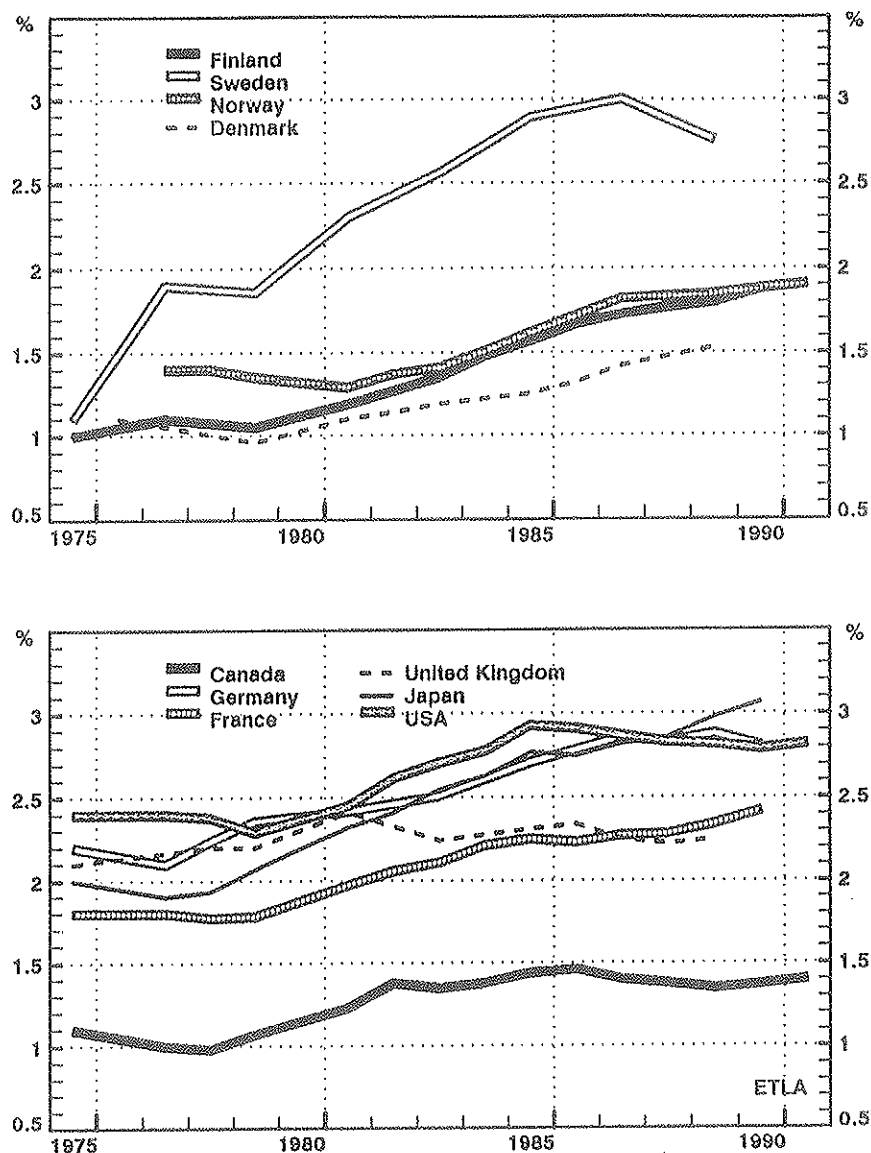
Labour productivity = Business sector value added, USD at 1980 PPPs

### Input measures of technological level

Finnish industry started to intensively raise its technological level relatively late, but after the start the development has been quite rapid. From the period covering the 1950s and 1960s there is only scattered quantitative information about the development of research intensity in Finland, and the figures are not fully comparable with those systematically gathered from the late 1960s onwards. For example, on the basis of a survey concerning 1956 it was estimated that total research expenditures (excluding research at universities) amounted to 0.35 percent of GDP in that year. Within manufacturing, the metal and engineering industries were already at that time the major spenders on research, with a 61 percent share of the total. In contrast, the forest industries had a 13 percent share while the chemical industries, still at the emerging industry stage in Finland, only accounted for 9 percent of the total manufacturing research expenditures. (See Elfvingren 1958.) According to another study, the share of technical research in GDP increased from 0.39 percent in 1962 to 0.49 percent in 1968. In the latter year total research expenditures were estimated to be 0.8 percent of GDP; in Sweden the corresponding figure was already 1.6 percent (Nurmi 1970, pp. 27-28).

In the late 1970s and the 1980s investments in research and development increased very rapidly in Finland. The annual growth rate in the volume of R&D was about 10 percent on average in the 1980s, or faster than in any other OECD country. Compared with the major spenders on R&D, however, the level of R&D investments is still fairly low. Instead, Finnish R&D expenditures relative to GDP are on a comparable level with e.g. Canada, Denmark and Norway (see Figure 6).

Figure 6. R&amp;D as a percentage of GDP in selected countries



Even if small countries are in some cases able to raise their technological level substantially, they nevertheless stay in absolute terms in a totally different position from that of larger countries and huge multinational companies. Because of their larger resources those larger units will always have the leading position in the technology race. In 1990, Finland's total research expenditures were only 0.4 percent of the OECD total, and at the same time the corresponding share in OECD total population was 0.6 percent and in OECD total GDP about 1.1. percent.



