From natural resources to high-tech production: the evolution of industrial competitiveness in Sweden and Finland

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1. INTRODUCTION

Sweden and Finland are among the world's richest and most highly developed economies today, but it is often forgotten that the Nordic region was still one of Europe's poorest and most backward corners around the middle of the 19th century. The remarkable transformation that commenced around 1850 in Sweden and some decades later in Finland has gradually changed both countries from underdeveloped agricultural economies to advanced industrial welfare states. This process is interesting not only from an historical perspective, but also from the point of view of today's developing economies.

One of the distinguishing features of the Nordic development history is that growth was fuelled by the expansion of industries based on domestic raw materials, such as timber and iron ore. From a position as suppliers of simple intermediate products to more advanced economies in Western Europe, Sweden and Finland were able to upgrade the technological level of their raw material based industries, and establish a foundation for a more diversified economic structure. Over time, both countries managed to successfully diversify into related activities, such as machinery, engineering products, transport equipment, and various types of services. Many of today's developing economies have abundant supplies of natural resources, but few countries seem to base their long term development strategies on resource intensive sectors. The reason is arguably the risk that they may never be able to move from production and exports of low value added commodities to more advanced industries. However, the Swedish and Finnish experiences suggest that development strategies based on raw materials may form a solid base for sustainable development, and demonstrate some of the requirements for diversification and growth of more advanced industries.[1]

Another notable observation regarding the Nordic economies is that industries based on domestic raw materials still account for a significant share of manufacturing activity, although the export, production, and employment shares of more knowledge intensive manufacturing and service sectors have increased rapidly during the past decades. The forest and metal industries together employ almost one-fifth of the industrial labor force in Sweden and supply about a quarter of total Swedish exports – in Finland, the corresponding shares are even higher. The continuing prominence of these sectors implies that raw material based production is not only a temporary stage in economic development, but can instead be a sustainable element of an advanced industrial structure. This kind of long-run success requires public policies and company strategies that preserve the raw material resources and create the skills and competence that are needed to remain competitive in the face of increasing labor costs and changing technologies.

A third point to note is the rapid change in industrial structure that has taken place in both Sweden and Finland during the past decade. Since the early 1990s, Sweden and Finland have taken leading roles in the development and application of information and communications technologies, and enjoyed remarkable success in knowledge based sectors.

[1]For a more comprehensive discussion about the relevance of the Scandinavian development model for today's developing countries, see Blomström and Meller, eds. (1991). This volume also points to the importance of political and demographic factors in long run growth.

For instance, the Swedish firm Ericsson and the Finnish Nokia are world leaders in the telecom industry, and have accounted for a major share of the very significant export increases recorded in the two countries during the past decade. Table 1.1 shows how the world market shares of Sweden, Finland, and some other advanced countries in four broad industry groups have changed from 1980 to 1996. The industry groups are distinguished by their level of technological sophistication, ranging from high tech industries like telecommunications and pharmaceuticals to low tech sectors like wood and paper products. The most striking feature of the table is the rapid growth of the Swedish and Finnish world market shares in the high tech sectors. It is also notable that the fastest changes have occurred during the 1990s. As late as 1990, computer and telecom products accounted for less than 7 percent of Swedish and Finnish exports. By 2000, this share had increased to nearly 20 percent in Sweden, and 30 percent in Finland. This development is very encouraging for small countries that are arguably in a relatively weak position in R&D intensive sectors were economies of scale are important, but raises many questions regarding the explanations for the Swedish and Finnish success in this field.

Table 1.1. Changes in world market shares in broad industrial groups, 1985, 1990, and 1996. Index 1980=100.

	Technology level											
	High			Medium high			Medium low			Low		
	1985	1990	1996	1980	1990	1996	1985	1990	1996	1985	1990	1996
Sweden	94	91	130	90	86	90	120	129	111	98	89	80
Finland	100	167	321	94	82	93	87	103	121	86	79	69
UK	80	87	91	135	115	113	115	79	86	85	88	91
Germany	86	88	76	111	140	138	127	113	139	104	115	97
Japan	143	122	107	93	107	91	95	112	95	107	66	53
USA	98	90	86	89	103	92	99	128	106	90	92	102

Classification of industries
High technology: pharmaceuticals, computers, telecommunications equipment, aeroplanes.
Medium high technology: chemicals, machinery, electronics, transport equipment, instruments.
Medium low technology: petroleum, plastics, stoneware, steel, metal products, shipbuilding.
Low technology: food products, clothing and textiles, wood products, paper and pulp, printing.
Source: M. Hultin (2000), "Internationell handel, en möjlig tillväxtmotor!" in Svenskt näringsliv och näringspolitik 2000, Nutek, Stockholm. based on the OECD–STAN Database 1998.

The present report aims to describe and analyze the evolution of industrial competitiveness in Sweden and Finland in a long-term perspective, with some focus on lessons for growth and development strategies in today's developing countries. It consists of four substantial chapters in addition to this introduction. Chapter 2 looks at the foundations for industrial take-off in Sweden. The focus is on Sweden, for good reasons. Swedish economic development has progressed in a remarkably steady fashion during the past 100 or 150 years – the average annual GDP growth rate has been around 2 percent, with few booms and depression. The main explanations are that Sweden managed to stay out of the two world wars, and that political development has been very stable, with few (if any) dramatic changes in economic policies. Finnish development, by contrast, has been rocked not only by the Second World War, but also by a civil war, a long period as a Grand Duchy under Russian rule, and many

decades under the shadow of the Soviet Union. This notwithstanding, most of the factors underlying Swedish industrialization are found in Finland as well.

Chapter 3 turns to a more detailed description of the development of the Swedish forest industry in a historical perspective. The focus in the first part of the chapter is on identifying the factors facilitating the initial take-off and the subsequent diversification from simple timber exports to more advanced products like pulp and paper. Some of the main findings are related to the successful transfer of foreign technology to Sweden, and the development of universities and other institutes for education and training of labor. The same conclusions apply also for Finland. The chapter also outlines the structure of the Swedish forest industry cluster in the early 1990s, with some emphasis on one aspect that has seldom received sufficient attention in the international debate: the institutions supplying knowledge and skills to the industry. We argue that the institutional network is one of the major determinants of the continuing success of the Swedish forest industry, and that many of the problems in e.g. the sawn wood products industry are related to weaknesses in the industry's knowledge institutions. The description of industry structure is centered on the early 1990s, when the importance of the forest industries in the national economies arguably reached a peak. The financial crisis that hit Sweden in 1992 and the EU accession in 1995 had a profound impact on the forest industries, and the rapid structural adjustment that started around this time complicates the description of developments in these industries during the second half of the 1990s. The structure of both the pulp and paper industry and the wood products industry has changed dramatically as a result of international merges and acquisitions, and the short run business environment has also been profoundly affected by events such as the Asian crisis and the large fluctuations in exchange rates towards the end of the 20th century.

Chapter 4 discusses the strategies of the forest industries during the 1990s. It is clear that the relative importance of the raw material based sectors diminished during this decade, while the "knowledge based" industries have expanded. However, one of the conclusions of this chapter is that even seemingly simple activities like pulp and paper production need to be knowledge based in order to remain competitive in a changing international environment.

In Chapter 5, we shift our attention to the factors underlying the success of the telecommunications industry in Sweden and Finland, which has taken over as the strategically most important sector, at least in a short and medium run perspective. Although the chapter will discuss both countries, the focus is on Finland, since Nokia's breakthrough has been more surprising than Ericsson's (which emerged as a world leader in the telephone industry already at the end of the 19th century). The tentative conclusion from this chapter is that the industry's success is a mix of systematic knowledge creation and random technological innovation. Although it is impossible to plan major technological breakthroughs, such as the digital telephone exchanges underlying the GSM cellular phone systems, we argue that it is possible to create an environment where firms or entire industries are well positioned to adjust to changing conditions and to benefit from innovations and market opportunities.

Chapter 6 provides a conclusion and restates the main findings of the report.

2. CREATING A BASE FOR INDUSTRIALIZATION: THE SWEDISH EXAMPLE.

During the 100 years from 1870 to 1970, Sweden developed from one of the poorest countries in Europe to one of the richest and most advanced economies of the world. This development was fuelled by the growth of several raw material based industries: sawn wood, pulp and paper, iron ore, steel, and grains were the most important ones. In this part of the report, we summarize some of the factors contributing to the Swedish industrial breakthrough. The purpose is to highlight two central observations. Firstly, much of Swedish growth and development has been determined by factors that have little to do with domestic policies, such as foreign demand for Swedish products. Secondly, when domestic policies or decisions have been important, they have typically influenced institutions, education and learning. These observations are relevant also for the present debate on development strategies, since they suggest what type of policy interventions are possible and desirable.

Section 2.1 points to some important prerequisites for the Swedish industrialization process, while Section 2.2 goes on to describe the industrial breakthrough, with some emphasis on the role of technology transfer and the creation of domestic competence.

2.1 The Prerequisites for Industrialization

Most studies of Swedish economic history suggest that industrialization commenced around the middle of the 19th century, and that the real take-off occurred some decades later, during the 1870s and 1880s. However, the Swedish economy had begun to change already from the beginning of the 19th century, and the transformation laid a necessary foundation for the subsequent industrialization process. This foundation was, to some extent, created through conscious policies in agriculture and education, but exogenous technical changes also played an important role.

Agriculture

The most significant changes took place in the agricultural sector. Up to the end of the 18th century, Swedish agriculture had relied on archaic production techniques, and harvests were barely sufficient to feed the population. Famines were not uncommon: the last wide-spread famines occurred in the early 19th century. Three main changes contributed to a transformation of agriculture that began around 1800, and continued through the 19th century.

Firstly, the structure of land ownership was reformed. Traditionally, the land holdings of rural families had been divided into several separate strips of land, dispersed around the village. The purpose was to make sure that farmland of different quality was distributed fairly among all families belonging to the village. However, the fragmented ownership pattern also contributed to inefficiency and slow diffusion of innovations, since all production decisions - including adoption of new technologies - had to be coordinated among the village members. To overcome these obstacles, land reforms were undertaken in most parts of the country during the first decades of the 19th century. The traditional ownership pattern was broken up, and land was redistributed so that each farm got one larger plot instead of the many separate pieces (see further Carlsson, 1980). In some parts of the country (especially in the more fertile

southern regions), this also meant that the villages were broken up: the peasant families moved their houses from the village to the center of their own plot of farmland.

Secondly, new production techniques were adopted, and agricultural productivity increased. This was partly a result of the land reforms – diffusion of new techniques became faster when it was not necessary to convince the village majority about adoption of new practices – but it was also related to technical progress in the machinery industry. The most important innovations during the early part of the century were better ploughs, and after the 1850s machinery for sowing, harvesting, and threshing also became widely used. Furthermore, increasing use of fertilizers made more intensive cultivation possible.

Thirdly, potato became the new staple crop. It had been introduced to Sweden several centuries earlier, but its breakthrough did not come until the end of the 18th century. Potato was well suited to Swedish conditions, and it yielded larger harvests than the traditional staple foods, beets and turnips.

One result of the changes in the agricultural sector was a marked improvement in food supplies. Together with improvements in medicine (and a long period of peace beginning in 1809), this led to rapid population growth. During the first 60 years of the 19th century, the Swedish population increased from 2.3 million to about 4 million. The area of farmland grew from 1.5 million hectares in 1800 to 2.6 million hectares in 1850 and 3.6 million hectares in 1900 (Larsson, 1991, p. 28). Agricultural productivity grew continuously, and output sufficed to feed both the farmers and a growing urban population. In fact, Sweden became a significant exporter of cereals in the 1850s. This is remarkable, since the country had been a steady net importer of grains until the 1830s.

It is hardly possible to over-emphasize the importance of the improvements in agricultural productivity for Swedish industrialization. The higher productivity facilitated the transfer of labor to urban occupations, and made possible exports that generated capital for investments in forestry and manufacturing. The increasing rural incomes also translated into demand for the goods produced in the emerging manufacturing industries.

Education and Human Capital

Another important development that had commenced before the advent of industrialization was an improvement in the level of education and human capital. Like the institutional changes in agriculture, this was also a result of conscious policies. Both formal and informal types of education and training were supported by the state and some private institutions.

At the summit of the formal education system were the old universities in Uppsala and Lund, established already in the 15th and 17th centuries. These expanded throughout the 19th century, with heavier emphasis on the natural sciences than earlier (when law and theology had been the dominant subjects). Institutions for advanced technical education were founded during first half of the 19th century: both the Technological Institute in Stockholm and the Chalmers Technical School in Gothenburg, which later became the country's first technical universities, were established in 1820s. The universities and the technical schools played a central role for the creation of new technology. Many of the successful Swedish innovations that emerged towards the end of the 19th century were made by people educated in these institutions, as we will discuss in closer detail later.

The introduction of a mandatory school system in 1842 was also crucial for the creation of a skilled human capital base and for the dissemination of technologies. The official ambition

was to guarantee basic skills in reading, writing, and arithmethics to all citizens, and literacy rates reached nearly 100 percent within one generation. This was essential for the ability of individuals and firms to learn and adopt new technologies: much elementary learning and technology transfer was based on written instructions, like blue-prints and handbooks.

Parallel to the development of formal education, there also appeared other institutions that were involved in development of technology and industry. The Royal Swedish Academy of Science dated back to 1739, and the Swedish Ironmasters' Association was established in 1747. The Ironmasters' Association, which was partly state-financed, was particularly important for the transfer of foreign technology to Sweden. The Association started the publication of the mining science journal *Annalerna* in 1817, and financed a very large number of foreign study trips made by Swedish engineers and scientists, requiring detailed written reports that were made available to the rest of Swedish industry. New engineering workshops, like Motala Verkstad, established for the construction of lock-gates and iron bridges for the Göta canal network in the early 19th century, were also indispensable as training centers. In addition, it is necessary to note the importance of labor migration. Swedish engineers were often trained and educated in Great Britain and Germany, and important contributions were made by several British engineers that immigrated to Sweden (Schön, 1982). Ahlström (1992) argues that Sweden possessed the fundamentals of a modern engineering industry already by about 1850, as a result of this development of technical skills and competence.

Protoindustrialization

The industrialization process was also facilitated by the development of primitive manufacturing activities - a kind of protoindustrialization - which had begun several centuries earlier. Unlike the changes in agriculture and education, these activities were not part of any explicit policy to strengthen productivity or technical progress, but they provided valuable skills and expertise for the industrial era.

One type of industrial operation that existed before the 19th century had grown from the Swedish army's procurement of supplies and equipment. Cloth, uniforms, weapons, utensils, tobacco, and alcohol were produced by so called "manufaktur" companies, and these were relatively large, although their production methods were primarily based on handicrafts. Yet, they provided some elements of industrial culture, and the towns where the "manufaktur" firms were located had an advantage over other locations after the advent of the industrial revolution.

Due to the highly seasonal nature of Nordic agriculture, the rural households had traditionally produced significant amounts of handicrafts during the winter months: leather goods, textiles, shoes, and simple tools were made by most families. After 1800, this production increased and became more specialized, both because of population growth and increases in agricultural productivity, and because demand was growing due to higher incomes. In some parts of the country, merchants purchased a large share of the output, and they sometimes commissioned the production of entire villages. The main significance of this type of activity may have been the development of commercial skills. As modern technologies for production of textiles became available after the middle of the 19th century, the Swedish textile factories were often established by merchants who had been involved in the trade with handicrafts.

A related development was apparent in mining and forestry. Swedish producers had strong positions in the European markets for copper, iron, and tar already from the 17th century, and it has been argued that one of the most important skills learned during the early years was international marketing (Hallvarsson, 1980, p. 13). Merchants and traders were involved in the establishment of many of the ironworks and sawmills that emerged because of good export opportunities during the 19th century. Hence, some important elements of industrial culture were in place already before industry was.

2.2 The Industrial Breakthrough

The industrial breakthrough was largely based on the progress in agriculture, education and skills, and handicrafts discussed above, but it was triggered by several other events that occurred more or less simultaneously around 1850. These were related to increasing foreign demand for Swedish products, and to technical innovations, the continuing development of skills and competence in Sweden's emerging industrial sector, and some important institutional changes.

Exports.

The most important reason for the inception of Swedish industrialization in the 1850s was a boom in foreign demand for Swedish products. Export demand continued to be a major determinant of industrial development throughout the century, although the domestic market took the lead towards the 1890s. The early stages of the Swedish industry's growth was fuelled by exports of simple products like sawn wood (and cereals), whereas more advanced commodities like pulp and paper and iron ore became the main exports later on.

Exports of cereals were of tremendous importance for the industrialization process, although their origin was in the agricultural sector rather than in manufacturing, and although the era of cereal exports lasted only from the 1850s to the 1880s. One reason was that the expansion of agriculture during these three decades provided employment for the increasing population at a time when industry was not sufficiently developed to absorb enough employment. Another reason was that exports brought in large amounts of capital, which were used to finance important parts of the early industrial expansion.

Sweden had been a net importer of cereals until the 1830s, as noted earlier, and exports were still limited during the late 1840s, reaching some 40,000 barrels annually. At the peak, 30 years later, exports had grown to 4 million barrels per year (Carlsson, 1980, p. 212). The reasons for the cereal boom were largely to be found outside of Sweden. Demand was high, especially from England, where the industrialization process had taken off, and domestic cereal production was not sufficient to feed the growing urban population. Bad harvest in England and elsewhere on the European continent during the early 1850s increased demand further. At the same time, Swedish harvests were unusually plentiful. Moreover, the leading European cereal exporter, Russia, was hit by the Crimean War in 1853-56, and Russian exports ceased almost completely.

The successful Swedish response to these new export opportunities was a combination of the flexibility of the agricultural sector (that had been created by the institutional changes in the structure of land ownership) and the appearance of various technical innovations that increased productivity, e.g. machinery for sowing, harvesting, and threshing. Sweden managed to hold on to large shares of the English cereal imports until the 1880s, but the trade

disappeared as suddenly as it had emerged after that. The reasons were that Russian exports resumed at large scale, and the United States emerged as the new leader when the Great Plains had been taken into production.