The small absolute size of the total R&D expenditures of Finland can also be demonstrated by a few figures concerning some foreign major organizations performing R&D. When for example in 1989 the gross national research expenditures of Finland were 1343 million current dollars in purchasing power parities and correspondingly 828 million dollars for the entire business sector, the research budget of the U.S.-based company General Motors alone was as much as 5248 million dollars. The total R&D expenditures of five major U.S. companies (General Motors, IBM, Ford, AT & T, and Digital Equipment) were 17792 million dollars, or 13 times higher than the total Finnish research expenditures, and 21.5 times higher than the business sector expenditures. Comparable levels with the Finnish research expenditures were reached by the Japanese ministry MITI (1147 mill.\$), the German Ministry of Defence (1418 mill.\$), the French company Thomson (1264 mill.\$), and the Japanese companies NEC Corp. and Fujitsu Ltd. (1374 and 1350 mill. \$ respectively). (See Technology and the economy, 1992, p. 91.)

When looking separately at the R&D spending of the manufacturing industry, the international picture is quite similar to that prevailing on the national level: while manufacturing spends relatively more on research than the whole economy, the major spenders are the same countries (the U.S., the United Kingdom, Germany, Japan and France of the larger countries, and Sweden of the smaller ones, see Figure 7). In absolute terms, the industries which spend the largest amounts on R&D in Finland are, just as in most other industrialized countries, the metal products and engineering industries and the chemical industries. The former group of industries accounts for as much as two thirds of the total research expenditures of the manufacturing industries (Figure 8).

Figure 7. R&amp;D as a percentage of value added in manufacturing in selected countries

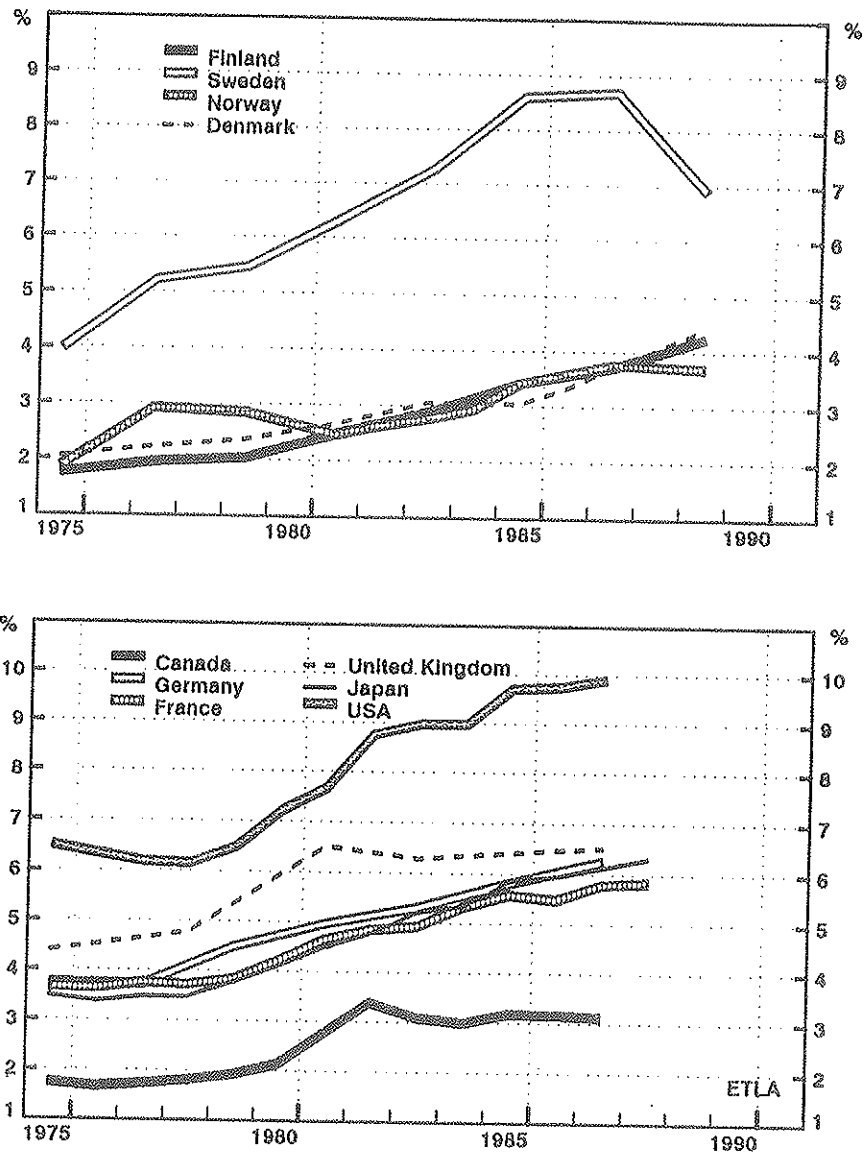
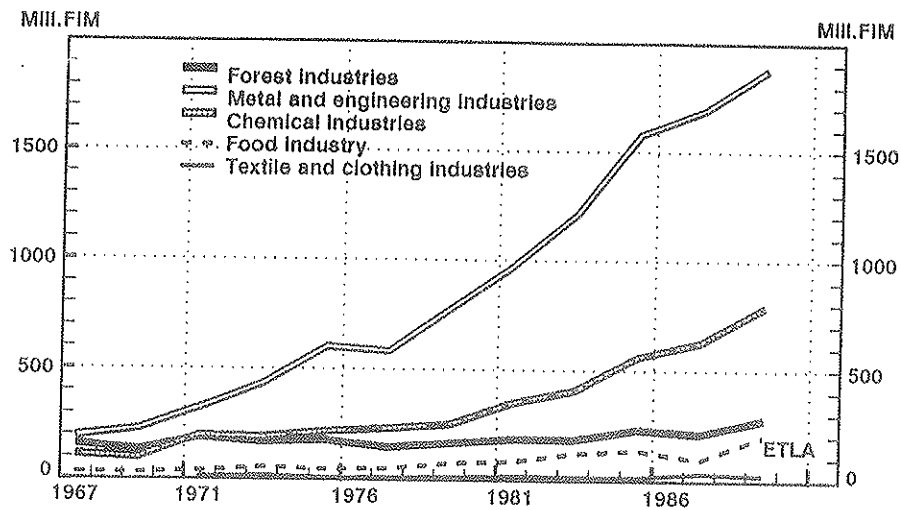


Figure 8. Volume of R&amp;D in Finnish manufacturing industries



A closer look at the figures indicates that there is considerable variation between subsectors of the different industries as to how much they spend on research and development. In some product groups the share of research expenditures in value added was for instance in 1989 quite high: 24 percent for drugs, 55 percent for petroleum and coal products, 29 percent for machines and turbines, 37 percent for computers and office machines, etc. (Table 3). Most of these sectors are regarded as genuine high-tech industries.

Table 3. Research and development expenditures of Finnish manufacturing firms in 1989, share in value added, percent, selected product groups

Product group	%
Food	1.8
Clothing	0.1
Wood and wood products	0.5
Pulp, paper and paper products	2.2
Industrial chemicals	8.7
Drugs	24.2
Petroleum and coal products	54.9
Machines and turbines	28.6
Pulp and paper making machines	9.5
Computers and office machines	37.1
Instruments	14.7
Total manufacturing	4.7

Source: Central statistical office, Finland.

In contrast, the pulp and paper industry, which is especially important in the Finnish industrial structure, is a quite different example. In international classifications the industry is regarded as a low-tech industry, and in Finland the product group as a whole spent in 1989 only 2.2 percent of its value added on R&D - about half of the manufacturing average. Nevertheless, parts of the paper industry have clear high-tech industry characteristics: without a high level of expertise and ability to use technologically complicated processes the production of high-quality grades of paper would simply not be possible. A substantial part of the technologies used in the industry

have been created outside the sector, i.e. in the sectors producing machinery and equipment. Thus the research efforts made in these sectors benefit the paper industry also. In fact the sector producing pulp and paper machinery is much more research-intensive: in 1989 it spent 9.5 percent of its value added on R&D.

In addition, the pulp and paper industry funded research activities performed outside the firms themselves with an amount which was about a fourth of the industry's "intramural" research expenditures; this is an exceptionally high share. Thus, the picture given by looking at the firms' own research expenditures alone is far from complete; in many cases the diffusion and use of technologies developed by other firms or research units may be highly important.

In international classifications the R&D intensity of industries is in general used as the basis for naming high- and low-tech industries and countries. According to these classifications Finland is often regarded as a medium-tech country. However, in a recent OECD study (Technology in a changing world, 1991), Finland is listed in the group of "other high- tech countries", to be compared with the more advanced group of "technological leaders", such as the United States, Japan and Sweden (see Table 4). In this case the classification was based not on the R&D intensities of individual industries, but on the share of the business sector's R&D expenditures in GDP. Because of the relatively high share of the business sector in total national R&D expenditures and the exceptionally high growth rate of research expenditures, Finland managed in the 1980s to climb up to this group of other high-tech countries, defined here to include countries where the business sector's R&D expenditures relative to GDP were between 1 and 1.5 percent. It is interesting to note that such countries as Austria, Canada and Denmark ranked clearly below Finland, in the group of "middle tech countries".

Table 4. Development of business sector R&D as a percentage of GDP in selected OECD countries

	Business sector R&D, per cent of GDP		
	1979	Most recent year	Growth most recent year/1979 a)
A. The "technological leaders"			
Germany	1.66	2.00 (1990)	1.86
Japan	1.20	1.98 (1988)	7.18
Sweden	1.30	1.91 (1989)	4.71
Switzerland	1.92	2.24 (1986)	2.38
United States	1.55	1.90 (1990)	2.05
B. The "other high-tech countries"			
Belgium	0.95	1.19 (1988)	2.80
Finland	0.57	1.09 (1989)	9.07
France	1.06	1.40 (1990)	2.92
Netherlands	0.97	1.30 (1988)	3.78
Norway	0.67	1.14 (1989)	7.01
C. The "middle tech countries"			
Austria	0.59	0.70 (1985)	2.55
Canada	0.46	0.70 (1990)	4.74
Denmark	0.48	0.79 (1987)	8.25
Italy	0.43	0.70 (1990)	5.71

a) Average annual growth (percentage growth from the base year over the period implied in the left two columns).

Source: Technology in a changing world, 1991.

a) Average annual growth (percentage growth from the base year over the period implied in the left two columns).

Source: Technology in a changing world, 1991.

In most industrialized countries the manufacturing industry has increased its R&D expenditures much more rapidly than investments in fixed capital over the past 15 or 20 years. This structural shift has been remarkable in countries like the U.S. and Sweden; in the U.S. the research expenditures have even surpassed the expenditures on fixed capital in a couple of years (Figure 9). Also in Finland the growth in research expenditures has been much faster than the growth of fixed investments; this is clearly seen also when looking at the growth rate differentials of the main subsectors of manufacturing in the 1980s (Table 5).