From the middle of the 19th century, there was also an increase in the demand for forest products - mainly pit props and sawn wood - that was fed by the English urbanization. Swedish exports of sawn wood products had been insignificant before the 1840s, for several reasons. Norway was a stronger exporter, both because of shorter transport costs and because the technical level of Norwegian sawmills was higher. In addition, the English *Navigation Acts* gave preferential treatment to Canadian producers (Carlsson, 1980, p. 218). However, the situation changed very rapidly in the early 1850s. The English import protection was abolished, and the Norwegian forest resources were over-exploited, which gave ample opportunities for Swedish wood exporters to step in. Other factors that facilitated the export success were of an institutional or technical nature. Most importantly, the Swedish state had restructured its forest holdings some years earlier. Large amounts of forest land had been distributed to private owners, especially in Southern Sweden, and the structure of forest ownership had been registered. This meant that property rights were well defined, and the private owners were in a position to respond rapidly to the increasing export demand. There were also some technical improvements, as steam-powered saws were introduced, and the sawmills became more efficiently organized, after Norwegian models. In fact, several Norwegian firms moved to Sweden, because of the dwindling forest supplies in Norway.

As a consequence, exports of sawn wood increased from less than 200,000 m^3 in the 1830s to 4,800,000 m^3 at the end of the century. In the 1870s, wood products had grown to make up 43 percent of Swedish exports (Hallvarsson, 1980, p. 14).

Later on during the 19th century, there were new export booms, for pulp and paper and iron ore. Exports of pulp and paper began growing towards the end of the 19th century, and Sweden had become the world's largest pulp exporter by 1913. However, this expansion differed from the sawn wood boom in several ways. Sawmilling had been an easy start, since the capital requirements were low and the technology was simple. Pulp and paper production was significantly more capital intensive and technology intensive, and posed much stricter requirements on domestic institutions and technological competence than sawmilling had done. Domestic policies were also much more important for the success of the industry. Thanks to the development of a relatively efficient banking system, profits from sawmills could be channeled to finance the expansion of pulp and paper mills. The development of domestic technological capability had also proceeded far enough to allow production and exports of more advanced goods. In fact, Swedish inventors had taken the lead in the development of pulp technologies, and the world's first chemical pulp factory was established in Bergvik, on the coast of Norrland, in 1872.

The mining industry that started expanding during the last decades of the century was also heavily dependent on modern technology. Table 2.1 illustrates the changes in the structure of Swedish exports between 1881-85 and 1911-13. The relative importance of sawn wood and cereals fell, whereas more advanced products, like pulp and paper, engineering products, and iron ore became more important.

Table 2.1. The structure of Swedish exports 1881-85 and 1911-1913.

	1881-85 (percent)	1911-13 (percent)
Sawn wood	40	26
Iron and steel	16	9
Cereals	12	1
Butter	6	6
Pulp and paper	5	18
Engineering products	3	11
Iron ore	-	8
Other	18	21
Total	100	100

Source: Larsson and Olsson (1992), Table 3.

Domestic Demand.

The driving force behind the early stages of industrial development, during the 1850s and 1860s, was undoubtedly export demand. However, the domestic market became gradually more important, partly as a result of explicit policy intervention. One example was the development of the domestic infrastructure. The heavy investments in railroads (especially during the 1870s) and the introduction of electric energy (from the 1880s) made it possible to specialize production and transport raw materials and finished goods across the country. The earliest industrial developments, in e.g. sawmills, had relied on waterways, but now a more general industrialization, based on the domestic markets, was possible. The demand for metal and wood generated by the construction of infrastructure facilities, mainly railroads, also stimulated domestic demand.

Another reason for the heavier emphasis on the home market was more directly related to policy. The export booms during the early stages of the industrialization process took place at a time when economic liberalism and free trade ideologies reached a first peak. This meant not only that Sweden could freely sell primary products to the rest of Europe, but also that Sweden imported much of advanced consumer and investment goods from the industrially more developed countries in Europe. These policies changed from the late 1880s, when a wave of protectionism swept over Europe. Both agricultural and industrial imports were restricted, and the average tariff level in Sweden before the First World War reached about 15 percent of value added. A further sign of the changing policy climate was the introduction of policies to limit foreign ownership of Swedish resources. Earlier, foreign participation and investment had been welcomed. This meant that domestic markets became more important, since similar developments occurred in the rest of Europe as well.

One can only speculate about the significance of the timing of policy regimes. It appears that Sweden was fortunate, in that the inward-looking policies were not introduced until there was a firm base for domestic development. Agriculture had expanded and the increased productivity created incomes and demand for various types of consumer goods. Technological skills had been developed, which facilitated the creation of a variety of import substituting industries. The export success had brought in foreign capital, and a foundation for a more comprehensive industrialization was in place. These elements have not been in place in most of the developing countries where inward-looking policies have failed during the 20th century.

Technical Innovations

In addition to the exogenous changes in foreign demand for Swedish products, there were exogenous changes in technology that had a heavy influence on the direction of Swedish industrialization.

In the metal industries, Sweden had held a strong position in the international market for several centuries. The main export product until the middle of the 19th century was bar iron. The production of iron was strictly controlled by the state, in order to avoid deforestation and degradation of forest resources: the industry used massive amount of timber, in the form of charcoal. It has been estimated that mining industry's use of wood was 4-5 times larger than wood exports as late as 1854. Hence, exports of iron ore and pig iron (which were low value added products) were restricted.

The strict rules were liberalized in 1850s, when technological innovations - the Bessemer and Martin processes - made it possible to use coal and coke instead. However, the Swedish production and exports of iron and iron ore stagnated during the decades after 1850, because the comparative advantage of the Swedish iron industry had been the abundant supply of charcoal. Instead, coke and coal based steel production in continental Europe increased rapidly. It was not until the so-called Thomas process was introduced that the industry started recovering. It was known since centuries that there were rich iron ore deposits in northern Sweden (Lappland). These had not been exploited earlier because of their high content of phosphor, which made the steel weaker. Now it became economically viable to develop the industry, and new ironworks were established. Production of steel for domestic use increased rapidly, but exports of steel remained low. Instead, iron ore was exported directly to the main iron and steel plants in Germany and Great Britain.

The development of mechanical and engineering industries, which started during the latter part of the 19th century, was also driven by technological innovations, but these were more directly connected to domestic capabilities and skills. Especially the 1880s proved to be a golden decade for Swedish industry, when several path-breaking innovations were presented, and when industrialization really took off: the number of industrial workers increased by 66 percent between 1880 and 1889 (Hallvarsson 1980:9).[2]

Examples of long-lived Swedish firms that were established during the late 19th century or the first years after the turn of the century are Ericsson, Alfa Laval, ASEA, AGA, Nobel, and SKF. The exceptional performance of these firms has been based on the ability of Swedish industry to create, adapt, and disseminate new technologies. The development of institutions for science, technology and education has made up the foundation for this kind of success.

Science, Technology, and Education

The first technical universities of Sweden date back to the early parts of the century. The Technological Institute in Stockholm was founded in 1826, and it became the Royal Institute of Technology in 1877. In Gothenburg, the Chalmers Technical School was established in

[2]Yet, agriculture was still the dominant activity. It was not until about 1900 that the GDP share of manufacturing equalled and eventually surpassed that of agriculture, and agricultural employment remained larger than manufacturing employment until the 1930s (Jörberg, 1984, pp. 9-10).

1829, and it provided scientific and technical education at a university level already from its inception, although it was not formally named a Technical University until 1937 (Ahlström 1992:4). Concurrent with the development of specialized institutions for technical education, there was also an expansion of the natural sciences at the universities in Uppsala and Lund, and it has been argued that the great increase in the number of professorial chairs between 1870 and 1914 was of "immense importance" for the industrial breakthrough (Ahlström, 1993:38).

Technical colleges were established in several Swedish cities - Malmö, Borås, Örebro, and Norrköping - during the 1850s. From the middle of the century and onwards, numerous vocational training schools were also set up in various parts of the country, to number about 35 at the end of the 19th century and 66 in 1908-1909 (Ahlström, 1992, p. 7). The guild system was abolished in 1846, and these schools quickly began to replace apprenticeships as the main form of vocational education. Most of the vocational schools depended on private initiatives, although some were financed by the state. Among the latter were nautical training schools (from 1842), forestry secondary schools (from 1860), and agricultural colleges (from 1887) (Nilsson and Svärd 1991:5).

Among the other institutions that were involved in the creation and dissemination of skills and knowledge, we have already mentioned the Royal Swedish Academy of Science and the Swedish Ironmasters' Association. Several new organizations emerged during the 1860s, e.g. the Swedish Association of Engineers and Architects and the Stockholm Engineering Association. The Swedish Academy of Engineering Sciences, the Wood Pulp Association, and the Swedish Institute of Metal Research were added during the 1910s. These institutions were closely in touch with scientific research and technical education, and they played - and continue to play - a significant role for the diffusion and dissemination of technical skills.

It is difficult to find accurate measures of the importance of these different types of investment in skills and human capital. However, it is clear that the supply of skilled increased steadily from the 1850s. The number of engineers educated at the higher technical institutes amounted to about 700-800 in 1850, and some 2,000 in the late 1890s. The number of engineers with secondary education also reached about 2,000 at the end of the 19th century (Ahlström 1992: 9).

Moreover, the founders and leaders of several of the most successful Swedish companies were educated at the technical institutes and had received foreign training that was paid by the state or some of the institutions discussed above. For instance, Hans Tore Cedergren, who played a central role for the emergence of the Swedish telephone industry, and Gustav de Laval, founder of AB Separator in 1883 (known as Alfa-Laval from 1963) were educated at the Technological Institute of Stockholm. Gustav Dalén, manager and chief engineer of AGA, was a graduate of Chalmers, and Sven Winquist, founder of SKF, had been educated at the technical college of Örebro. Lars Magnus Ericsson, the founder of the telephone company still carrying his name, had received state grants for studying the electrical engineering industry in Germany and Switzerland company, as had most other leading industrialists in the country.

Ahlström (1992, 1993) argues that the successful innovators and entrepreneurs illustrate that there existed a network between the technical institutions, industry, and government already from the middle of the 19th century, and that this contributed significantly to the success of Swedish industrialization. The networks were of central importance for the

development of industry, especially after the 1880s, when products became more differentiated and goods such as pulp, paper, and engineering products became more important. Until the inter-war period, these networks substituted for specialized research and development departments in many firms.

The importance of education and labor skills for industrial success has not diminished since the early era of Swedish industrialization. On the contrary, the increasing supply of skilled labor has generally been considered as one of Sweden's main comparative advantages during the last decades. Apart from a well-developed educational system of the classical type, attention has also been called to the existence of large scale vocational education programs (Nilsson and Svärd 1991).

Swedish vocational education dates back to several schools started during the 19th century, as we have noted above. Yet, the real growth in the area did not start until the 1920s, when the state became more engaged in the provision of vocational education. The number of people involved in vocational training programs increased rapidly during the 1920s and 1930s, partly because of persistent unemployment: special courses were arranged for unemployed youths. However, the system was criticized because the courses focused more on upholding the moral of unemployed people than on useful vocational skills (Nilsson and Svärd, 1991, p. 6). From the 1940s and 1950s, however, the system changed. There was a shift from manual to more intellectual skills, which meant that most courses included general education as well as specific training, and full-time courses became more common. The quantitative explosion of vocational education can easily be illustrated with some figures. In 1950, some 15,000 people graduated from full-time vocational courses lasting at least one semester. By the late 1960s, the number had increased to over 100,000 (Nilsson and Svärd 1991:18).

Institutional Change.

Several of the institutional changes that contributed to the industrial revolution have already been mentioned, e.g. the establishment of property rights for forest land, trade policies, and the support to education and science. Another notable reform was the introduction of Limited Company laws in 1848. This made it possible to raise more capital and take risks, which was necessary as the rate of technical change increased during the second half of the century. Earlier, most firms had been owned or at least dominated by one single family, and the owners were personally responsible for the firm's debt (Larsson, 1991:32-33). Limited companies - where the owners' stake was limited to their share of the firm's initial capital - employed 45 percent of the industrial labor force in 1872, and 80 percent of the labor force in 1912 (Hallvarsson, 1980:19).

Moreover, credit markets and banks emerged during the second half of the 19th century. The development of the banking sector was supported both by the export booms and by the construction of the Swedish railroad network. The railroad system was largely financed with foreign capital, and several of the larger commercial banks were employed by the state to sell Swedish government bonds abroad. At the end of the 1870s, the Swedish financial system comprised 35 commercial banks with offices in 160 cities, which was comparable to the most highly developed nations in the world (Larsson and Olsson 1992). It is interesting to note that the foreign debt built up to finance the domestic infrastructure investments was comparable to the present debt burden of many developing countries. For instance, the interest payments to foreigners amounted to 10 percent of export value in 1908 (Hallvarsson 1980:26). The

eventual repayment of the debt also illustrates the importance of chance and luck for long-term development. Most of the debt stock was denominated in German marks and French francs, and the heavy depreciation of these currencies after the first World War reduced the value of the outstanding liabilities to very modest amounts.[3]

[3]The importance of chance is also reflected by the sizable Swedish migration to America during the second half of the 19th century. This made it possible to urbanize at a rate that was consistent with industrial development. It is estimated that a quarter of the Swedish population (1.2 million people) emigrated between 1850 and 1910. As a result, Sweden avoided the worst problems related to rural poverty and mass unemployment: it is also likely that this helped avoid political problems caused by polarization between left and right. See further Haavisto and Kokko (1991).

3 THE SWEDISH FOREST INDUSTRIES

Although Swedish sawmills had felt the increasing demand from England already during the first half of the 19th century, the breakthrough for the wood industry did not come until the middle of the century, as noted earlier. Up to that time, Swedish exports had been hampered by the competition from Norwegian sawmills, and by the British *Navigation Acts*, which favored Canadian producers. When British imports were liberalized around 1850, Sweden became the major supplier: Norwegian exporters were not able to expand production because of short supplies of raw materials, and Canadian producers were more expensive because of the longer transports.

The first steam-powered sawmills were established at this time. The early development of the industry benefited greatly from contacts with the international economy. Much of the industry's technological development was driven by the relations with Norwegian firms and technicians, and a significant share of the investment capital was raised in England. Several of the individual entrepreneurs were also of foreign origin, and established long-lived firms such as Ljusne and MoDo (Larsson, 1991, p. 37). However, the new technologies did not change the overall structure of the sawmill industry very much. Most mills were small and remained water-powered until the 1880s, because few of the owners were willing to undertake the necessary investments. Moreover, there were no changes in the geographical distribution of sawmills, although the introduction of steam-powered saws would have made it possible to locate saw mills elsewhere than at the major rivers. The reason was that the raw material, the timber, was still transported along the old waterways. The development of the Swedish railway network during the 1860s and 1870s had a stronger impact on the industry, since it facilitated the establishment of many new sawmills in the inner parts of the country.

Hence, the sawmill industry expanded rapidly in the eastern and northern parts of Sweden during the 1860s and 1870s, but growth slowed down during the 1890s. The main reason was a shortage of raw material. From the 1860s, sawmills had to begin competing with the paper and pulp industry for raw material. A first growth period for the pulp industry, up to 1890, was based on mechanical wood pulp that was produced mainly in southern and western Sweden. However, the chemical pulp (cellulose) industry, which emerged during the 1890s, was largely based in the northern parts of the country. The pulp companies were much larger than the sawmills, and many of them had purchased large amounts of forest land from farmers in Northern Sweden during the preceding decade. Many of the smaller sawmills therefore encountered problems in securing their raw material supplies. These problems led to the creation of a comprehensive legal structure for the forest sector. In 1903, laws were established to guarantee re-planting, and to ensure that fellings would not exceed the growth of the timber stock. In 1906, a law was passed to restrict the forest industry's further land purchases.

The development of the forest industry during the inter-war period was unstable. Most firms had invested heavily in new capacity during the brief boom after the first World War, but prices turned down already in 1920. Consequently, many firms were caught with both debt and overcapacity. This crisis resulted in some restructuring of the industry, because few of the old-fashioned family based companies managed to generate the resources to bring them over the depression. Hence, many of the smaller companies were forced out of business or taken

over by larger firms. Another important development during the late 1920s was an increasing emphasis on paper and pulp, motivated by weak productivity in simple sawmilling operations. This period saw the beginning of the "integrated forest firm", with operations in several of the forest industries - pulp and paper, timber, sawn wood, boards, and so forth.

The financial problems of many of the smaller companies also paved the way for considerable concentration of the pulp industry. Ivan Kreuger, who had established Swedish Match during the First World War, gained control over a large share of the forest industry in the northern parts of the country. His ambition for the new large firm, SCA, was to become the price leader for an international cellulose cartel. However, the attempt failed in a crash that culminated with the suicide of Kreuger, but the company SCA remained fairly intact and still holds a leading position in the Swedish forest industry.

The Second World War hurt the Swedish forest industry, since the export markets disappeared. A short upturn in prices and exports during the early 1950s was followed a stagnant development until the mid-1960s. The weak market development mandated several changes for the industry. Paper increased its share of production and exports. Many of the remaining local sawmills were also forced out of business, and there was some concentration in the industry. However, the main elements of the industry structure established during the inter-war period - with a relatively small number of large integrated firms in sawmilling and pulp and paper - remained largely intact. By the mid-1960s, the largest producers of sawn wood were SCA and the state owned company ASSI. The largest pulp and paper producers were SCA, MoDo, and Stora Kopparberg. As we will see later on, these are still the dominant actors.

The improvement in the business climate for the forest industries during the mid-1960s led to large productivity gains through mechanization and rationalization of operations. However, the boom ended with the first oil crisis, and the development of prices was largely negative during the mid-1970s. The companies with small own holdings of forest were hardest hit by the recession: forest owners were simply not willing to sell raw material, although timber prices did not fall at the same rate as prices for finished products. The situation did not improve until the early 1980s, with the upturn in the international business cycle. The 1980s also witnessed a new phenomenon, namely a comprehensive internationalization of the Swedish pulp and paper industry. The industry's strategies during the past couple of decades have aimed to increase the degree of processing and value added of the final products. This has required close contact with customers in the European market, and a large number of foreign firms manufacturing paper and paper products have been acquired. By the early 1990s, Swedish forest companies had established nearly 200 subsidiaries in the rest of Europe. The sawmill industry remains more domestic, although increased value added and more advanced products are also major strategic objectives.

By 1990, the forest industry - producing sawn wood, prefabricated houses and building joinery, wooden furniture, pulp and paper, paper products and various other goods - accounted for some 15 percent of value added and employment in the Swedish manufacturing sector, and 20 percent of the sector's exports. In addition to the 107,000 people directly employed in the forest industry, suppliers of investment goods and inputs, transport companies, and service industries employed another 75,000 people, and about 40,000 were engaged in the forestry sector.

The remainder of this chapter provides an overview of the structure of the Swedish forest industry around 1990. The first section describes the Swedish forestry sector, with some comments on ownership structure and the legal framework, and the second section goes on to examine the two main product groups in the industry: sawn wood products, and pulp and paper. Section 3.3 presents the institutional framework for the generation and dissemination of the knowledge and skills that are used in the industry: as noted earlier, this cluster is perhaps the most central determinant of the Swedish forest industry's competitive advantages. A brief discussion about related industries - machinery and transports - is provided in section 3.4.