Figure 9. R&D expenditures as a percentage of fixed investment in manufacturing in selected countries

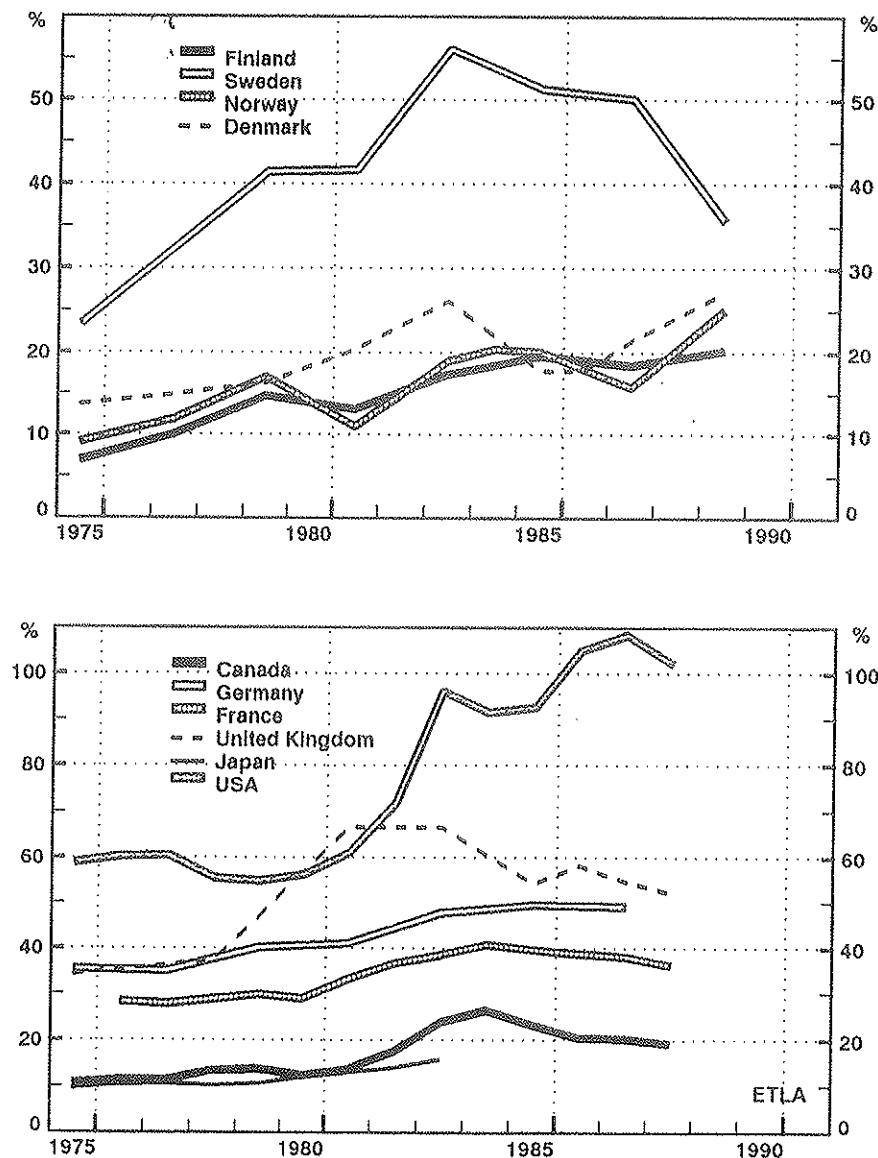


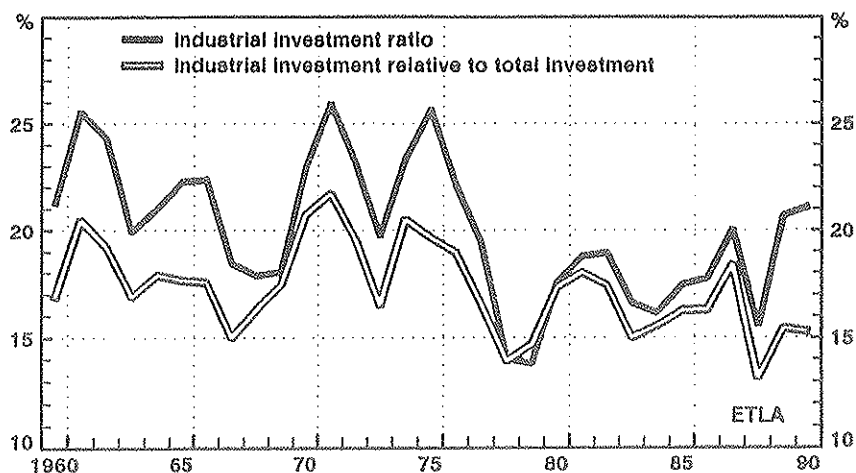
Table 5. Manufacturing fixed investment and R&amp;D expenditures by industry in 1980 and 1990

INDUSTRY	FIXED INVESTMENT			R&D EXPENDITURE		
	Share in total manufacturing (%)		Average annual change in volume(%)	Share in total manufacturing		Average annual change in volume(%)
	1980	1990	1980-1990	1980	1990	1980-1990
Food manufacturing	13,1	10,6	1,4	5,1	7,2	13,7
Textile, wearing apparel and leather	4,7	1,9	-5,1	1,1	0,7	6,8
Forest	32,1	38,2	4,5	11	8,5	10
Chemical	12,3	12,2	3,8	19	23,7	15,1
Metal and engineering	26,4	24,6	3,8	61,3	55,6	10,1
Other manufacturing industries	11,4	12,5	5,5	2,5	4,3	16,2
Total manufacturing	100	100	3,67	100	100	11,3

In Finland the investment ratio has been internationally high in the post-war period. In the 1980s gross fixed capital formation amounted to about 25 percent of GDP on average, which was almost 5 percentage points higher than the EC average and about 3.5 percentage points higher than the average for small European OECD countries. This high ratio is partly explained by rather heavy investments in the housing sector and in agriculture, but also within manufacturing the investment ratio has remained on a relatively high level, although there has been a long-run downward trend (Figure 10).



Figure 10. Industrial investment ratio and share of industrial investment within total investment



Among the larger industrial sectors in Finland, the wood, pulp and paper industries are the most capital-intensive ones: in 1989 firms in these industries accounted for 44 percent of the fixed capital investments of total manufacturing, and they spent 12.5 percent of their turnover on these investments, whereas the manufacturing average was 7 percent. At the same time, these industries' share in the total intangible investments (including R&D, training, marketing, software etc.) of manufacturing was only 15.5 %; firms in these industries spent 1.7 percent of their turnover on intangible investments, while the manufacturing average was 2.7 percent. These figures can be compared with the corresponding figures for the industries producing machinery and equipment, which are much less capital-intensive but more research-intensive. These industries' share in the fixed capital investments of total manufacturing was only 6.5 percent, whereas their share in the intangible investments of total manufacturing was as much as 14.5 percent. (Teknologian soveltaminen ja siirto 1990 (1992)). As mentioned above, part of the research results of industries producing machinery and equipment are transferred to the end users.

Another feature of the Finnish figures concerning R&D expenditures is that by international comparison, a very small fraction of the total outlays goes to defence-related research (Table 6).

Thus in several countries with a high share of R&D expenditures in GDP the share of civilian research is considerably smaller.

Table 6. Defence R&D, civil GERD<sup>1</sup> and GERD as a percentage of GDP

COUNTRY	DEFENCE R&D		CIVIL R&D		GROSS DOM.EX-PENDITURE	
	1 981	1 989	1 981	1 989	1 981	1 989
FINLAND	0,01	0,01	1,2	1,8	1,2	1,8
SWEDEN	0,18	0,02	2,1	2,6	2,3	2,8
NORWAY	0,05	0,07	1,2	1,8	1,3	1,9
DENMARK	0	0	1,1	1,5	1,1	1,5
USA	0,6	0,8	1,8	2,1	2,5	2,8
CANADA	0,03	0,05	1,2	1,3	1,2	1,4
JAPAN <sup>2</sup>	-	-	2,3	2,8	2,3	3
GERMANY	0,1	0,1	-	-	2,4	2,9
UNITED KING. <sup>3</sup>	0,6	0,4	-	1,83	2,4	2,3
FRANCE <sup>4</sup>	0,5	0,5	1,6	1,84	2	2,3

1) GERD = Gross domestic expenditure on R&D

2) Data in 1989 is for 1988

3) Data in 1989 is for 1985

4) Data in 1989 is for 1987

### Output measures of technological level

While it is clear that the growth of R&D investments has been internationally quite high in Finland in the 1980s, the results of these investments are not easy to measure. The section on industrial growth and productivity (above) dealt with productivity developments, which are in general thought to be related with the changes in research efforts. Another way to try to find out the outcomes of increasing research investments is to look at the developments in patenting activities and the trade in high-tech products. As for many other industrialized countries, the

United States is the most important foreign country where Finnish applicants apply for patents. In the 1980s there has been a rapid increase in Finnish patenting activities; the average annual growth rate for patents granted in the U.S. was 8.5 percent during the decade. This rate can be compared with the growth rate in domestic patent applications: only 4.5 percent per annum on average (see Table 7). The growing intensity of patenting can be seen as an indication of increased research activities and thus of more patentable research results, but it may also possibly be due to changes in patenting behaviour, as a result of, for example, keener international competition.

Table 7. Patenting activities of Finnish applicants, 1980 to 1990.

Year	Patents applied in Finland by Finnish applicants	Patents granted in the U.S. to Finnish applicants
1980	1354	140
1981	1419	164
1982	1633	157
1983	1713	136
1984	1769	181
1985	1719	227
1986	1751	222
1987	1851	293
1988	1977	241
1989	1944	271
1990	2068	320
Average annual growth, percent	4.5	8.5

Sources: Valkonen and Lovio 1991 and Central Statistical Office, Finland.

Also in terms of being able to produce exportable high-tech products the performance of the Finnish manufacturing industry has considerably improved in the 1980s (Table 8). While the share of high-tech products in total merchandise exports is still low by international standards, it has grown steadily and, in the last few years, quite rapidly. The growth in high-tech imports has been much slower, and thus the relative size of the high-tech trade deficit has been decreasing. In 1990 the Finnish share of high-tech exports in total exports was higher than in Denmark and Norway, but still clearly lower than in Sweden. A trade deficit exists in almost all product groups, the most important exception being telecommunication equipment: in this product group in 1990 exports exceeded imports by as much as 86 per cent (Teknologian soveltaminen ja siirto 1990, Koulutus ja tutkimus 1992:2, Tilastokeskus).