3.1. The Swedish Forestry Sector

More than 60 percent of Sweden is covered with forests. Pine and spruce are the dominant tree species, with about 85 percent of the total, while birch accounts for 10-15 percent. The northern part of the country, Norrland, has the largest timber supplies, but growth rates are higher in the more intensively managed forests in souther Sweden. The aggregate timber supply has been estimated at 2.8 billion m^3. The annual growth lies at about 100 million m^3, whereas felling have fluctuated between 50 and 70 m^3 per year over the past decades. Hence, timber supply is increasing continuously, and it is today more than twice as large as a decade ago: in debates with environmental organizations, forest companies seldom fail to point out that the growing stock is probably larger now than ever before.

About 10 percent of Swedish forests are owned by public authorities, which is a low share compared to many other European countries. The share of forest industries is 40 percent, which is higher than elsewhere in Europe - apart from Swedish firms, only the Finnish, Norwegian, and Spanish industries have any significant forest holdings. The industry's forest holdings are concentrated to the largest pulp and paper companies - most sawmills and other wood working industries do not posses any notable forest holdings. The remaining 50 percent of the total forest area are held by private owners. The average size of public and industry holdings is very large, above 100,000 hectares, whereas the average private forest holding is about 50 hectares. There are also some 60,000 private forest farms (corresponding to a quarter of the total number of holdings) with less than 10 hectares of forest.

The large number of small forest owners is sometimes considered to be a problem. One commonly heard argument is that transaction and coordination costs are likely to be high, and the standard of forest management may be low, when the ownership structure is very fragmented. In particular, it is maintained that it is difficult to mechanize operations and introduce rational harvesting methods in small forest farms (UN, 1986). However, the ownership and size structure of Swedish forest holdings does not seem to have posed any major problems for the management of forest resources, as witnessed by the increasing total supplies. The majority of private forests are relatively well managed, partly because the forestry sector is strictly regulated by law, and partly thanks to fiscal incentives and training and extension services provided by the public sector.

The laws in the forestry area were initially (i.e. from their institution in 1903) focused on securing sustainable raw material supplies, and the central rules stipulated that fellings should not exceed the growth of the timber supply, and that replanting should be undertaken after all felling operations. Over time, the forestry laws have come to cover an increasing number of objectives. Nowadays, environmental considerations are among the most important issues,

although the laws also aim to guarantee a steady flow of raw material to the forest industry. For instance, all forest owners are required to prepare a forestry plan, outlining expected thinning, felling, replanting and other operations. Thinning is mandated to optimize growth rates, and it is prohibited to use high quality timber for fuel (Hultkrantz and Wibe, 1990). It should be noted that the forestry regulations are of an extremely long-term nature, since the regeneration time for most softwood species are between 80 and 120 years.

Although the ownership structure has not constituted any major problem for forestry management, there are some frictions in marketing. Many of the smaller private forest owners (who have accounted for some 60 percent of the industry's timber supplies during the past decades) are not dependent on revenue from the forest, but have also other sources of income. Consequently, they may be unwilling to harvest when market conditions are bad, and instead await better prices. During times of high inflation, it may also be rational for the private owner to keep capital in a growing forest rather than in other forms of wealth, with lower real yield. Hence, delivery volumes may fluctuate widely, depending on market conditions.

To avoid this type of volatility, the pulp and paper industry, in particular, has tried to segment the market. A large share of the industry's raw material supplies is regulated through long-term contracts with individual forest owners and regional associations of forest owners. Simultaneously, there is a spot market to accommodate fluctuations in demand. This system has managed to stabilize the raw material flows, although the price sensitivity of small, private forest owners was illustrated by their unwillingness to harvest in the late 1970s, when roundwood prices were unfavorable. However, the resulting raw material shortages affected mainly the independent sawmills whose own forest holdings are limited, and forced market reorganizations and price increases (UN, 1986, p. 28). To balance the market power of the large pulp and paper firms and the forest owners' associations, sawmills and other wood manufacturers have been forced to establish cooperative purchasing organizations.

3.2. The Swedish Forest Industries.

Table 3.1 summarizes some information about the size of the two main industry groups in the Swedish forest sector in 1990: sawn wood products and pulp and paper. The sawn wood products group includes sawmills and plants producing various types of wood boards and plywood, building joinery, pre-fabricated wooden houses, and wooden furniture. The pulp and paper category includes pulp and paper mills, and manufacturing of paper products such as paper board and other packaging materials, stationery, tissues, and wall paper. It can be seen that the pulp and paper group was largest in terms of sales and value added, although more people were employed in the sawn wood products industry. The higher productivity in paper and pulp is explained by the industry's high capital intensity: the investments in new pulp and paper mills are denominated in billions of Swedish kronor (SEK).

Table 3.1. The Swedish forest industry 1990: sales, value added, and employment.

	Sales		Value added		Employment	
	Billion SEK	% of total mfg.	Billion SEK	% of total mfg.	'000s	% of total mfg.
Sawn wood products	52.8	7.6	21.3	6.9	55.1	7.6
Pulp and paper	69.5	10.0	26.7	8.6	51.7	7.1
Total	122.3	17.6	48.1	15.5	106.7	14.7

Source: SCB Industry, Svensén (1992).

The value of the Swedish forest product exports in 1990 was SEK 66 billion, while imports amounted to SEK 12 billion. Thanks to the large net exports, the forest sector made a larger contribution to the Swedish balance of payments than any other industry. Table 3.2 shows that the quantitatively most important export products were paper, pulp, and sawn wood products, and it can also be noted that the only two categories where Sweden was a net importer were roundwood and wood chips, and veneer and wood boards. Imports of roundwood and chips have increased over time, due to low raw material prices in e.g. Russia and the Baltic states after the fall of the Berlin Wall. The imports of veneers consist largely of hardwoods that are not available from domestic sources.

Table 3.2. Exports and imports of forest products 1990. (Billion SEK)

	Exports	Imports
Paper and paperboard	32.8	2.6
Pulp	11.4	0.7
Sawn wood products	11.0	0.6
Paper products	4.5	2.0
Recycled paper	0.2	0.2
Roundwood and chips	0.5	1.7
Veneer, wood boards	0.6	1.5
Wood furniture	2.1	1.5
Prefabricated houses	0.7	0.6
Other	2.0	0.8
Total	65.8	12.2

Source: SCB Foreign Trade, Svensén (1992).

In aggregate terms, Sweden was the world's third largest exporter of both pulp and paper in 1990 (with 12 percent of world trade) and sawn softwood products (with 9 percent of world trade) as shown in Table 3.3. The major competitors were USA, Canada, and Finland, although Russia, Brazil, Chile, and other developing countries have emerged as significant exporters in some product groups.

Table 3.3. World production and exports of pulp, paper and paperboard, and sawn softwood products in 1990.

	Pulp (million tons and percent)			
	Production		***Exports***	
	Quantity	Share	Quantity	Share
Canada	22.8	14	6.5	27
USA	57.2	36	5.0	21
Sweden	9.9	6	2.8	12
Finland	8.9	5	1.5	6
Soviet Union	8.4	5	0.6	3
Brazil	4.5	3	1.0	4
World	160.6	100	23.5	100
	Paper and Paper Board (million tons and percent)			
	Production		***Export***	
	Quantity	Share	Quantity	Share
Canada	16.5	7	11.8	22
Finland	9.0	4	7.7	14
Sweden	8.4	4	6.7	12
USA	71.5	30	5.2	10
German	11.9	5	4.1	8
Japan	28.1	12	0.9	2
World	238.8	100	54.0	100
	Sawn Softwood Products (million m^3 and percent)			
	Production		***Export***	
	Quantity	Share	Quantity	Share
Canada	58.0	16	40.5	50
USA	85.0	23	8.2	10
Soviet Union	87.7	24	7.7	9
Sweden	11.3	3	7.0	9
Finland	7.7	2	4.5	6
World	373.4	100	81.5	100

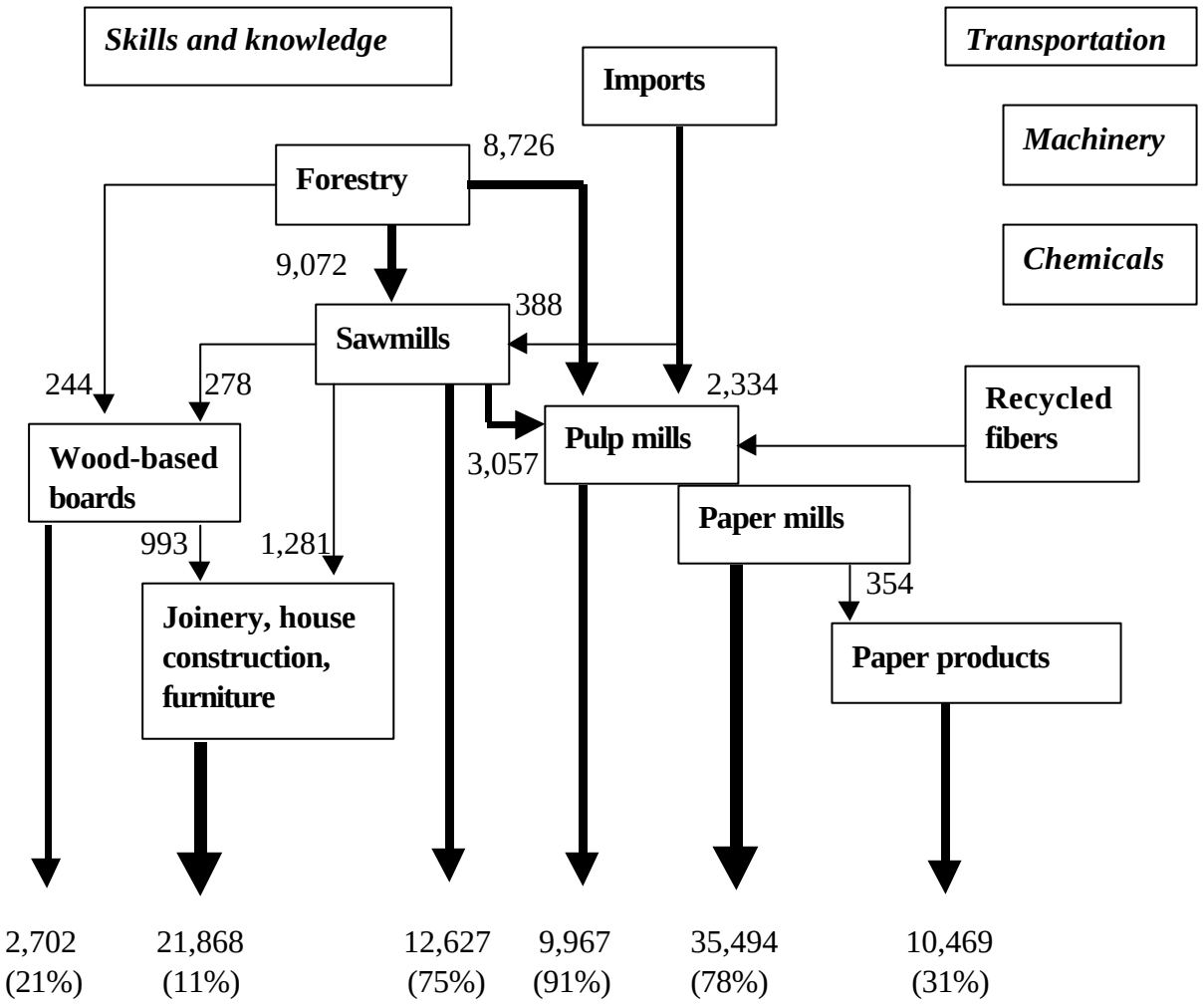
Sources: Pulp and Paper International, FAO Yearbook of Forest Products, Svensén (1992).

Below, we will look separately at the structures of the paper and pulp and sawn wood products groups in the early 1990s, although it is occasionally difficult to account for the distribution of resources between the different kinds of activities. Most of the leading Swedish forest companies had integrated their operations, and owned and managed both sawmills, paper mills, and various value added activities: the largest Swedish firms - Stora, ASSI-Domän, SCA, and MoDo - were all involved in production of pulp, paper, and sawn wood

products. In addition, the firms owned significant amounts of forest, which adds forestry as an important activity.

Figure 3.1 shows the core of the Swedish forest industry cluster, and illustrates some of the connections between the different types of activities. The figure depicts the flow of goods from each of the major product groups to customers at home and abroad, and also the flow of raw materials and intermediates within the cluster. The data on sales and resource flows (in million SEK) are for 1987, since information for more recent years is not conveniently available. Numbers in parentheses denote export shares.

Figure 3.1 The Swedish Forest Industry Cluster



Data are for 1987, in million SEK. Figures in parentheses denote export shares.
Source: DS 1991: 62.

Some of the linkages between the different parts of the industry are obvious. For instance, the forestry sector's sales of timber are divided roughly equally between sawmills and pulp mills, but the two do not demand the same types of raw material. The best roundwood is usually bought by the sawmills, whereas smaller trees, branches and waste from thinning and cutting

operations are sold to pulp mills. In addition to the deliveries from the forestry sector, Swedish pulp mills also buy significant amounts of wood chips and waste from the sawmills. These synergy effects explain why most of the leading Swedish forest companies operate both sawmills and pulp and paper mills. Similarly, building joinery, house construction, and furniture production are natural targets for sawmills aiming to increase value added, while pulp mills tend to coordinate and integrate their operations with paper mills and manufacturers of paper and paperboard products.

In other cases, the connections between operations are more subtle. For instance, product and process innovations in one industry typically affect both upstream producers and other industries. An example is the development of glue-lamination, which allows sawmills to use logs of smaller dimensions – small logs were earlier demanded almost exclusively by the pulp industry. Changes in forestry practices, caused e.g. by environmental concerns, may also lead to changes in downstream activities. In all, this means that the development of the different industries is interrelated, and that generalizations regarding any specific industry must be cautious. Yet, the sawmills and the pulp mills are at the base of two sub-sectors of forest industries with slightly different characteristics. As we will see, the firms in the pulp and paper group are larger, use more advanced technologies, and export more advanced products.

Pulp and Paper.

The pulp and paper industry produces a large assortment of different pulp and paper grades, which are used for a variety of purposes, ranging from writing paper and newsprint to packaging of liquids and hygienic tissues. Table 3.4 describes some of the most common paper grades and their main end-uses.

Table 3.4. Paper grades and end-uses.

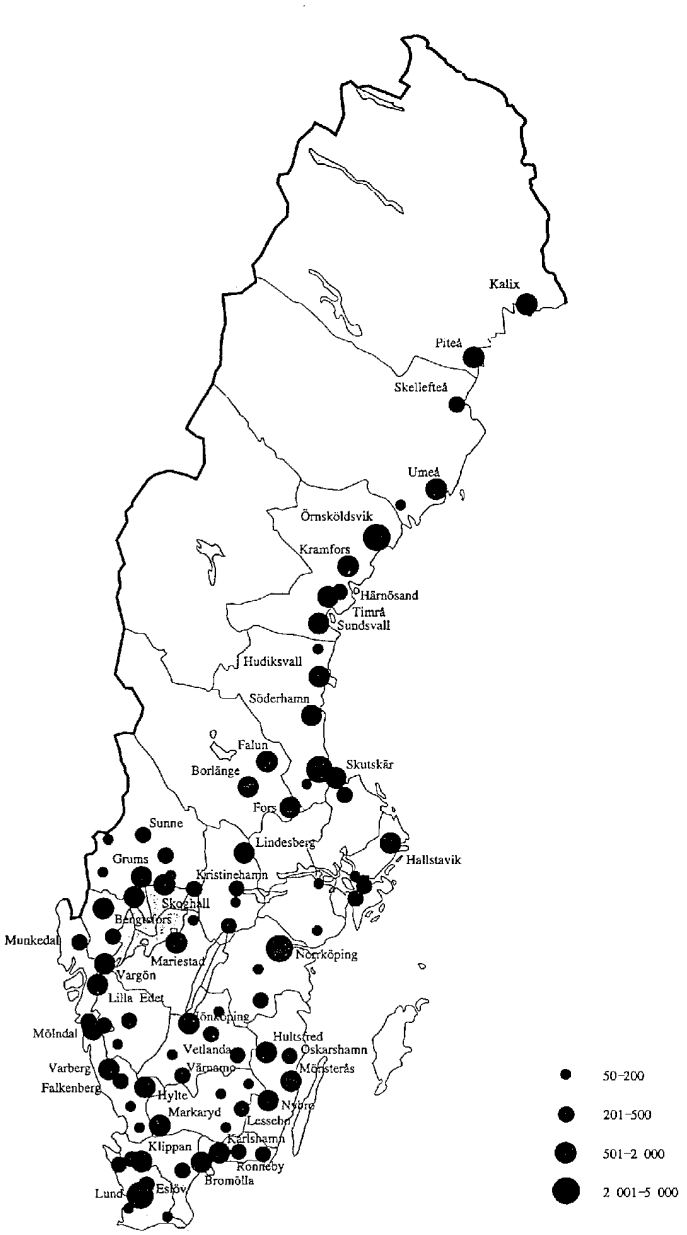
Paper grade	End-use
Coated woodfree	High quality printing for advertizing, special interest magazines, and books
Uncoated woodfree	Copying and duplicating, stationery, educational writing paper, and books
Coated wood-containing (incl. LWC)	Special interest magazines, mail order catalogues, inserts.
Uncoated wood-containing (incl. SC and upgraded newsprint)	Mass circulation magazines, newspaper supplements, directories, paperback books.
Newsprint	Newspapers.
Kraft liner and fluting	Corrugated board, shipping cases, display packs.
Paperboard	Consumer goods packaging, liquid packaging.
Sack paper, kraft paper	Sacks, bags, and other packaging materials.
Cellulose wadding, soft and crepe tissue	Wiping and cleaning products, personal hygiene products.

Source: UN (1986). p. 140.

Since the emergence of industrial technologies for mechanical pulp production in the 1860s, and the first chemical pulp mills in the 1870s, pulp and paper have grown to become the

largest product groups in the forest industry. The technology for pulp and paper production has also developed over time, and today, the industry must be counted among the most R&D intensive sectors of the Swedish economy, in spite of the seemingly simple end products. Over 4 percent of the industry's value added is devoted to R&D, in addition to the research efforts that take place in the industry's various research institutes. Due to the industry's high export intensity, plant location is determined mainly by transport requirements. Hence, most pulp and paper mills are found along the coast line and the shores of lake Vänern, where shipping facilities are conveniently available, as shown in Figure 3.2.

Figure 3.2 Distribution of employment: pulp, paper and paper products 1990.



Source: Svensén (1992).

The Pulp Mills.

Pulp production went through remarkable structural changes during the decades after the Second World War, as shown in Table 3.5. While Sweden had 127 pulp mills in 1960, there were only 48 mills left in 1993. Yet, total capacity increased from 5.6 million tons to 10.9 million tons - the average plant size quintupled, from 45,000 tons to 225,000 tons.

Table 3.5. Structural change in pulp production 1960-1993.

	1960	1970	1980	1990	1993
Number of mills	127	98	72	54	48
Total capacity (million tons)	5.6	8.9	10.5	11.2	10.9
Capacity per mill (´000 tons)	45	90	145	210	225

Source: Svensén (1992), Skogsindustrierna (1994).

The pulp industry's product mix also changed. Stricter environmental regulations reduced the production of sulphite pulp, and the smaller mills producing mechanical pulp also disappeared for cost reasons. Instead, bleached sulphate pulp (which is mainly used for production of printing paper and paperboard) become the main output, accounting for over 40 percent of production. The importance of market pulp decreased significantly, from 64 percent of total output in 1960 to 34 percent in 1993. This was a result of the two dominant trends in the industry's development. Firstly, a long wave of mergers and acquisitions created a small number of large, integrated pulp and paper companies, that used much of the pulp for their own paper production. About two thirds of all pulp produced in Sweden was processed to paper in the same company. Integration does not only secure a market for the pulp that is produced, but it also reduces costs when the pulp and paper mills are physically integrated: the pulp does not have to be dried for transport to a paper mill elsewhere. Secondly, sales of market pulp were reduced because the industry's dominant strategy mandated increased processing and value added.

Table 3.6. Pulp production and exports 1993. ('000 tons)

Pulp type	Total production	Market pulp	Exports
Mechanical	2,722	355	247
Semi-mechanical	264	--	--
Bleached sulphite	618	289	236
Unbleached sulphite	97	18	16
Bleached sulphate	4,189	2,626	2,303
Unbleached sulphate	2,063	120	106
Total	**9,953**	**3,408**	**2,908**

Source: Skogsindustrierna (1994).

The structural changes did not only create larger production units, but also higher industry concentration. There were altogether 20 companies involved in pulp and paper production in 1990, but the three largest firms - Stora, SCA, and MoDo - together accounted for about 75 percent of the pulp and paper industry's turnover. Assi-Domän and NCB were the other significant integrated pulp and paper producers. Only a few companies, most notably

Södra Skogsägarna, remained specialized bulk producers of market pulp. Rottneros was another specialized pulp producer, but the company chose to focus on variety, and offered 47 different qualities of pulp in the early 1990s. Table 3.6 illustrates the product mix in the pulp industry in 1993: this has remained more or less stable since that time.

Raw material costs account for about 45 percent of the sales value of pulp production. Transport is the second largest cost item, whereas labor costs are limited to about 8 percent of the sales value. This illustrates the high capital intensity of the modern pulp industry.

The Paper Mills.

The structural changes in the paper industry were not quite as radical as those in pulp production. Average plant size grew rapidly during the period before 1990, as shown in Table 3.7, but total production also increased fast. Consequently, only about 25 paper mills disappeared between 1960 and 1990. In fact, the number of paper mills was about the same in 1920 as in 1960, so the trend towards concentration was relatively weak. The reason is probably that the possibilities to specialize are better than in the pulp industry: the market for special grades of paper is relatively large and can accommodate a fairly large number of producers.

Table 3.7. Structural change in paper and paperboard production 1960-1993.

	1960	**1970**	**1980**	**1990**	**1993**
Number of mills	76	68	62	54	51
Total capacity (million tons)	2.3	4.8	7.2	9.1	9.5
Capacity per mill (´000 tons)	30	70	115	170	185

Source: Svensén (1992). Skogsindustrierna (1994).

Yet, the major paper producers - Stora, SCA, and MoDo - had chosen to specialize on bulk production of a few standard grades of paper. Stora and MoDo focused mainly on newsprint and paperboard, while SCA also produced large quantities of kraftliner and corrugated board. ASSI-Domän and Korsnäs had a smaller product range with emphasis on packaging paper, but they were remarkably successful in the production of paperboard packages for liquids. For this particular product group, Swedish firms held about 60 percent of the Western European market in the early 1990s, largely thanks to their close contacts with Tetra Pak. Finepaper (writing and printing paper) and tissue paper were less important for the largest Swedish firms. Finnish firms dominated the European finepaper exports, and the Finnish firm Metsä-Serla had also taken over MoDo's consumer products division, with tissue paper and personal hygiene products.

Table 3.8 summarizes data on Swedish production and exports of some common paper grades in 1993. During the last decades, kraftliner, paperboard, and printing paper have increased their shares of total production, while the importance of kraft paper has diminished. The increasing use of recycled paper is expected to have a significant impact on the paper industry's future development. Hitherto, access to fresh wood fibers has been one of the main Swedish comparative advantages in bulk products like kraftliner and newsprint. However, waste paper is becoming a more important raw material source, and several of the larger Swedish firms have invested heavily in the more populated areas of Europe, in order to come

closer to the new raw material supplies. Sweden has also started to import waste paper from the continent. Furthermore, Swedish firms have continued diversifying into more highly processed goods, and foreign investment has been an integral element also of this strategy. It has been necessary to acquire established companies and their distribution networks in order to manage the closer customer contacts that are necessary for marketing of more advanced products.

Table 3.8. Paper and paperboard production and exports 1993 ('000 tons).

Paper type	Total production	Exports
Newsprint	2,325	1,912
Mechanical printing paper	608	538
Woodfree coated printing paper	473	391
Woodfree uncoated printing paper	803	642
Sack paper	647	548
Other kraft paper	335	248
Tissue paper	298	157
Semi-chemical paper	314	252
Other paper	48	29
Total paper	*5,851*	*4,717*
Kraft liner	1,516	1,340
Other paperboard	1,414	1,083
Total paperboard	*2,930*	*2,423*

Source: Skogsindustrierna (1994).

Paper and Paperboard Products.

The paper products industry refines and converts various grades of paper to corrugated board, sacks and bags, cartons, stationery, napkins, sanitary articles, wallpaper, and other similar goods. The distribution of plants, employment, and value added between the different segments of the industry is shown in Table 3.9.

Table 3.9. Paper and paperboard products 1970 and 1989.

	Plants (number)		Employment (´000s)		Value added (billion SEK)	
	1970	**1989**	**1970**	**1989**	**1970**	**1989**
Paper and paper-board packaging	99	78	8.0	7.1	0.4	2.5
Corrugated board	15	30	2.6	3.2	0.1	1.2
Other packaging	84	48	5.4	3.9	0.3	1.3
Other paper and paperboard products	49	60	3.4	6.2	0.2	2.5
Total	148	138	11.4	13.3	0.6	5.0

Source: SCB Industry, Svensén (1992).

Packaging products accounted for most of the industry's employment, but other paper and paperboard products had gradually become more important since the 1970s, and made up half of the industry's value added by 1990. The two separate parts of the packaging products segment - corrugated board and other paper and paperboard packaging - exhibited opposite trends. Corrugated board had grown significantly, both regarding the number of plants and employment, whereas other packaging stagnated. Both these product groups were heavily oriented toward the domestic market, primarily because the end products are bulky and expensive to transport. Their export shares were only slightly above 10 percent.

Productivity grew faster in the category "other paper and paperboard products" than in the rest of the industry, and employment also increased significantly. Most of the products in this category are consumer oriented, and marketing and product design are more important than for packaging. Exports of these products were also much larger, accounting for about half of sales. Moreover, imports were significant. The product group is very heterogeneous, however, and it is difficult to provide more general characterizations of the industry structure and growth strategies.

Sawn Wood Products.

Sawmills and plants manufacturing wooden houses and building joinery (doors, window frames, sashes, staircases, and so forth) accounted for most of the activities in the sawn wood products industry, as shown in Table 3.10. The table also illustrates the magnitude of the structural changes that occurred between the 1970s and 1990s. Nearly half of the work places and a third of the employees disappeared, at the same time as productivity and plant size increased. Moreover, there was a shift from sawmills to joinery and house production, i.e. towards more advanced products with higher value added.

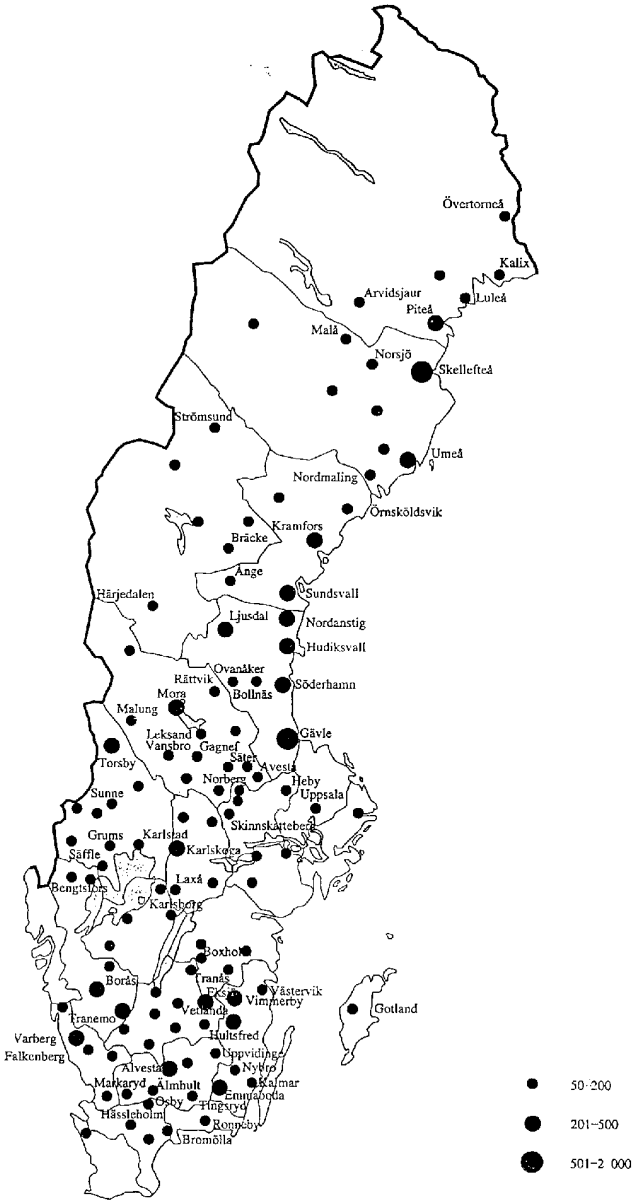
Table 3.10. Sawn wood products (excl. wooden furniture) 1970 and 1989.

	Plants (number)		Employment (´000s)		Value added (billion SEK)	
	1970	**1989**	**1970**	**1989**	**1970**	**1989**
Sawmills[a]	916	435	28.1	16.5	1.4	6.6
Wooden houses and building joinery	771	411	26.2	20.5	1.2	7.3
Wood-based boards and related products	43	31	3.7	4.4	0.2	1.4
Packaging and other Wood products	253	126	5.4	3.2	0.2	0.8
Total	1,983	1,003	63.4	44.6	3.0	16.1

[a]Excludes plants with less than five employees. In 1990, the number of small sawmills with less than five employees was estimated at over 2000. (Svensén, 1992, p. 211).
Source: SCB Industry, Svensén (1992).

Figure 3.3 shows that most sawmills were located on the east coast of the Norrland region, i.e. close to the raw material supplies. There were also many sawmills in the Småland region, in the southern part of the country, which is still a relatively forested region. The location of sawmills is determined mainly by the availability of raw material, since the transport costs of raw timber are much higher in relation to the goods value than those for sawn wood products.

Figure 3.3 Distribution of employment: sawmills 1990

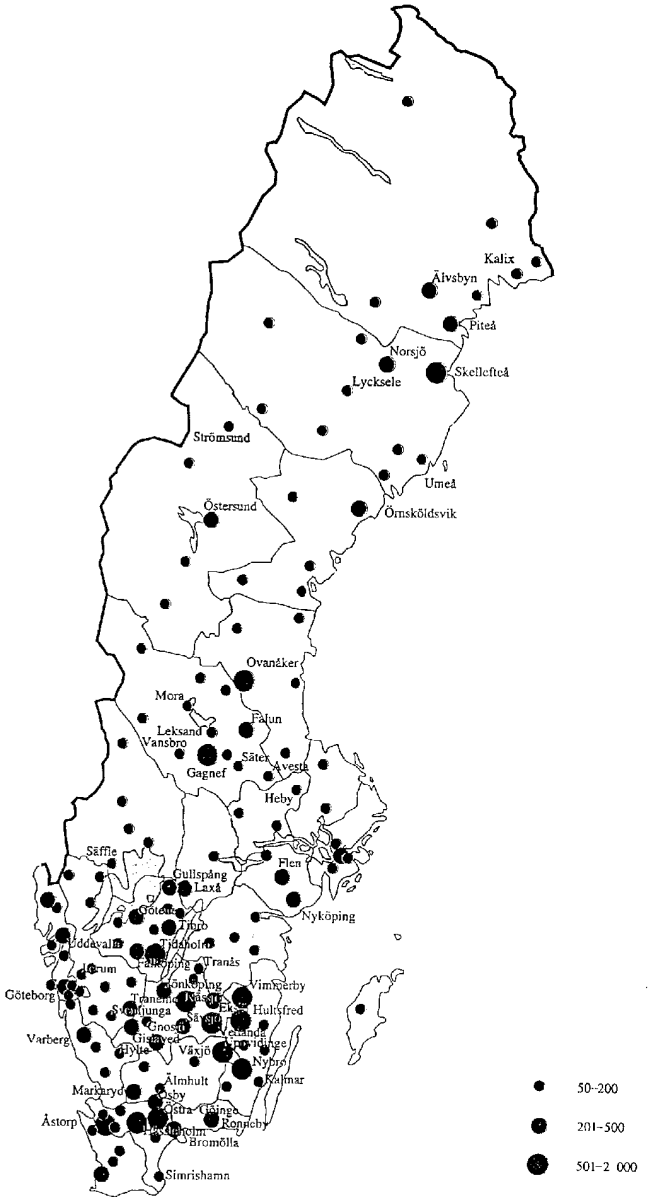


Source: Svensén (1992).

Figure 3.4 illustrates the geographic distribution of other wood product industries (including manufacturing of pre-fabricated houses, building joinery, and wooden furniture), and the pattern is clearly different from that of the sawmills. The southern and western parts of Sweden

were favored locations, because proximity to markets is more important: the products are more advanced and must often by manufactured according to customer designs.

Figure 3.4 Distribution of employment: other sawn wood products 1990.



Source: Svensén (1992).

The sawn wood products group accounted for about 20 percent of the Swedish forest exports. Sawmills exported more than half of their annual output, whereas the exports from the other product categories were more limited. Only about 20 percent of wood-based boards and some 5-15 percent of building joinery products and prefabricated houses were exported. The geographical distribution of the industries, shown in Figures 3.3 and 3.4, is consistent with this trade pattern: export oriented production was located closer to raw material supplies, whereas production for the home market followed the population distribution.

The sawmill industry.

The Swedish sawmill industry produces sawn softwood products that are used mainly for construction purposes, and to a lesser extent for packaging and furniture manufacturing. Swedish production of sawn hardwood is very limited. The sawmill industry's production peaked in the early 1970s, when annual output reached above 13 million m^3. Production fell to some 11 million m^3 during the 1980s, but production expanded in the early 1990s, to about 12.5 million m^3, largely thanks to increasing export demand. Exports amounted to about 7 million m^3 during the 1980s, but grew to over 10 million m^3 by 1993, as a result of a large depreciation of the Swedish currency in 1992. The main export markets are Great Britain and Germany, and the Swedish market share in Western Europe was somewhat over 20 percent. Canada and Finland are the main competitors. Japan also emerged as an interesting export market in the mid-1990s, although quantities are still small.

Most of the industry's production takes place in medium-sized production units - the 22 largest sawmills accounted for 27 percent and the 62 largest for 50 percent of total production in 1993 - but there are also some 2,000 small sawmills with less than five employees. Although the number of sawmills has been greatly reduced by mergers and acquisitions during the past decades - see Table 3.11 - the trend towards increasing concentration has not been as strong as in the pulp and paper industry, and it appears that scale economies are much less important. However, the most successful companies are coordinating the operations of several sawmills, and trying to increase capacity utilization by running several shifts. The leading actors in the sawmill industry are largely the same firms as in pulp and paper: SCA, Södra Skogsägarna, MoDo, Stora, and ASSI-Domän, who all own several mills.

Table 3.11. Structural change in sawmill industry 1960-1993.

	1960	**1970**	**1980**	**1993**
Number of mills (approx.)	6,500	4,000	2,400	2,500
Capacity per mill (m^3, approx.)	1,200	3,800	4,500	5,000

Source: Svensén (1992), Skogsindustrierna (1994).

Some of the larger sawmills, that are often integrated with plants producing pulp, building joinery, or wooden houses, source their raw material from their own forest holdings, but most sawmills do not own any forest and they buy their supplies in the timber market. The complaints about imperfections and lack of competition in the timber market are often voiced by the independent sawmills. The concentration among the largest timber buyers - the pulp and paper producers - has meant that the forest owners have also been forced to join in cooperatives and sales organizations in order to get equal bargaining power. This inhibits the smaller independent sawmills, who have to confront monopolistic sellers with high raw material prices and unfavorable contracts. Concurrently, most sawmills supply raw material to the pulp and wood board industries, since much waste is generated in the production process: the production one cubic meter of sawn wood requires about twice as much roundwood. The raw material costs are significant, and account for approximately 60 percent of total production cost.

The home market is the single largest market, but about 70 percent of production was exported. Traditionally, wholesalers have played a significant role in marketing, distribution, and value added operations, but their importance has gradually diminished. The growing level of competence in individual companies and the emergence of various supporting industry organizations has enabled the industry to integrate distribution and marketing, both domestically and in the export markets. Furthermore, high costs for labor, capital, and raw materials have forced the sawmills to increase the value added in their production. An increasing number of sawmills are investing in drying kilns and equipment for planing, and many are also producing components tailored for the building joinery industry and for manufacturing of pre-fabricated houses. Together with wholesalers and retailers of building materials, these are also the main customers of the Swedish sawmills, and the domestic demand for sawn wood is highly dependent on the development of the construction industry.