Table 8. Share of high-tech products in foreign trade in some OECD countries, per cent

COUNTRY	1981		1983		1985		1987		1990	
	I	E	I	E	I	E	I	E	I	E
FINLAND	10,1	3,7	11,5	5,1	13,1	6,2	16,2	8,6	15,2	10,8
SWEDEN	11,5	12	14,4	13	14,4	13	16,3	14,1	16,6	15,2
NORWAY	10,1	4,4	11,2	4,1	13,1	4,1	13,5	6	13,6	5
DENMARK	10	8,2	11,1	8	12,1	10	13,8	10	14,5	9
AUSTRIA	9,6	8,3	10,6	10,9	11,9	12,1	13,1	13,9	14,9	15,7
GERMANY	10	13,8	11	14,9	12,7	15,3	14,3	16	14,9	15,7
UK	12,7	16,6	14,8	17,2	16,4	19,2	17,1	19	17,5	20,1
FRANCE	11,3	12,3	12,4	13,5	13,5	15,1	15,8	16,2	16,1	16,2
JAPAN	4,3	16,1	5,6	18,9	6,5	0,3	8,1	24,5	9,7	26,6
USA	9,1	17,4	12,1	22,5	13,6	24,5	15,7	25,1	17,7	25,4

Note: I = imports, E = exports

Source: Central Statistical Office, Finland

### 3. INTERNATIONALIZATION AND CHANGES IN BUSINESS STRUCTURE

The inherent characteristics and nature of growth of firms as well as changes in the industry and company structure are key elements in industrial growth and technological transformation. The major part of innovative activity takes place in firms and firms are also the most important vehicles in the diffusion of new techniques.

In a dynamic economy there is a continuous restructuring of the business sector: old companies grow and change or die away, new companies are established and grow or are taken over by other firms. It has been shown that new (innovative and competitive) entries are of vital importance for rapid and stable long-run macro-economic growth (see Eliasson 1991). On the other hand, it is the group of large companies that is responsible for the bulk of aggregate output and employment growth in the short and medium term.

Up to the 1920s Finnish industrial firms were mainly quite small - often established by trading houses in the latter half of the 1800s. The 1930s saw a surge of mergers and acquisitions and the average firm size grew rapidly. Many firms diversified into new industries. Multibranch corporate structures, typical in parts of industry already before the 1930s, prevailed up to the 1980s as a special feature of the Finnish manufacturing. However, many of the large companies had the forest industry as the main branch. Still in the 1960s the forest based companies dominated the group of the largest manufacturing corporations (see Table 9). The 1960s was, again, a period of major restructurings; large companies made strategic acquisitions in order to prepare themselves for increasing international competition.

Table 9. Breakdown of 30 largest manufacturing companies by industries

	1860/62	1890/91	1927	1964	1990
Forest industries	4	11	16	12	6
Textile and clothing	7	4	8	3	1
Mining, metal and engineering industries	13	9	2	10	11
Other industries	6	6	4	5	13
Total	30	30	30	30	30

Sources: Hjerppe 1979 and ETLA data base

Developments in the structure of industrial firms entered a new dynamic phase in the latter half of the 1970s. Entries and exits of firms increased rapidly, i.e. the renewal of the businesses accelerated, implying a new type of firm dynamics in the economy (see, e.g., Vuori - Ylä-Anttila 1987). The number of industrial firms grew steadily up to the end of the 1980s. In the beginning of the 1990s, however, the number of bankruptcies rose sharply as a consequence of the recession and financial crisis and the number of firms started to decline.

The business structure was also strongly influenced in the 1980s by a rapid rise in the number of takeovers and mergers. This merger wave was larger than any of the previous ones in the Finnish industrial history. The role of large and often multinational companies increased significantly. A

major common feature in these mergers and acquisitions was that firms moved away from the diversification strategies to concentrate on fields where they held their strongest competitive edge. In many cases the mergers were motivated by the ongoing European integration process: The Finnish firms were regarded as too small to be competitive in the integrated European market. Indeed, in an international perspective Finnish industrial companies are still quite small: The average size of the top 8 manufacturing corporations is less than half of that of the Swedish companies or about one fifth of that of the Swiss companies (see Figures 11 and 12). However, the largest Finnish companies are larger than, e.g., Norwegian, Danish or Austrian companies.

Figure 11. Aggregate sales of the 8 largest manufacturing companies in selected countries Bill.USD, 1989