The sawmill industry is not only affected by the aggregate level of activity in the construction industry, but also by the type of construction activity that is going on. Until the early 1990s, wood was used for about 90 percent of single-family houses, whereas larger buildings were generally constructed with steel and concrete structures. However, it has been noted that wooden structures are commonly used for much larger buildings - up to six stories high - in the US and Canada. The introduction of stress graded wood products and the development of glue-laminating, edge-jointing, and finger-jointing techniques have raised the use of wood for this type of demanding construction purposes also in Scandinavia.

It is worth noting already here that the development of the sawmill sector is closely connected to the activities of the industry's marketing and research organizations. The explicit aim is to move into operations with higher value added, and the industry organizations are heavily involved in various types of ventures to facilitate this. For instance, the organizations provide advice and detailed instructions (including plans and blue-prints) for various construction projects, efforts are made to establish common European standards for building components and other wood products, and the industry is working continuously to disseminate information about the characteristics of wood as a construction material. The same applies also for other wood product industries, as well as for paper and pulp, and we will return later to a more detailed discussion about the organizations that create and disseminate the skills and knowledge used in the forest industries.

Wood-Based Boards and Plywood.

The wood board industry produces particle board, fiberboard, plywood, and veneer. Particle board has traditionally been connected with the furniture industry, but new varieties are found also in built-in-kitchens, cupboards, and in the production of pre-fabricated houses. The furniture industry is also the main user of some newer types of fiberboard, such as medium-density fiberboard, and most kinds of veneer. Fiberboard and plywood are employed in the construction industry, for thermal and acoustic insulation, floors, walls, roof underlay, shuttering, and various other purposes.

Swedish board production expanded rapidly in the 1970s and peaked during the 1980s, but output was concentrated to fewer units and fell during the second half of the 1980s, because of increasing foreign competition at home and abroad. Both domestic and foreign market shares shrank, and imports, primarily made up of veneer and plywood, grew to about twice the value of exports. Yet, a new plywood mill was established in 1990, and

domestic production increased somewhat during the 1990s. Table 3.12 illustrates the trends in total production. In addition, it can be noted that total employment in the Swedish board industry (consisting at the time of 4 plywood mills, 7 particle board mills, and 5 fiberboard mills) dropped below 1,200 by 1993 (Skogsindustrierna, 1994), and there were serious doubts about the industry's future success. However, some recovery was recorded in the late 1990s, although the production volumes are still below the level of 1990. The main particle board producers during the 1990s were Byggelit and Swedspan, fiberboard (wallboard) was produced by Rottneros Board, and Mälarply and Vänerply were the main plywood mills.

Table 3.12. Swedish production of wood-based boards 1970-1993.

	1970	**1980**	**1990**	**1993**
Fiberboard (´000 tons)	718	423	214	82
Particle board (´000 m^3)	389	1,193	843	597
Plywood (´000 m^3)	63	87	68	72

Source: Svensén (1992), Skogsindustrierna (1994).

Building Joinery.

The building joinery industry produces doors, windows, wooden staircases, and cupboards, shelving units, and other kitchen components. Some firms have also specialized in fittings and furnishings for schools, hospitals, and other public spaces. Many companies are sub-contractors to construction entrepreneurs and producers of pre-fabricated houses. Consequently, variations in the construction industry's business cycles have significant repercussions also for the joinery industry. The Swedish construction industry was highly volatile, with a booming, overheating market during the late 1980s and a deep depression during the early 1990s. The joinery industry followed these swings, and the crisis of the early 1990s led to significant reductions in production. However, the production of building joinery is often a complement to sawmill operations, and exports of sawn wood substituted to some extent for the fall in domestic demand.

In all, the building joinery industry employed some 10,000 people in the early 1990s. Most firms were small, focusing on limited local markets, and the industry was evenly spread out over the entire country. There were some exceptions - specialized producers of wooden floors (Tarkett-Pegula, Kährs), windows (Elitfönster, Modulfönster), doors (Swedoor), and kitchen and bathroom furnishings (Ballingslöv, Marbodahl, HTH) that recorded international success - but the industry's aggregate exports seldom reached above 15 percent of production. Nevertheless, the trend in the industry's production strategies pointed toward closer contacts with customers and production of customized components, and away from the concentration on long production lines that was aimed for during the 1960s and 1970s. This shows that the home market, or at least locally based construction firms, was expected to remain central for most of the firms in the industry.

Pre-Fabricated Houses.

Some 90 percent of the single-family houses built in Sweden during the past decades have been made of wood, and more than half have been pre-fabricated wooden houses. Several factors have contributed to the domestic success of the production of pre-fabricated houses:

the short building season and high labor costs have favored pre-fabricated designs, house construction has been a natural diversification route for sawmills looking for opportunities to increase the value added in their production, and the tough climate has forced producers to develop constructions with high quality (Porter et. al, 1993, 126). The largest firms - Gullringshus, LB-Invest, and Myresjöhus, all located in the Småland region in the south of Sweden - accounted for 40-50 percent of the domestic market in the early 1990s, and recorded some success in exporting to neighboring Nordic countries and Germany. However, most firms were quite small and lacked the capability to market their products abroad, which meant that the aggregate export share stayed at 5-10 percent.

Like the building joinery industry, the production of pre-fabricated houses also varied strongly with the construction industry's business cycles. Employment increased during the construction boom, from 5,000 in 1986 to 7,000 in 1990, but dropped again to about 5,000 in 1993. Several of the leading firms experienced severe financial difficulties during the economic crisis of the early 1990s, which meant that expanding markets in central and eastern Europe became increasingly important for the Swedish producers during the mid-1990s.

Wooden Furniture.

Swedish production of wooden furniture is concentrated to the regions Småland, Västergötland, and Skåne in the southern part of the country. The industry comprises many small family-owned firms, although there was a tendency towards increasing concentration since the mid-1970s. The fastest restructuring took place during the period 1976-1982, when domestic production fell by 4-5 percent per year because of increasing import competition, and about 20 percent of the industry's jobs disappeared (SIND PM 1986:10). The situation improved during the second half of the 1980s, largely due to increased export demand. In 1990, the approximately 300 firms in the industry employed slightly more than 11,000 people and accounted for about one percent of the value added in the manufacturing sector, as shown in Table 3.13. Exports grew from 10-15 percent during the 1960s to about half of production in the early 1990s: the main markets were Norway and the EU. Imports were slightly lower than exports, and came mainly from low-cost producers in Eastern Europe and Asia.

Table 3.13. The wooden furniture industry 1990: sales, value added and employment.

	Sales		Value Added		Employment	
	Billion SEK	**% of total industry**	**Billion SEK**	**% of total industry**	**´000s**	**% of total industry**
Wooden furniture	7.2	1.0	3.3	1.1	11.1	1.5

Source: SCB Industry, Svensén (1992).

It is customary to separate between producers of home furniture and office furniture. Home furniture dominated the market until the 1980s, but the two sectors were roughly of the same size in the early 1990s as a result of the faster growth in the production of office furniture. The firms focusing on office furniture (e.g. FACIT, Kinnarp, and Polator) were generally larger and stronger than those producing home furniture. One reason was that the office furniture market was less fragmented and less sensitive to business cycles - in particular, the public sector was

an important customer. The producers were therefore able to operate with longer production runs, and concentrated on more expensive, high quality products where import competition is less severe. In many cases - and in contrast to most home furniture producers - they were also large enough to create their own export marketing channels.

The firms producing home furniture have always been more dependent on retail chains, which control about 75 percent of the market. The drawbacks are weak bargaining power and low output prices, but the advantages, in terms of access to distribution channels and marketing, have probably dominated. In particular, it seems that the reasonable export success of the Swedish home furniture industry owes much to the remarkable international expansion of the furniture retailer IKEA. Over 100 IKEA stores are now found throughout Europe, North America, and Asia, and IKEA still purchases a large share of its furniture from Swedish suppliers, in spite of its international character. Only a few of the larger home furniture producers operating in higher-price segments of the market (e.g. Dux and Ulferts) have managed to become successful exporters on their own.

3.3. The Knowledge Cluster.

The forest sector is still often characterized as a mature low-technology industry facing many difficult challenges, with bleak prospects for the future. For instance, it is often pointed out that increasing competition from the transition economies of Eastern Europe and emerging markets like Chile, Brazil, and Indonesia will depress prices and reduce the profitability of Swedish production. Increases in Swedish costs for labor, capital, and energy will worsen the situation. The growing concern about the environmental effects of forestry practices and production methods will present other types of demands that necessitate changes in both products and processes. The most pessimistic predictions have for a long time suggested stagnation and decline of the kind seen in industries such as textiles, shipyards, or mining.

However, one of the main points argued in the present report is that this is not an appropriate description of the forest sector. Pulp, paper, and sawn wood products have been among the most important Swedish exports for nearly 150 years, and it is likely that they will continue to be important also in the future, in spite of the many challenges facing the forest industry. One important reason is that most forecasts point to a continuing high demand for the industry's products, both at home and abroad. The consumption of paper products is estimated to continue growing with growing incomes and education levels in Western Europe and other major markets for Swedish exporters, while the development and growth in the transition economies of Eastern and Central Europe is expected generate demand for sawn wood products.

Another reason is that the knowledge and skills used by the industry are continuously being updated, in response to changes in the competitive environment. Swedish industry has managed to overcome the disadvantages caused by high raw material and labor costs by mechanizing production processes, and by moving into operations with higher value added. At the same time, product development is generating new uses for forest resources. For instance, wood is becoming an increasingly important input in the construction industry as the use laminated and finger-jointed products spreads. Moreover, Sweden has become a leader in the development and implementation of environmentally correct forestry practices and industrial processes. The forest industry is one of the few modern industrial activities that are inherently "green", in the sense that all products are bio-degradable and can be recycled or used to

generate energy, and even the most polluting processes, such as pulp production, can be made completely self-contained. Many of these opportunities are available because the forest industry has created dynamic networks of institutions and organizations involved in the production and dissemination of the knowledge and skills that are needed to remain competitive. *This network of organizations - or institutional framework or knowledge cluster - is perhaps the main strategic and competitive asset of the Swedish forest industry*, as we have already argued above.

Since the forest industries - and the related organizations - are closely integrated, it is difficult to define separate institutional clusters for each industry group: new knowledge and technology may be developed by institutions that are intimately connected to one specific actor, but the innovations typically also affect the other industry groups. For instance, the development and introduction of glue-lamination may be driven by sawmills, but joinery plants, building constructors, and furniture makers are also directly affected as customers. To the extent that the innovation requires specific grades of raw material, it will also influence the operations in the forestry sector. Nevertheless, it may be useful look separately at the knowledge clusters in the sawn wood products group (including furniture) and in paper and pulp, because there are some differences in structure and performance. Most importantly, it appears that the cluster in the sawn wood products group is weaker than that in pulp and paper. This may be an important factor to explain why the pulp and paper industry has been relatively more successful in recent decades.

3.3.1 Skills and Knowledge in Sawn Wood Products.

For purposes of presentation, it is useful to distinguish between two essential elements of industrial technology and competence: skills and knowledge (see Ds 1991:62). Skills are embodied in people and generated through various types of education and training, be it on-the-job training or formal schooling. Knowledge is a public good that is generated by research and development activities, and can be transferred from person to person through various means of communication - lectures, scientific articles, handbooks, manuals, and so forth. It is also convenient to distinguish between institutions and organizations that generate and disseminate skills and knowledge, although the distinction is seldom very sharp. For instance, most organizations involved in the generation of knowledge are also engaged in disseminating research results to potential users or the general public.

Table 3.14 identifies some of the participants in the network supplying skills and knowledge to the sawn wood products industries in the early 1990s. Some forestry institutions are also included. The table covers the main actors in the knowledge and skill cluster, but it is not complete: there was a total of over 100 different associations, institutions, and organizations in the forest sector at the time, and most of them were involved in the generation and dissemination of knowledge and skills.[4]

Table 3.14 Participants in the knowledge and skill cluster in the Swedish sawn wood products industry.

[4]The Handbook of the Northern Wood Industries 1991/92 provides an incomplete list with 74 different associations at the national level.

	Generation	Dissemination
Skills (Education)	Royal Technical University University of Agricultural Sciences University of Luleå (School for Forest Engineering) (Forest Institutes)	---
Knowledge (Research)	Royal Technical University University of Agricultural Sciences University of Luleå Swedish Institute for Wood Technology Research Swedish Furniture Research Institute Chalmers Technical University Lund Technical University (School for Forest Engineering) (Institute for Forest Improvement) (Forest Operations Institute)	Swedish Institute for Wood Technology Research Swedish Furniture Research Institute University of Agricultural Sciences Swedish Building Material and Building Trade Fed. Swedish Furniture Manufacturer's Association Swedish Sawmill Federation Swedish Wood Exporter's Association. Swedish Timber Council

Note: Institutes in parentheses are primarily involved in forestry.
Sources: Ds 1991:62, Statistical Yearbook of Forestry 1993, Handbook of the Northern Wood Industries 1991/92.

Academic education at the university level was provided by several institutions. The University of Luleå and the Royal Technical University of Stockholm educated engineers specializing in wood technology. The number of graduates varied between 15 and 40 per year in the late 1980s and early 1990s. Forest officers and forest engineers were trained at the Swedish University of Agricultural Sciences (SUAS) in Uppsala and Umeå, the School for Forest Engineers, and several Forest Institutes. About 170 students per year graduated from the forestry programs in the early 1990s.[5] The wood products industry's own investments in education and training of labor were considered to be small (Ds 1991:62, p. 26).

Except for the School for Forest Engineers, all the institutions mentioned above also offered post-graduate training and managed extensive research programs in areas related to forestry and wood manufacturing. The Swedish University of Agricultural Sciences was particularly active, and managed special research programs on wood construction technology, wood treatment and protection, and integration of forestry and sawmilling in various parts of the country. The research budget of the Faculty of Forestry at the University of Agricultural Sciences amounted to over SEK 225 million in 1991. Forestry research was also found at the Institute for Forest Improvement, which employed 81 people and spent SEK 36 million per year, and the Forest Operations Institute, with 62 employees and a budget of SEK 62 million. Other universities, such as Chalmers in Gothenburg and Lund Technical University were also involved in wood research, but at a more limited scale.

The main actor in the generation of knowledge directed towards the wood manufacturing sector was the Swedish Institute for Wood Technology Research, which is the

[5]In addition to university education, there were also upper secondary schools specializing in forestry, with over 500 graduates per year. See NBF (1993).

sawmill industry's collective research institute. It employed some 80 people in three research divisions, and its annual budget amounted to around SEK 80 million. The research at the Stockholm branch was focused towards sawmills and wood construction. Building joinery was the main research area at the Skellefteå branch, which was also closely connected to and coordinated its research with the department for wood technology at the University of Luleå. Research on other wood products, e.g. furniture, was concentrated to Jönköping. Thus, the geographical structure of the Institute coincided largely with that of the sawn wood products industry. The Institute was also involved in some research dealing with wood-based boards, although at a relatively limited scale. The Swedish Furniture Research Institute, located in Stockholm, was the locus for research, development, and testing of materials and products in the furniture industry. This was a smaller institute, with a staff of 20 people and a research budget of about SEK 8 million.

The Institute for Wood Technology Research, the Furniture Research Institute, and University of Agricultural Sciences were all actively involved in the transfer and dissemination of research results. In addition, several other industry organizations focused on providing information and technical support to member companies, customers, and the general public. Some of these were the Swedish Building Material and Building Trade Federation, the Swedish Furniture Manufacturer's Association, the Swedish Sawmill Federation, and the Swedish Wood Exporter's Association.

However, the efficiency of the technology and knowledge transfers was sometimes questioned. One problem seemed to be that too little resources were spent on the dissemination phase, particularly taking into account the fragmented nature of the industry. Another problem was that many firms in the industry were unable to absorb the information provided by these organizations. This was related to the lack of institutions or organizations focusing on the transfer and dissemination of skills from the universities to the industry. In fact, it was claimed that the main structural weakness of the entire sawn wood products group was a shortage of academically educated staff in sawmills and other firms (Ds 1991:62, p. 33). If the necessary skills are not available within the companies, it is difficult to keep pace with technological developments and changes in the competitive environment: even if the research organization manage to generate product and process innovations, few individual firms will recognize the opportunities and adopted the innovations. The lack of institutions promoting the transfer of skilled personnel from the universities to the industry may also have explained the volatility in the interest for academic education in wood technology.

The knowledge cluster in the pulp and paper industry had apparently managed to overcome some of these problems, and improvements in the institutional framework of the sawn wood products industry - presumably based on lessons that can be learned from pulp and paper - were integral elements of the industry's growth strategy, as we will see later.

Skills and Knowledge in the Pulp and Paper Industry.

Most companies in the pulp and paper industry devoted considerable resources to research and development activities, as well as to in-house education, which was contrary to the situation in the sawn wood products industry. One explanation was, of course, that the average size of pulp and paper companies was very much larger than that of e.g. sawmills.

Firm-specific R&D had also become relatively more important as the pulp and paper companies grew through mergers and acquisitions during the past couple of decades. Yet, the network of institutions permeating the industry was still essential for maintaining and developing international competitiveness, not least concerning education and dissemination of skills from universities and research organizations to the industry.

Figure 3.15 illustrates the institutional network connected to the pulp and paper industry. University training of engineers specializing in pulp and paper processing and related fields was provided by the Royal Technical University in Stockholm and the Chalmers Technical University in Gothenburg. Degree programs in pulp and paper technology and biotechnology were also offered by the University of Karlstad. It is also notable that the industry's leading research institution, the Swedish Pulp and Paper Research Institute, was actively involved in academic education, by financing student research projects, arranging guest lectures, and providing lecture rooms and equipment. About half of the graduate engineers recruited by the industry had this type of training, but the increasingly sophisticated production technology requires an increasing number of specialists from other fields as well. In addition, most of the forestry training programs mentioned in the section on sawn wood products were equally relevant for the pulp and paper industry.

A major share of postgraduate education was managed jointly by the Swedish Pulp and Paper Research Institute and the technical universities. The Research Institute also accounted for a major share of the research and development activities taking place in the cluster. With 250 employees, half of whom were qualified researchers, and a budget of somewhat below SEK 200 million per year, it was one of the largest research institutions of any kind in Sweden, and recognized as one of the internationally leading centers as well. However, during the early 1990s, the character of the Institute's operations was changing somewhat, because of the growing level of competence in the industry's larger companies. Product development was gradually shifting to the industry's corporate research laboratories, while the Pulp and Paper Research Institute concentrated on basic and applied research (and advanced education) of common interest for the entire industry. Research was also conducted at the technical universities, and at several of the industry's smaller collective research institutes, such as the Institute of Surface Chemistry, the Graphical Research Laboratory, the Swedish Packaging Research Institute, and the Swedish Newsprint Mills' Research Laboratory.