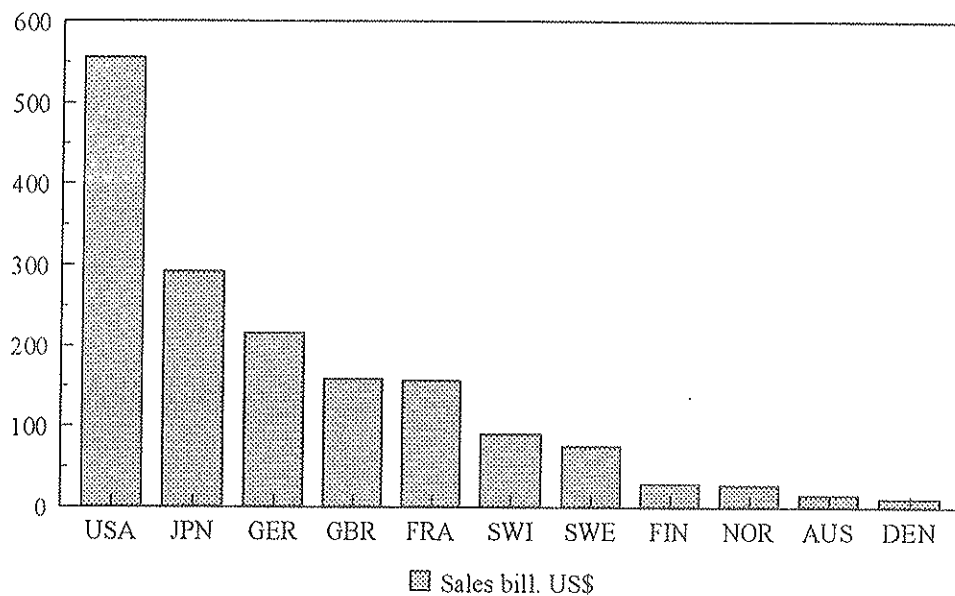
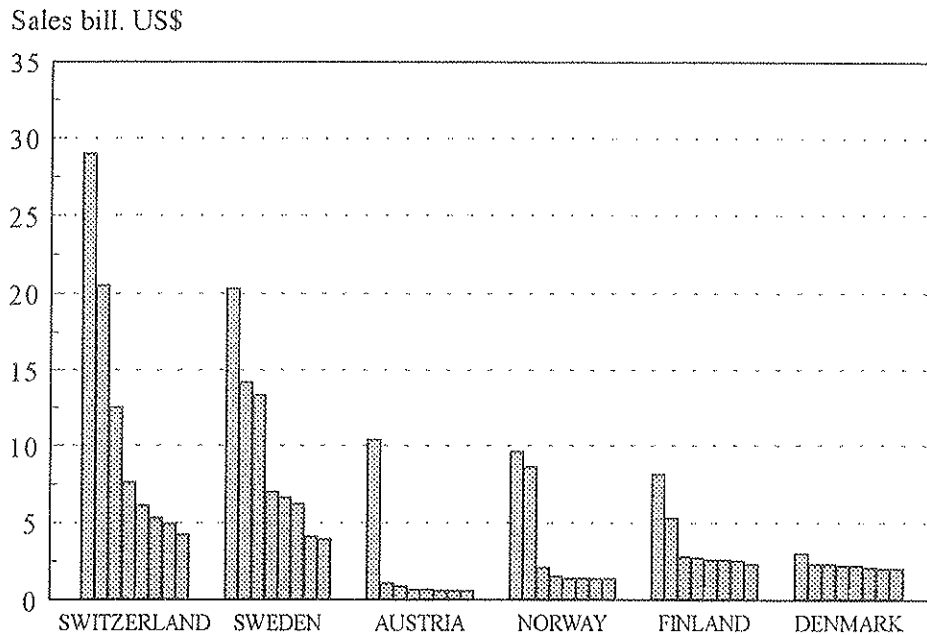


Figure 12. Individual sales of the 8 largest manufacturing companies in selected countries. Sales Bill. USD, 1989

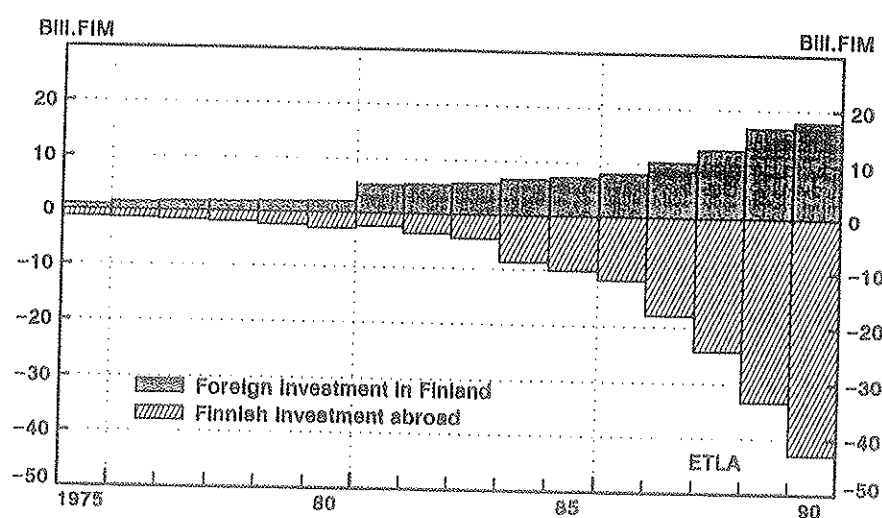


Rapid internationalization of industrial firms has been one of the most important factors behind the changed structure and operations of manufacturing since the early 1980s. The internationalization of business in the form of foreign direct investments started comparatively late, strictly speaking not until the end of 1970s. The expansion has nevertheless been very rapid. The stock of Finnish FDI expanded ten-fold during the 1980s (see Figure 13). The peak level of FDI was reached in 1989. Since then the investments abroad have considerably fallen down as a result of the economic recession (see Kajaste et al., 1992).

As a consequence of takeovers and mergers, and increased internationalization the significance of large companies has grown (see Table 10). However, since the mid-1980s the bulk of the growth of the large firms has taken place outside the national borders and their direct contribution to the growth of domestic industrial output has been small (see Heum - Ylä-Anttila 1992).



Figure 13. Stocks of Finnish direct investment abroad and foreign investment in Finland

Table 10. Employment (total and domestic) of the largest manufacturing companies as a percent of total domestic manufacturing<sup>1</sup>

LARGEST	DENMARK		FINLAND		NORWAY		SWEDEN	
	1974	1990	1974	1990	1974	1990	1974	1990
10								
TOTAL	12,7	19,5	21,8	42,2	17,2	37,4	44,4	76,4
DOM	-	-	19	22	16,2	24,2	23,9	26,7
20								
TOTAL	18,6	27,2	33,2	68,3	24,2	47	57,4	97,9
DOM	-	-	30	40	23	32	32,7	36,8
30								
TOTAL	22,8	31,8	40,3	80,5	28,8	52,7	65,3	105
DOM	-	-	37	49,2	27,4	35,8	39,2	39,6

<sup>1</sup> Mining and manufacturing



## REFERENCES

Airaksinen, Timo (1991), Metalliteollisuuden kansainvälistyminen ja sopeutumistarpeet. In: Haavisto, Pirkko, Kuitunen, Tero, and Saralehto, Sampsa (eds.), *Kansainvälistyvä yritys ja muuttuva Eurooppa* (Internationalizing Firms and Changing Europe), Tehokkaan Tuotannon Tutkimussäätiö ja Elinkeinoelämän Tutkimuslaitos ETLA; Helsinki: Taloustieto Oy.

Elfvengren, Elisabeth (1958), *Kostnaderna för teknisk, naturvetenskaplig och ekonomisk forskning i Finland*. Helsinki: Taloudellinen Tutkimuskeskus, Sarja B:10 (in Swedish with Finnish and short English summary).

Eliasson, Gunnar (1991), Deregulation, Innovative Entry and Structural Diversity as a Source of Stable and Rapid Economic Growth, *Journal of Evolutionary Economics*, No. 1, pp. 49-63.

Heum, Per and Ylä-Anttila, Pekka (1992), *Firm Dynamics in a Nordic Perspective. A Comparative Study on Large Nordic Corporations*. ETLA (The Research Institute of the Finnish Economy) (forthcoming).

Hjerppe, Riitta (1979), *Suurimmat yritykset Suomen teollisuudessa 1844-1975*. Bidrag till kännedom av Finlands natur och folk. Helsinki: Finska vetenskaps-societeten, H. 123.

Kajaste, Ilkka (1991), Suomi Euroopan työnjaossa. *Kansantaloudellinen aikakauskirja* 4/1991, 87. vsk.

Kajaste, Ilkka, Parviainen, Seija, and Ylä-Anttila, Pekka (1992), Foreign direct investment of Finland in the 1990s. Helsinki: VATT (Government Institute for Economic Research), VATT-Discussion Papers, 28.

Lammi, Markku (1992), Paino- ja kirjoituspaperien tuotanto ja markkinat. Helsinki: ETLA (Elinkeinoelämän Tutkimuslaitos), Sarja C 62.

Nurmi, Markku (1970), Tekninen tutkimus Suomessa vuosina 1962 ja 1965-68. Helsinki: Taloudellinen Tutkimuskeskus, Sarja B 17 (in Finnish with short English summary).

OECD Economic Outlook 50, December 1991.

Porter, M. E. (1990), The competitive advantage of nations. New York NY: The Free Press.

Raumolin, Jussi (1992), The diffusion of technology in the forest and mining sector in Finland - The shift from the object to the subject of transfer of technology. To be published by ETLA in the book "Mastering Technology Diffusion - The Finnish Experience".

Ray, George F. (1992), The diffusion of selected technologies in Finnish industry. To be published by ETLA in the book "Mastering Technology Diffusion - The Finnish Experience".

Technology and the economy (1992), The key relationships, The Technology/ Economy Programme, Paris: OECD.

Technology in a changing world (1991), The Technology/Economy Programme, Paris: OECD.

Teknologian soveltaminen ja siirto 1990 (1992), Helsinki: Tilastokeskus (Central Statistical Office of Finland), Koulutus ja tutkimus 1992:2.

Valkonen, Pekka and Lovio, Raimo (1991): Suomalaiset patentoiijat Yhdysvalloissa 1980-luvulla: Menestyksen suhteellisuus. ETLA (The Research Institute of the Finnish Economy), Discussion Papers No. 383 (in Finnish).

Vuori, Synnöve (1986), Returns to R&D in Finnish and Swedish manufacturing industries. ETLA (The Research Institute of the Finnish Economy), Discussion Papers No. 203.

Vuori, Synnöve (1991), Returns to R&D in Nordic manufacturing industries, 1964 to 1983. ETLA (The Research Institute of the Finnish Economy), Discussion Papers No. 357.

Vuori, Synnöve (1992), R&D, technology diffusion and productivity performance in Finnish manufacturing industries. To be published by ETLA in the book "Mastering Technology Diffusion - The Finnish Experience".

Vuori, Synnöve and Vuorinen, Pentti (1992), Introductory chapter (manuscript), to be published by ETLA in the book "Explaining technical change in a small country - The Finnish innovation system".

Vuori, Synnöve and Ylä-Anttila, Pekka (1987), Structural change in Finnish manufacturing. Bank of Finland Monthly Bulletin, 1987:12, pp. 33-39, Helsinki.

Ylä-Anttila, Pekka (1985), Kannattavuuserojen sopeutuminen Suomen teollisuudessa. Helsinki: ETLA (Elinkeinoelämän Tutkimuslaitos), Sarja C 38.

Ylä-Anttila, Pekka (1990), Investoinnit, kasvu ja talouden tasapaino: pohjoismainen näkökulma. Kansantaloudellinen aikakauskirja 1990:2, 148-157.

Ylä-Anttila, Pekka and Lovio, Raimo (1990), Flexible production, industrial networks and company structure - Some Scandinavian evidence. ETLA (The Research Institute of the Finnish Economy), Discussion Papers No. 338.



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