In addition to the activities that took place in each of the research institutes, there were collaborative research projects involving several of the industry's institutions. One example is a multi-disciplinary research program entitled Paper-Color-Print, which aimed to develop Swedish competence in paper processing, paper coating, and printing technology. The project was conducted jointly by the Royal Technical University, the Swedish Pulp and Paper Research Institute, the Institute of Surface Chemistry, the Graphical Research Laboratory, and the Swedish Newsprint Mills' Research Laboratory, with financing from the participating institutions, independent research foundations, and the government. Launched in 1993 and expected to run for 6 years, employing on average 40 full-time researcher, the project is estimate to result in 5 doctoral dissertations, 20 licentiate dissertations, 50 graduate engineering degrees, and 100-150 scientific publications and lectures.[6]

[6] The Swedish Licentiate Degree corresponds roughly to the American Master's Degree, requiring about five to six years of university studies.

Table 3.15 Participants in the knowledge and skill cluster in the paper and pulp industry.

	Generation	Dissemination
Skills (Education)	Royal Technical University Chalmers Technical University University of Karlstad Swedish Pulp and Paper Research Institute	Swedish Pulp and Paper Research Institute
Knowledge (Research)	Royal Technical University Chalmers Technical University University of Karlstad Swedish Pulp and Paper Research Institute Institute of Surface Chemistry Graphical Research Laboratory Swedish Packaging Research Institute Swedish Newspaper Mills' Research Laboratory	Swedish Pulp and Paper Research Institute Institute of Surface Chemistry Graphical Research Laboratory Swedish Packaging Research Institute Swedish Newspaper Mills' Research Laboratory

Sources: Ds 1991:62, Statistical Yearbook of Forestry 1993, Handbook of the Northern Wood Industries 1991/92.

Most of the industry's research institutions were involved in the dissemination of research results. Technology transfer was significantly more efficient in the pulp and paper industry than in sawn wood products, because the industry's general level of education and skills was markedly higher. The reason was probably that the Pulp and Paper Research Institute had been very active in transferring skills from the academic institutions to the industry. In fact, the Research Institute acted on two fronts. On the one hand, it attempted to stabilize the demand for engineers and researchers by recruiting skilled labor during slumps in the business cycle. These recruitment activities were financed directly by the pulp and paper industry. On the other hand, it encouraged the industry to employ skilled labor, both by providing information about various types of education to the industry, and by influencing the content of higher education in the direction of the industry's demand.

3.4. Related Industries

The forest sector has also made up a firm base for the evolution of some related and supporting industries, and there are several examples of firms that have subsequently developed internationally competitive positions. Below, some such examples are noted briefly. A more detailed analysis of these related industries lies beyond the scope of the present report.

Machinery.

With the mechanization of forestry operations, Sweden built a leading position in several types of specialized machinery. Some examples are specially designed tractors, forwarders, log harvesters, and machines for thinning and planting. Many of the firms in these product groups

(ÖSA, Bruun System, Umeå Mekaniska Verkstad) have subsequently been merged with the two Finnish firms Repola and Valmet.

Also pulp and paper production generated strong machinery producers. In the manufacturing of various kinds of pulp machinery, Götaverken, Sunds Defibrator and Kamyr were the leading Swedish firms until recently. Both Sunds and Kamyr were acquired by foreign (Finnish and Norwegian) firms during the wave of mergers and acquisitions in the 1980s. Similarly, the leading Swedish manufacturer of paper machinery, KMW, was sold to the Finnish firm Valmet during the 1980s. Sweden still has a strong position in drying machinery (ABB Fläkt) and production of fabrics and felts for paper machinery (Nordviror, Nordiska Filt, and Bruzaholms Viror). Swedish producers are also strong in production of systems for process automation and production control (ABB, EKA Nobel, Loreentzen and Wettre, and Boliden Kemi) and pump equipment (Scanpump).

The Swedish producers of sawmill machinery, such as conveyors, drying kilns, and saw tools, have not been equally successful in the international market, and exports have stayed at around 20 percent of production. At the same time, the leading companies (Söderhamns Verkstäder, Ari, Renholmens Verkstäder, Sandvik Saws and Tools, Uddeholm Strip, Stridsberg, and Brusaholms) have managed to control the home market, with imports reaching only 5 percent of sales.

Transportation.

The forest sector is a major user of transportation services, and transportation is actually the second largest variable cost for pulp and paper producers: only raw materials account for a large cost share. Forest industry products have accounted for a third of domestic rail transports and a fifth of domestic road transports (excluding iron ore) in recent years. In fact, adopting a historical perspective, it is obvious that the transport needs of the forest sector have been major determinants of the construction of roads and railways in Sweden, especially in the less populated areas. The forest industry's shares of the export industry's goods transports have been even higher than the domestic shares, with nearly half of sea transports, two-thirds of rail transports, and over one-third of road transports involving forest products.

In addition to its significance for the transport service industry, the forest sector has also been important for the production of transport equipment. The production of heavy trucks by Volvo and Scania has partly been motivated by the demands for timber and paper transports, and both companies are world leaders in the industry. Earlier, the transport needs of the forest sector were also instrumental in the development of shipyards and production of railway equipment, but the only significant company in this sector is ABB, which offers a wide range of equipment and railway systems.

Chemicals.

The chemical sector at large has never been strong in Sweden, but the country has historically hosted a number of leading suppliers of chlorate and other chemicals for the pulp and paper industry. However, after several mergers and acquisitions during the past decade, only one strong firm remains in the industry, the Dutch Akzo-Nobel.

4. STRATEGIES IN THE SWEDISH FOREST INDUSTRIES.

The global consumption of wood has increased by about 50 percent over the past 25 years, as world population has grown and incomes have risen. More than half of the world's aggregate wood consumption is still accounted for by fuel wood, some 30-35 percent are consumed in the form of sawn wood products, and the remaining 10-15 percent are used for paper and paperboard production. However, the pattern of wood consumption differs widely across countries: fuel wood is less important and various products manufactured from wood are more important the higher the level of income or development.

The positive relation between income levels and consumption of sawn wood products and paper products is the basis for most global analyses of future demand and market conditions. At an aggregate level, consumption of wood products is expected to continue increasing for the foreseeable future, since both world income and world population are increasing. The processes that bring about this demand increase are easy to see in the case of developing countries. The shift from agriculture to services and manufacturing boosts the demand for packaging materials, e.g. in the food industry. Urbanization leads to an expansion of the construction sector, which is the main user of sawn wood products. In addition to construction materials and building joinery, furniture demand is also growing as a result of urbanization. Higher levels of education bring increasing demand for writing paper, newspapers, journals, and books. Hygiene products, such as various types of tissue paper, become more widely used.

These processes have recently been observed throughout the developing world. For instance, parts of Latin America already exhibit demand patterns similar to those in the Nothern hemisphere. Looking at Asia, it is clear that the Japanese industrial expansion fuelled the regional demand for wood products for several decades. Several other countries have followed since Japanese demand stabilized at European levels. South Korea, Taiwan, Hong Kong, and Singapore have reached almost the same consumption levels. Assuming that the problems caused by the Asian crisis are only temporary, it is safe to expect that Malaysia, Thailand, and the Philippines will follow in the foreseeable future, with China, Indonesia, and Vietnam in a subsequent wave. As a result, total paper consumption in Asia is already nearly as high as in Europe, and the region is expected to become the largest market for forest products during this decade.

The market for forest products in the established industrialized countries has also grown over time, in line with the rising level of income, although the structural changes that bring about growth are less explicit than in developing countries. Hence, the slow-down in economic growth during the 1970s led to fears that demand for paper and many other forest products was stagnating, but the upturn in the business cycle during the 1980s showed that consumption growth is still matching increases in population and per capita incomes, at least at an international level. One of the driving forces in the industrialized countries appears to be the growing importance of the service sector, which consumes more wood - in the form of paper - than many manufacturing industries, e.g. machinery or transport equipment. Increasing educational levels also play an important role. Contrary to forecasts from the 1970s and 1980s, there are no signs that the digitalization of administrative services sector will reduce the consumption of paper.

The picture is more obscure in the short run for individual industrialized countries, where differences in domestic supplies of wood resources, environmental regulations, trade policies, and industry structure can have significant effects on the development of the market. For instance, an economy where growth occurs mainly in the service sector will demand different types of forest products than a country where growth takes place in agriculture or construction. Similarly, changes in the environmental awareness of consumers, or the introduction of specific requirements or regulation, will change the structure of the demand for forest products, and perhaps create entirely new products and market segments. How strong the connection between economic growth and increases in the consumption of forest products will be depends on how successfully the forest industry can supply the products that are demanded by the expanding sectors. Flexibility - that is, ability to recognize and respond to new types of demand and competition - and active product and process development are therefore important key words in the strategies of Swedish forest companies, both in the pulp and paper and the sawn wood products industries.

The following section points to some changes in the forest industry's overall strategies that have been mandated by the increasing environmental awareness in Europe. After this discussion, which applies to all the actors in the forest sector, sections 4.2. and 4.3 describe the major company strategies in the pulp and paper and the sawn wood products industries in the early and mid-1990s: the pulp and paper industry is discussed first, because the differences between strategies are often easier to identify than in the sawn wood products industry. Section 4.4 focuses on the strategies for the development of the Swedish forest industry's institutional network during the same period.

4.1 Environmental and Industry Strategy.

One of the main challenges facing the Nordic forest industries in the early 1990s was the need to adapt forest management practices, production processes, and products to stricter environmental regulations and requirements. The development in Sweden and the other Nordic countries had not yet become as dramatic as that in North America, where the preservation of old trees in British Columbia and efforts to save the spotted owl in Oregon halted the logging operations in federally-owned forests.[7] Nevertheless, important changes were underway also in Scandinavia, both as a result of changes in public policies, and because of pressure from environmental groups, who backed up their demands with threats of consumer boycotts of firms who did not comply with the new standards.

In the area of resource management, much of the pressure for change came from environmental organizations, who attacked commercial cultivation and felling methods - for instance, the practice of clear-cutting - which destroy the bio-diversity of natural forests. Many species of herbs, lichens, fungi, and insects have simply not survived in the managed forests, where old trees, deciduous trees, rotting wood, forest fires, and other important elements of natural forests are missing. Forest companies in Sweden were therefore more or less forced to adapt their operations, and introduced new practices that reduce the size of clear-cut areas, allow old trees to be left standing, limit the building of logging roads, and restrict felling around river banks, lake shores, and other important wildlife habitats.

[7] In fact, the volume of timber sold by U.S. government agencies has fallen by almost two-thirds since 1987.

These new practices are often referred to as site adaptation and ecological landscape planning. The former procedure means that tree species, management methods, and regeneration methods are chosen on the basis of the biological prerequisites of the individual site, often in combination with various conservation measures. Ecological landscape planning involves preserving a pattern of relatively untouched forest land, to serve as "safe havens" for endangered animals and plants, within larger commercial forests (Skogsindustrierna 1994). Other changes in forest management give more emphasis to natural regeneration of forests, involving seeding instead of planting (using only indigenous species of trees) and reductions in chemical treatment and ploughing.[8] Moreover, some companies have stopped buying old-growth timber for its pulp mills, and started replacing the mineral oil in their forest machinery with biodegradable vegetable oils. It is estimated that these measures will reduce felling by about 10 percent in the long run.

The innovations in the production processes have aimed in the same direction. The toxic emissions from pulp and paper mills have been reduced as chlorine gas has been replaced by less harmful substances, such as chlorine dioxide, hydrogen peroxide, and enzymes. Some producers were alse developing closed production lines with built-in cleaning stages, so called *kidneys*, that remove hazardous substances from pulp and process liquids: several are already in operation. In some areas, effluent from mills is used to heat buildings, and waste material is used for electricity generation. The combined effect of the necessary adaptations in production technologies - to create more environment friendly processes - is to increase production costs.

The increasing use of recycled paper is another major determinant of changes in products and production processes. Both the pressure from environmental groups and public legislation have contributed to increase the recovery and recycling of used paper, and recycled paper today makes up over 40 percent of the raw material for the world's paper mills. The development has reached the furthest in Germany, where legislation was introduced in 1995 to ensure that 80 percent of all packaging paper and paperboard is collected, and that at least 80 percent of this is recycled. The aim is also to reach a recovery rate of at least 60 percent for newsprint, magazines, and office wastepaper. As a result of these decrees (and government subsidies to recycling) there have been large increases in the supply of used paper in Central Europe, and large reductions in prices for recycled paper. At the same time, there have been large increases in demand for products based on recycled fibers, partly because of the pressure that environmental organizations have exerted on newspaper and magazine publishers, and other paper users.

Together with the increases in wood and production costs in the Nordic countries, the increasing supply and demand for used paper have motivated some new strategies for the largest paper producers. Their main foreign investments have been directed to recycled newsprint mills in Continental Europe, which benefit both from the proximity to customers and the cheap supplies of raw material in the densely populated urban areas. The domestic operations are moving away from commodities, such as market pulp and newsprint, and focusing more closely on specialized products requiring high proportions of virgin fibers. To this end, domestic investments have largely aimed to improve product quality and

[8] Unlike other types of forest, large shares of the natural Nordic forests are characterized by periodic large-scale changes, due to regular forest fires. Modern regeneration techniques are intended to mimic these natural processes, by controlled burning in felled areas.

environmental safety. The strategies in other product groups, such as sawn goods, are also characterized by the emphasis on high-quality products, added value, and greater material processing. It can be expected that these trends will continue to be strong during the foreseeable future, not least because of the increasing competition in world markets for commodity products coming from countries such as Brazil, Chile, and Indonesia. The long-term ability of the Nordic forestry firms to adapt is closely related to their assets in terms of human capability and technological skills, which we have already discussed in some detail.

4.2 Strategies in the Pulp and Paper Industry.

Looking more closely at the companies in the Swedish pulp and paper industry, there are signs of several different development strategies focusing on different products and customers, and entailing slightly different requirements for skills and research and development efforts. Although few firms have adhered strictly to any single strategy - in particular, the larger companies sometimes have several separate divisions that follow different approaches - it is possible to identify three main philosophies with conceptually clear and well-defined objectives.

The Fiber Strategy.

A first strategy, commonly entitled the **Fiber Strategy**, departs from the traditional comparative advantage of the Swedish forest industry: the availability of high-quality raw material, i.e. wood fiber. The pulp producers opting for this strategy select to operate mainly as suppliers to paper producers in regions with less abundant forest resources. They compete by supplying pulp with higher quality or lower prices than their competitors. Södra Skogsägarna appears to be the Swedish company that most conspicuously has operated according to this strategy.

There are two strong arguments favoring specialization of the type implied by the Fiber Strategy. Firstly, pulp production is the area where the Swedish comparative advantages are probably strongest. Both the Swedish pulp producers and the industry's research institutions are leading the international development, and many of the industry's process innovations have been developed and introduced in Sweden. Secondly, Sweden is located in the periphery of the European market, which is a disadvantage for firms manufacturing more advanced products for consumers and industrial customers in continental Europe. More advanced products must generally be adapted and designed according to customer preferences, which benefits producers that are located closer to the market.

At the same time, the Fiber Strategy requires that Swedish prices are not higher than those of the main competitors. Pulp wood has traditionally been more expensive in Sweden than in many competing countries, and although some cost reductions are possible - through further improvements in forestry practices, introduction of new species, and creation of industrial plantations - they will not suffice to allow Swedish firms to compete on the basis of low raw material prices alone. Furthermore, producers in central Europe and other densely populated areas have access to larger and cheaper supplies of recycled paper, which has become an increasingly important raw material. This means that the strategy is not likely to be viable for simple market pulp, nor is it appropriate during periods with surplus production and depressed output prices. Yet, the conditions for pulp production were good during the 1990s,

with high international prices for softwood pulp, which meant that the Swedish companies following the Fiber Strategy were quite successful until the recent price falls.

However, in the long run, the raw material cost disadvantages mean that Swedish producers must either stay more productive than their competitors, or focus on high-quality pulp that exploits the special characteristics of Nordic wood fibers and does not compete with the output from existing low-cost producers. At the time being, there are few products requiring top-grade pulp of this type, and the sustainability of the strategy therefore depends on the industry's ability to develop production processes that are more efficient than those used by competitors enjoying lower raw material prices. The strategy also requires large, financially strong firms that are able to weather the inevitable slumps in the pulp industry's business cycle.

Strictly speaking, the Fiber Strategy mandates a concentration of the forest companies' research and development efforts to two areas. Firstly, research in the forestry area will be necessary to maximize yields, in order to counteract the disadvantages related to Swedish raw material costs. Secondly, development of production processes that reduce raw material use and increase productivity and efficiency are of central importance for long-run competitiveness. Competence in both these areas is available in Sweden.

However, the trend towards increasing environmental awareness will have a significant impact on what type of development and progress we can expect. We have already commented on some of the achievements in the forestry sector. The measures taken to protect old-growth forests and diversity will not increase yields, but rather reduce felling. This stands in apparent contradiction to the need to increase yields, and will probably increase the raw material costs of Swedish producers. Similarly, recent Swedish innovations in production processes have focused on adapting technologies to stricter environmental regulations. The toxic emissions from pulp and paper mills have been reduced, and closed production lines with built-in cleaning stages have been developed. These changes are also raising production costs, rather than increasing efficiency and productivity. Yet, the long run competitiveness of Swedish producers may still benefit from the process, since the environment-friendly forestry practices and production technologies may provide the quality argument that allows higher output prices. The innovations will also make up important advantages for Swedish producers if and when stricter environmental requirements are introduced for the main competitors.

Development of new products that are based on the special characteristics of Nordic high-quality pulp is also high on the industry's priority list, but research projects aiming explicitly for this kind of innovations are not common.

The Value Added Strategy.

A second strategy found in the Swedish pulp and paper industry is known as the **Value Added Strategy**, which implies that the sales of market pulp should be phased out over time, and be replaced by sales of more refined products, embodying higher value added. Some of the arguments favoring the strategy are that the disadvantages of high raw material costs diminish as more processing is added, that more advanced products allow higher prices and profit margins, and that there are gains to be made from integrating pulp and paper mills with downstream production stages. Another motive for the strategy is to reduce the risk that follows with demand fluctuations. The demand for pulp is considerably more sensitive to

business cycles than the demand for paper and paper products, and diversification reduces the exposure to this type of risk.

The Value Added Strategy has been implemented by most of the large Swedish pulp and paper companies, e.g. SCA, StoraEnso, and MoDo. In addition to the integration of pulp and paper production, these companies have also diversified by expanding their product range, in order to reduce the effects of fluctuations in the demand for any specific product. This has been done through numerous mergers and acquisitions over the past decades, and one result is that the three leading firms now exhibit very similar structures. All three produce and sell pulp, and in addition, StoraEnso and MoDo focus on newsprint, paperboard, and finepaper, whereas SCA concentrates on newsprint, finepaper, kraftliner, and corrugated board. Smaller companies have not had the resources to diversify, but have instead integrated pulp and paper mills within one of the product lines. For instance, Korsnäs, ASSI-Domän, and NCB have produced different varieties of pulp, kraft paper, and sacks. Trends in demand and prices have a notable influence on how the sales of these companies are distributed between pulp and paper products: the massive increases in pulp prices in the late 1990s stimulated the sales of market pulp, whereas the price reductions in the recent past have led to increasing reliance on higher value products.

The main drawback of the strategy is that it requires heavy investments in production facilities, distribution channels, and marketing operations, whether it is done from scratch or through acquisitions of existing firms. Foreign direct investment is also necessary in many cases, since sales of more advanced products to foreign customers require presence in the foreign market. Hence, only large and financially strong companies are able to integrate and diversify to the extent that is aimed for. Another problem is that investments have sometimes been made in fields where there are no gains from integration: financially strong companies have simply acquired their customers without examining whether there are synergy effects from integrating the operations. This may still allow a reduction of risks, since profits from one production stage can be used to subsidize temporarily less profitable operations, but it does not maximize the companies total profits.

There is an apparent connection between the Value Added Strategy and an increasing emphasis on product development in the companies' R&D efforts. However, the way the strategy has been implemented in the major Swedish companies, it has essentially involved a shift from pulp to standardized grades of paper, mainly newsprint and kraft paper. In this area, the main research requirements are related to surface chemistry and printing characteristics. The Swedish competence in the area is relatively low at present, and significant investments are necessary to stay competitive. As noted earlier, this is also one of the fields where large collaborative research efforts have been initiated by the organizations in the industry's knowledge cluster (the PCP-project). Similarly, Swedish R&D in downstream activities like printing and packaging has been limited, and increased attention is needed in the future.

The Specialization Strategy.

The search for gains from integration in the larger forest companies has, as noted above, led to a concentration of production to standardized paper grades. In the **Specialization Strategy**, achieving gains from integration is not the central objective, but the aim is instead to develop

products that can carry high prices and allow acceptable profit margins. The means to reach this end is increasing customization of the products.

Technical progress in both the pulp and paper industry and among the industry's customers during the past couple of decades has made the Specialization Strategy more interesting and viable. A wide assortment of new products and product variants have been introduced as the paper industry's technology has advanced, at the same time as changes in e.g. printing technologies have created demand for many different varieties and qualities of paper. Consumer preferences have also changed. For instance, increasing environmental awareness has made it possible to market "green" products, that are manufactured using environment-friendly processes.

The Specialization Strategy has been chosen primarily by smaller companies. Some examples are Rottneros, that has supplied up to 50 different qualities of pulp during the past decade, Klippan-Lessebo, concentrating on cigarette paper, napkins, table cloth, and colored paper, and Munkedal, that focuses on environment-friendly production processes. Some of the larger companies have also adopted elements of the specialization strategy. For instance, Assi-Domän and Korsnäs have cooperated with the packaging company Tetra Pak to build strong positions in paperboard containers for packaging of liquids. These examples show that technological complexity is not a necessary requirement for the strategy, but close customer contacts are. Consequently, the main problems faced by the Swedish producers focusing on the Specialization Strategy are related to their location, far from the center of the European market. The strategy is also more common among forest firms in continental Europe than in Sweden.

The intimate connection between producers and their customers makes up a significant entry barrier for newcomers, and a slightly lower price is seldom sufficient to overcome existing business relations. This means that there are only two effective entry strategies. One alternative is to develop entirely new products and create new markets. This is very costly, both in terms of financial resources and time expenditure. Another alternative is to acquire already existing firms, with established markets and networks of customer contacts, but the costs are usually large here as well.

The markets for specialized niche products are typically small, but they still require a lot of management effort. This explains why the leading Swedish forest firms have not been following the Specialization Strategy, but instead preferred to act on larger markets. The smaller firms that are prepared to focus on specialization and niche products usually have very limited resources for R&D, so the technology content in the sector has remained small. Their limited size is also a serious weakness in the long run, since the capital expenditures for new production facilities are so large that they require large volumes and high capacity utilization. Thus, the niche strategy is sometimes characterized as a viable alternative only during the last phase in a pulp or paper plant's life cycle.

One of the main research objectives for firms pursuing the Specialization Strategy is obvious from the discussion above: less capital-intensive pulp production processes. This would alleviate the main long run problem facing this segment of the industry, and facilitate a combination of flexibility and high capacity utilization. Another priority area is product development, with paper coating technology and composite materials as the most promising topics. In addition, many of the firms pursuing this strategy benefit greatly from the research and development of more environment friendly forestry practices, processes, and products.

4.3 Strategies in the Sawn Wood Products Industry.

The strategies employed in the sawn wood products industry are more difficult to categorize, because of the very heterogeneous structure of the industry, and because most of the smaller firms actually seem to lack explicit strategies. For instance, the behavior of the majority of Sweden's 2,500 sawmills cannot be described in terms of the pulp and paper industry's Fiber Strategy (or any other strategy), although the mills concentrate on the production of simple sawn and planed wood products without much further processing. The reason is that their concentration on manufacturing of basic products is not a result of explicit plans or thorough market analyses, but rather the consequence of a lack of alternatives. The equipment of most sawmills is limited to saws, planing mills, debarkers, and chippers, and there is usually not enough skills or capital in the firm to invest in activities with higher value added. Many of the older sawmills are able to survive only because their overheads are low and their capital equipment has been written off long ago. In fact, it is not uncommon to see small sawmills that are in business only during periods when output prices reach above some threshold level.

Many of the larger firms in the industry can still be characterized in terms of the **Value Added Strategy** used in the pulp and paper industry. The sawmills are trying to increase the value added of their output by refining the sawn wood in different ways, or by diversifying into building joinery, pre-fabricated houses, or furniture. The objectives and drawbacks of the strategy are in many ways similar to those in the pulp and paper industry. Adding processing stages is a way to overcome the disadvantages related to high Swedish raw material prices, and diversification helps reduce the volatility of sales and earnings. The necessary investments are costly, although the main barriers are not related to financial strength, but rather human capital. Diversification requires skilled labor, since the added production stages require competence in areas that are not familiar for most traditional sawmills. Hence, the success of the strategy is partly dependent on whether the transfer of skills from universities and research centers will function well: as noted in the discussion of the sawn wood products industry's knowledge cluster, this was the main weakness in the present institutional structure.

Value added in sawmill operations is increased by adding production stages, like drying, glue-lamination, finger-jointing, stress-grading, and pressure impregnation, or by establishing manufacturing of specially designed components for the construction or furniture industries. Outright diversification, meaning expansion into building joinery or production of pre-fabricated houses is another alternative. Only a handful of sawmills have diversified into furniture production, presumably because the furniture industry's distribution network is entirely separate from that of other sawn wood products. The furniture producers are more specialized, and are seldom involved in the simpler sawmilling operations.

The main difference between the Value Added strategies in the sawn wood products and pulp and paper industries is that the former focus very heavily on the marketing of products. Efficient marketing and long-term cooperation between sawmills and their customers have been difficult because of uncertainty regarding product quality and lack of product standards. (Standards for most common pulp and paper qualities have been established long ago.) The sawn wood products industry's strategy therefore requires significant investments in the establishment of product and quality standards for a host of different wood products, ranging from construction materials to home furniture. A number of such standards - the most widely used are related to stress grading and drying - have already been developed by the industry's

knowledge and skill institutions, and this is one of the prioritized research and development areas also for the future.

The standards for building materials and components regulate features such as size, weight, color, humidity, stress resistance, surface characteristics, and restrictions on the number and size of admissible splinters and other imperfections. These apply both for simple components, such as structural trusses, and more complicated elements, such as window frames and doors. In furniture, standards are related to function, durability, and workmanship. The efforts to establish a common language that facilitate the communication between producers and consumers are not limited to the national market. With the establishment of the European Economic Area and possible Swedish membership in the European Union, national standards are to be harmonized across the member countries, and the markets for many of the more advanced products will expand immensely.

The sawn wood products industry - in particular, producers of pre-fabricated houses and building joinery, such as doors, windows, staircases, and interior wood panels - have also developed strategies for penetrating the Japanese market. One of the main elements of these entry strategies is to adopt Japanese product standards, and to seek Japanese quality certification for Swedish products. The special character of the Japanese market has also forced firms to abandon plans to establish own marketing and distribution channels: instead, Swedish sawmills and house constructors have entered into various marketing arangements with Japanese trading houses and producers.

A few of the firms in the building joinery and furniture industries have managed to specialize in narrow product segments, such as wooden floors (Tarkett-Pegulan), kitchen and bathroom cabinets (Ballingslöv. Marbodahl, HTH), and exclusive furniture (Dux). The requirements for customer contacts posed by this **Specialization Strategy** are similar as in the pulp and paper industry, although brand names, trade marks, and design are more important and costly to establish. Another characteristic feature of these companies is that they have been forced to diversify from wood to other materials as well, in order to specialize in the *functions* provided by the products they sell: the emphasis is on a wide assortment of floors and cabinets for different purposes, rather than on wood products alone.

4.4 Strategies for the Knowledge and Skill Clusters.

The strategic requirements for the knowledge and skill clusters in the paper and pulp and sawn wood products industries differ slightly, because of the differences in the structure of the industries and institutions. Yet, both networks are affected by requirements in several different areas: education and recruitment, academic competence, research orientation, dissemination of research results, and financing of research and development.

Education and recruitment.

One of the main differences between the institutional structures in the sawn wood products and pulp and paper industries is that the former lacks organizations that are actively involved in the transfer of skilled personnel from universities and other research centers to the industry. As a consequence, the academic competence in sawmills and related activities is low, particularly considering the industry's objectives to diversify production and increase value added. The flow of students to higher education in wood technology is also low. The firms in the industry

recruit during booms, but not during slumps in the business cycle. These variations have a negative impact on young people's willingness to invest in a wood technology education. Students are worried that the business cycle will have turned when they graduate after three to five years, and that they will be unemployed or be forced to seek employment in other sectors instead. Shortages of wood engineers are therefore common.

In the paper and pulp industry, this problem is alleviated through the operations of the Pulp and Paper Research Institute, which recruits engineers as "trainees" during times when industry demand is low. This does not only stabilize the labor market for skilled labor, but it also improves the connections between research organizations and pulp and paper companies. Consequently, a major challenge for the sawn wood products cluster is to set up a similar arrangement, with the Institute for Wood Technology Research filling the void identified in Table 3.14.

Academic Competence.

The company strategies in the forest industry are all dependent on the creation of new knowledge regarding materials, products and processes. Much of the product development in the pulp and paper industry takes place in the research divisions of the larger companies, but basic research is done at the universities and the specialized research organizations. The firms in the wood products sector are smaller and have very limited resources for in-house R&D: the universities and research institutes account for almost all advanced research.

A general opinion in the forest industry is that the resources spent on forest related research at the universities are much too small in relation to the industry's requirements. The industry has therefore lobbied successfully to increase the number of tenured professors at the main universities. During the 1990s, some 20 new full professor's positions in the forest sector - each with a connected assistant professor, graduate students, secretaries, and technical support – have been established at the main research institutions. Part of the costs is financed by the forest industry.

In the pulp and paper sector, the Royal Institute of Technology presently employs tenured professors in pulp technology, paper technology, and wood chemistry, while the Chalmers Technical University has chairs in forest industrial chemistry. There are also chairs in paper surfacing, paper chemistry, and packaging technology (at the Royal Insititute) and wood chemistry (at Chalmers). The newest positions focus mainly on paper and printing technologies, and environmentally oriented pulp production technologies.

In the sawn wood products field, there are presently tenured positions at the Royal Institute of Technology (wood technique) and the University of Luleå (wood technology). The Royal Institute also has professors in wood physics and wood drying, wood material research, and glue-laminated wood and composite materials. In addition, there are several tenured professors in wood and forestry related areas at the University of Agricultural Sciences, focusing on issues like wood protection, bio-technology, and timber quality. The newest positions in the wood products field focus on wood substitutes, wood physics, and integrated production systems, and are based in the southern part of the country where most of the wood-working industry is located.

Another objective of the industry's research strategy is to improve the cooperation and coordination between the universities and the independent research organizations. To this end, there are attempts to concentrate the academic programs to two large research departments at

the Royal Insitute of Technology and Chalmers. This would not only facilitate the coordination of activities, but also allow the departments to benefit from economies of scale.

Research Orientation and Dissemination of Research Results.

The large firms in the pulp and paper industry devote significant resources to commercial R&D (about 4 percent of value added, as noted in the previous part) and concentrate on the development of products and processes that are of immediate commercial value. The basic research is carried out in the industry's research institutes and at the universities. Presently, there is no clear division of responsibilities between the institutes and universities. Another part of the industry's strategy is to define more clearly the areas of responsibility for these two institutions.

Much of the university research takes the form of doctoral or licenciate dissertations, which implies that the projects involved are of a relatively long-term nature. It is often impossible to direct dissertations to focus on the issues that are of acute interest to the industry. The industry's research institutes, on the other hand, are much more flexible, and can set up comprehensive research programs on relatively short notice. This distinction defines a natural division of responsibilities in research orientation. Regarding presentation and dissemination of research results, there are similar differences. The universities' research efforts are published in condensed form in academic publications that are not easily accessible for the industry. Hence, the Pulp and Paper Research Institute and other organizations make up a natural bridge between the academic institutions and the industry. In addition to presenting their own original research, these organizations are expected to take on a larger responsibility for the dissemination of academic findings, presented in a more operationally oriented manner.

A similar labor division applies for the relation between the sawn wood products industry, the research organizations, and the universities. The main difference is that the industry's expenditures for in-house R&D are very limited, meaning that the knowledge cluster will be responsible also for product and process development (and not only basic research) in the short and medium run. Moreover, the task of disseminating research results is very much more complicated, since the industry is so fragmented and there are few academically educated employees. Much resources must therefore be spent on finding efficient channels for the transfer and dissemination of innovations. It is likely that an intermediary between the research institutions and the individual companies must be created for this purpose, since most sawmills and related plants are too small to handle the contacts vis-a-vis the research institutions. Some local and regional networks of small companies have already been created to manage the communication, with research results coming in one way and information about the companies needs and problems going the other way. This is a costly way of creating the links, since the participating companies must employ a full-time administrator, but the results have apparently been positive. The success of these operations will not only influence the profitability of the sawmill industry, but also have a profound impact on the industry's future demand for academically educated personnel. Sawmills and related plants will demand engineers and other highly skilled employees only if they understand what the skills can be used for.

Financing of Research and Development.

In the same way as the forest industry's demand for academically educated personnel fluctuates with the business cycles, the industry's expenditures on research and development (both in-house and in the industry's research organizations) also exhibit a cyclical pattern. This is unfortunate, since most research is of a cumulative character: it is costly to compensate for temporary reductions in research efforts, especially if researchers are laid off or relocated to other activities during the slumps in the business cycles.

A less volatile system for the financing of R&D is therefore an additional objective in the strategy for the industry's knowledge clusters. Ideally, it should be possible to cumulate funds during profitable years, in order to spend them when the current income is not sufficient to maintain the desired level of activity. Swedish tax laws have not encouraged this kind of solution, but the industry has for a long time lobbied for suitable changes. Basic university research has been less volatile, and state financing of some of the larger research institutes, such as the Pulp and Paper Research Institute and the Institute for Wood Technology Research, has had a mild countercyclical effect, but this has not benefited the industry's in-house R&D.

Effects

While a detailed analysis of how these strategies have affected the industry's performance during the 1990s is beyond the scope of the present study, some comments are still in order. Firstly, the measures taken to strengthen the industry's competitiveness have been moderately successful. The sector's aggregate production increased by some 20 percent by the late 1990s, with higher increases in high-value added activities. For instance, while output of newsprint actually has fallen during the past decade, there have been larger increases in production of more sophisticated paper qualities. The value of exports grew significantly faster than total production, from around 60 billion SEK in 1990 to nearly 100 billion SEK 10 years later. However, this increase was not only due to higher productivity and competitiveness, but rather caused by the large depreciation of the Swedish currency after the financial crisis in 1992. In fact, the forest sector's share of total exports has fallen from around 20 percent around 1990 to 13-14 percent in 2000.

Secondly, the structural changes in the forest sector have continued. The production structure has become more concentrated in both paper and pulp, sawmills, and sawn wood products. This is likely to be particularly beneficial for productivity in the sawmill and sawn wood product industry. In paper and pulp, the structural changes reach across national boundaries, as the European paper industry is adjusting to the Single European Market. For instance, Swedish Stora and Finnish Enso merged in the mid-1990s, in order to achieve economies of scale in R&D and to coordinate their continental European production and distribution networks.

Thirdly, the efforts to strengthen the industry's knowledge and skill cluster have been reasonably successful. Several new programs in higher education and research have been established over the past decade, significantly raising the total investment in forest-related R&D. For instance, a new research center for pulp and paper technology has been established at Mitthögskolan University in Sundsvall, with main backing from the forest company SCA. New research projects focusing on sawn wood products, with financing from industry, government, and the European Union, have been established in the Dalarna region in the central part of the country. Similarly, a broad program for wood product development has

been established at Luleå Technical University. Altogether, several hundred million SEK have been invested in these ventures over the past decade. While the overall growth rate of the forest sector is likely to remain modest over the foreseeable future, it is likely that these investments will make it possible for the industry to maintain its competitive position. This is important, not least because the forest sector's net exports, amounting to some 75 billion SEK in 2000, are still as large as the aggregate net exports of telecommunications equipment and electronics, cars, and pharmaceuticals, which are at the core of the "modern" economy of Sweden. It is hardly possible to overestimate the importance of this source of hard currency and import capacity: Swedish economic development would undoubtedly be slower and more uncertain without these assets.

5 THE EMERGENCE OF THE NORDIC TELECOM INDUSTRY

At the same time as substantial resources were invested in the forest industry's knowledge cluster in the early 1990s – to protect and perhaps even strengthen the industry's competitiveness in a constantly changing international business environment – the Nordic economies were also in a process of fundamental structural change. Although the traditional raw material based industries were able to maintain their strong positions, they were quickly overtaken by the rapidly growing information and telecommunications sector. The frontrunners, companies like Nokia and Ericsson, have not only become strategic actors in the Finnish and Swedish economies, but have also gained considerable international fame. For instance, in early 2000, Nokia joined the ranks of Microsoft, Cisco and General Electric in the top ten list of the world's most valuable companies.

The step from raw material based industry to high-tech activities like telecommunications and information technology may appear large, but we will argue below that there are important similarities between the two. In particular, knowledge and human resource development – in the form of well developed knowledge clusters, as in the mature forest industry, or in the form of in-house assets, as in the early stages of Nokia's and Ericsson's breakthrough in the mobile phone industry – have been essential for success in both sectors. While it is not possible to systematically create innovations, like the NMT and GSM technologies that propelled Nokia's and Ericsson's breakthroughs, it is possible to systematically prepare for those commercial and technological opportunities and challenges that will inevitably occur. Both Nokia and Ericsson were well prepared when the pivotal innovations emerged, and could therefore exploit the opportunities that opened up.

The following section outlines Nokia's development from a raw-material based conglomerate to a high-tech telecom producer, with some focus on how the skills and knowledge needed for a high-tech breakthrough have been acquired. Section 5.2 points to some of the factors explaining Ericsson's success.

5.1 Nokia

Nokia is today best known for its mobile phones and telephone systems, but telecommunications has not been at the core of the company's business for more than about a decade. Yet, the history of Nokia reaches more than 100 years back in time. In 1865, the mining engineer Fredrik Idestam established a groundwood mill in Tampere in southwestern Finland, expanding it in 1869 to the nearby village of Nokia. There, the river Emäkoski provided the energy needed for Idestam's business venture, Nokia Ltd, which soon became Finland's largest pulp and paper mill. Some decades later, in 1898, the newly established Finnish Rubber Works also set up production at Nokia, attracted by the hydropower resources of the Emäkoski rapids. In 1912, Finnish Cable Works was established in Helsinki, to supply the cables and wires needed for the electrification of the country's emerging industrial sector. In all three cases, much of the relevant technology was imported. Idestam had studied the pulp technology during his travels in Germany in the early 1860s. The engineer Antti Antero, long-time manager of Finnish Rubber Works, had studied a Russo-French rubber factory in Riga, Latvia, Arvid Wikström, founder of Finnish Cable Works, had studied Werner Siemens' innovations in cable production technology in Germany. All three companies

rapidly managed to gain a strong position in the domestic Finnish market, as well as a foothold in the large Russian market: before independence in 1917, Finland was a Grand Duchy under Russian rule.

These three companies are the predecessors of today's Nokia. In 1918, Finnish Rubber Works acquired the majority of the shares in Nokia Ltd, to secure access to the hydropower resources at Nokia. Some years later, the new conglomerate also took control of Finnish Cable Works. Although a merger of the three companies was discussed already during the 1930, it was not realized until much later, and the three companies were allowed to develop independently during the following decades. All three were successful. Nokia Ltd became a large conglomerate producing electric energy, pulp, and paper, mainly toilet paper. Finnish Rubber Works produced rubber boots and car and bicycle tires, with the development of the world's first winter tire as a particular success. Finnish Cable Works posted the most impressive performance of the three, partly as a result of Finland's war repatriations to the Soviet Union after the Second World War. The bulk of war reparations were made in the form of industrial products, and Soviet demand exceeded the surplus capacity of Finnish industry. However, the lack of hard currency had led to strict import restrictions which made it hard to raise production capacity: instead, productivity increases were necessary to manage the war reparations. By the time the war reparations were completed, the Cable Works had not only been forced to improve productivity, but it had also secured a market in the Soviet Union that was able to absorb almost unlimited amounts of cable and wire. The existence of what seemed like a secure export market was a strong motive to increase capacity as soon as the post-war currency restrictions were lifted. Diversification was also possible: an electronics department with a group of R&D engineers was established in 1960, and resulted in the development and production of a variety of electronic goods. For instance, in 1962, Finnish Cable Works developed a prototype radiotelephone at the request of the Finnish Army (in competition with the country's two other leading electrical engineering firms Salora and Televa and the Swedish producer Sonab). The Army was eventually not able to place any orders due to cuts in the defense budget, but the companies found other customers. Televa's radiotelephones were sold to the Finnish police force, Salora sold to the coast guard and the state railway company, while Cable Works supplied the Postal authorities and exported successfully to the Soviet oil and gas industry (Pulkkinen 1997:75).

Nokia Corporation

In the mid-1960, the suggestion to merge the three companies came up again. Although there were good reasons for a merger – in particular, all three had outgrown the home-market and were hesitant to take on Western export markets on their own – there were also problems and risks involved. One problem was structural: there were clear synergies between cables and wires, electronics, and rubber products, but it was unclear how pulp and paper would fit in. Another complication was the difference in enterprise cultures. Unlike Nokia Ltd and the Rubber Works, Finnish Cable Works was a modern and reasonably dynamic company. It was also felt that the management of Finnish Rubber Works in particular was less flexible and more hierarchical than the others, with frequent conflicts and strikes as a result (Bruun and

Wallén 2000:17-19).[9] Still, the outcome was a decision to merge all three companies into Nokia Corporation in 1966, under the leadership of Cable Works' CEO, Björn Westerlund.

Nokia Corporation was organized in four divisions: Paper, Cable, Rubber, and Electronics. The electronics division was the smallest of these, with only 460 employees and 3 percent of the conglomerate's total turnover in 1967. The fastest growth during the 1960s and 1970s occurred in the Cable division, but significant resources were also invested in the Electronics division. In particular, the research department was given generous funding for product development, although its profitability was very low or even negative for a long time. Yet, Nokia's CEO Westerlund made sure that the electronics workshops had access to the latest technology, and protected the division's independence against criticism from the board of the Cable division, who argued that the entire Electronics division should be closed down (Bruun and Wallén 2000:22).

In addition to his long-term support to the Electronics division, which would eventually develop into the Nokia we know today, Westerlund was also instrumental in setting up a strategy for Soviet trade. Soviet demand for cable, radio telephones, rubber boots, and other Nokia products appeared unlimited during the 1960s and 1970s. After the first oil crisis in the early 1970s, so did Soviet import capacity. The trade between Finland and the Soviet Union was essentially barter trade, with the Soviet Union supplying oil and other raw materials in exchange for industrial products. The massive increases in the international oil price after 1972 translated into corresponding increases in the Soviet Union's ability to pay for imports (Haavisto and Kokko 1991). Many Finnish companies, including Nokia, became increasingly specialized in Soviet trade – altogether, the Soviet Union accounted for more than one-fifth of Finland's external trade until the 1980s. However, Nokia's Soviet export potential was significantly larger than the actually realized exports. To avoid becoming dependent on the Soviet Union, Westerlund insisted that any increases in Soviet trade should be matched by increases in trade with the West (which in practice meant a restriction on exports to the Soviet Union). When he resigned as CEO in 1977, handing over control to Kari Kairamo, half of Nokia's exports were directed to the socialist block, with the other half going to the West. Many large Finnish export companies that failed to implement similar restrictions for the lucrative dealings with the Soviet Union ended up in severe crisis in 1991, when Soviet trade collapsed.

To become a high-tech company

When Kairamo took over Nokia in 1977, it was Finland's largest private company, with around 16,000 employees (or about 2 percent of the country's industrial labor force). At this time, Nokia was still primarily a producer of paper, tires, and cable, but Kairamo was committed to change this and to transform Nokia into a leading high-tech company. The foundation was already in place, in the form of Nokia's Electronics division, which had managed to diversify significantly during the preceding decade. The production of

[9] Another complication was that Finnish Rubber Works was closely tied to Finland's Swedish-speaking community through its bank, Föreningsbanken, while Nokia AB was connected to Kansallisbanken, the bastion of Finnish-speaking capitalism. The compromise was that the two banks were given equal ownership shares and equal influence in Nokia Corporation.

radiotelephones had expanded when a nationwide public radiotelephone system had been established in the early 1970s. Since the late 1960s, there had also been discussions about the establishment of a Nordic mobile telephone network, and an open standard for telephones, base stations, and exchanges had been agreed in 1976. The cellular NMT network that was to be launched in the early 1980s in all the Nordic countries pushed Nokia (as well as the other Finnish producers Televa and Salora) to develop new products for what was expected to be a rapidly growing market. Nokia had also been marketing Siemens, Bull, Elliot, and Honeywell computers in Finland since the late 1960s, and had found a market adapting foreign computer equipment into package solutions for domestic industrial customers, e.g. the nuclear power plants built in Finland during the 1970s. By the late 1970s, the learning process had been successful enough to allow Nokia to produce and market its own computer terminals. Focusing on industrial customers, like banks, the postal service, and large retail chains, Nokia computer terminals and cash registers actually came to dominate the Nordic markets in the 1980s. By that time, Nokia had also managed to develop a very successful portable microcomputer that seriously challenged the dominance of Apple computers in the Nordic market.

But capturing the Nordic market was not enough for Kairamo, who had more ambitious plans for the company. Internationalization was the key objective. The problem was that Nokia could hardly develop into a leading international player in high-tech industry if it was to rely solely on internally generated growth. The company was too small, and although the Electronics division had been reasonably successful, it still lacked the necessary skills and experience to take on the world market. It was therefore necessary to focus on alliances and acquisitions to secure the strategic resources needed to grow large enough to compete with the large European, Japanese, and American incumbents in the international electronics market. This strategy was played out in two areas: telecommunications and televisions.

Telecommunications

In the 1970s, Finland had three major actors in the telecommunications industry: Nokia, Salora, and Televa. Salora, which had televisions and other consumer electronics as its core business, was the market leader in radiotelephones and had a 30 percent market share in the Nordic region. Salora's main sales argument was a technically advanced telephone that could operate on a larger number of channels than those of the competitors. Televa, which was state-owned, was stronger in telephone systems. In particular, Televa had been developing computerized telephone exchanges since the late 1960s. Unlike Siemens, Ericsson, and other large competitors that focused on analogue technology in the early 1970s, Televa was experimenting with both analogue and digital systems already from the outset. However, the project to develop a digital telephone exchange did not receive much support from company management. It was run by the young engineer Keijo Olkkola and a handful of colleagues, who were struggling to maintain the financing of the project. Bruun and Wallén (2000:49) report that the financing for Olkkola's research team was cut in each year's preliminary budget, only to be "temporarily" reinstated after heavy lobbying by Olkkola. In 1973, Televa's management finally presented an ultimatum to the project team. All financing would be stopped unless a buyer was found. After difficult negotiations, an agreement was made the same year to supply a digital exchange to a small 700-person municipality in the archipelago of

southwestern Finland, Houtskär. This deal secured the future for the DX-200 switchboard, which eventually became an essential component in Nokia's GSM systems.

Meanwhile, competition with Salora pressured Nokia to improve its radiotelephones, and important technical improvements were made during the 1970s. For instance, Nokia introduced a duplex filter that allowed both parties in a radiotelephone conversation to speak at the same time – the earlier technology had only allowed one party to speak at a time, ending each statements with "over" to signal that the other party could respond. The challenge from the new NMT system that would be introduced in the early 1980s, however, seemed hard to handle. The three Finnish radiotelephone producers and Swedish Ericsson were not the only ones busily engaged in product development for the NMT system. The standard was several years ahead of developments elsewhere in the world, and most leading companies – including Siemens, Motorola, Hitachi, NEC, and Mitsubishi – had decided to enter in order to stay on the frontier.

Discussions about collaboration between Nokia and Salora had therefore started already in the mid-1970s, and in 1979 the two companies decided to establish a joint venture, Mobira, to pool their research and development resources. By this time, Salora was pressured by severe financial problems and there was little doubt that Nokia was the dominant partner, although formal ownership was shared equally. The initial aim was to capture a 50 percent market share in Finland and 20 percent in the other Nordic countries, but Nokia's CEO Kari Kairamo also argued that the company should not settle for market leadership at home, but instead aim for the European and world markets. To begin with, being big in the North meant being a global player, since the Nordic countries accounted for half of the world's cellular phone sales until the mid-1980s.

After the first few years, the challenges increased. Nordic proposals to adopt the NMT as a European standard were rejected in favor of national standards that largely aimed to protect national producers. Five major analogue systems emerged: in addition to the NMT (which was also adopted in Australia and several Asia-Pacific economies, as well as in Eastern and Central Europe), the main ones where the Japanese NTT, the US AMPS (which was adopted throughout the Americas and in parts of Asia), the UK TACS (which was used in Ireland, Italy, Spain, the Middle East, and the Far East), the German C-NET (also used in South Africa and Portugal), the Italian RTMS, and the French RC-2000. All of these systems were mutually incompatible. To become a global player, it was therefore necessary for Nokia (that had bought Salora's shares in Mobira already in the early 1980s) to adapt to a multitude of standards. It turned out that Nokia was the only European manufacturer to aim for a global market in the 1980s.[10] The large European companies Alcatel, Ericsson, and Siemens restricted their operations to the Nordic and Continental European standards, staying out of the AMPS and TACS markets (Pulkkinen 1997:104). The decision to compete head-on with Motorola and the large Japanese manufacturers from the very beginning was perhaps the clearest expression of the management's ambition to become a global company. It was believed that the tough competition and the need to adapt to all the different mobile phone standards would force the company to acquire the skills needed to succeed at a global scale.

[10] The brand name Mobira was changed to Nokia-Mobiar in 1986, and survived until 1989, when the telecommunications division began to use the Nokia brand, signaling the gradually increasing importance of this business area for the entire Nokia conglomerate.

In 1984, Nokia bought the rest of the consumer electronics producer Salora. The acquisition of Salora's assets – in addition to technology, Salora had also cumulated much competence in distribution and marketing of consumer electronics – was of great importance for Nokia's subsequent success in digital cell phones in the 1990s. In the mid-1980s, Nokia also entered into several other alliances in phone production. One of the most important ones was a joint venture in 1984 with US Tandy corporation, which marketed Nokia phones through its Radio Shack outlets. Nokia and Tandy also established joint production of cell phones in South Korea. Arguably, Nokia benefited greatly (and learned much) from Tandy's competence in cost-efficient production design and from its sales and marketing skills (Pulkkinen 1997:152). The acquisition of the UK-based Technophone in 1991 was another notable event. Technophone had production in the UK and Hong Kong, and an export network covering 40 countries, in many of which Nokia's own distribution system was weak. Morover, Technophone was considered a more efficient producer than Nokia, with shorter manufacturing times and lower labor utilization rates (Pulkkinen 1997:138).

Regarding telephone systems, Nokia had little in-house capability until the mid-1970s. The increasing demand for computerized telephone exchanges forced Nokia to send a research team to Alcatel in France to learn all that was needed to start license production of Alcatel's new digital exchanges in Finland. This meant that Finland suddenly had two companies developing competing digital exchanges: Televa with Olkkola's small research team, and Nokia with its French technology. The Finnish post and telecommunications authority argued that this was not feasible in a small country like Finland, and encouraged the two companies to collaborate. The result was a joint venture, Telefenno, owned in equal shares by Nokia and the Finnish state. Nokia's first demand was to discontinue Olkkola's digital exchange project so that Telefenno could focus on the existing Alcatel system. Only the existing contract with the small Houtskär municipality saved Olkkola's DX 200 project.

To begin with, Telefenno marketed three different systems: Telefenno's analogue exchange, Alcatel's digital exchange, and the DX 200 system, which was not yet in production. The choice between these three was decided largely by the Soviet preference for Olkkola's system. The domestic Finnish market was small, and the export potential in the tightly regulated Western markets was very limited: almost each country had a domestic producer that was protected by national preferences in public procurement. Hence, it was believed that the only opportunity to achieve economies of scale in production was to sell to the Soviet Union and other east block countries, and a preliminary export contract was signed already in 1977. The successful introduction of the DX 200 in Houtskär in 1980 confirmed that the choice to focus on the domestic solution had been right. A short time after the introduction of the exchange in Houtskär, orders came in from the telephone companies in Helsinki and Tampere, Finland's two largest cities. By 1984, DX 200 had 50 percent of the Finnish market. Nokia had not had any part in the development of the first NMT system that was introduced in 1981, but the second generation of the NMT, introduced in 1986, was largely based on the product. Nokia's GSM systems that took over in the early 1990s also include DX 200 as an essential component. Much of the development work for the GSM technology was done in collaboration with Alcatel, which had already established a relation with Nokia in the 1960s, and the German AEG.

The acquisitions and strategic alliances that were made during the late 1970s and 1980s were of central importance for Nokia's transformation from a raw material-based to

knowledge-based high-tech company. Another component was a broad push for human resource development within the company. One part of CEO Kairamo's internationalization program was to encourage as many as possible of Nokia's Finnish staff members to gain international experience by working in Nokia's foreign affiliates.[11] Another area was formal education. Kairamo was engaged in several ventures to improve the Finnish (and European) public education system, which was considered bureaucratic and old-fashioned. Among other ideas, Kairamo emphasized the need for broad international student exchange programs, stressed the need for continuous, life-long learning, and called for close collaboration between industry and academia. The most tangible result was the establishment of "Nokia University". This was a comprehensive and ambitious education program managed by several Finnish universities in collaboration with Nokia, with the aim to raise the formal competence of all Nokia employees by one level. Bachelors were encouraged to obtain Master's or Licentiate degrees, and Masters and Licentiates were expected to aim for Doctorate degrees. The increase in the level of human resources was essential for Nokia's ability to absorb and diffuse the skills and knowledge that were obtained through acquisitions and strategic alliances during this stage of Nokia's development.

Taken together, this meant that Nokia was well prepared for the future development of the global telecom market by the late 1980s. The company was, in competition with Motorola, the world's largest mobile phone producer during 1986-1989. Nokia had also been the first to present a mobile telephone that could reasonably fit in a pocket, the Mobira Cityman. About a quarter of the world's NMT telephone systems were supplied by Nokia. The company had developed or acquired both the technical skills and the marketing, sales, and distribution skills needed for a global breakthrough. But there were also problems. Mobile phones and telephone systems accounted for less than 15 percent of Nokia's turnover.[12] Cables, rubber products, and forest products were more important. The quantitatively largest part of Nokia's business, however, was consumer electronics, in particular TV sets, and information technology (e.g. computers). The drive to make Nokia had not been focused on telecommunications – it was hoped that Nokia would make its breakthrough as a television and computer producer. Instead, these business areas nearly caused the collapse of the entire company.

[11] Kairamo argued that not only Nokia but all of Finland should become more outward oriented, which made him a strong proponent of Finnish membership in the European Community long before this was a politically correct view. In this context, Bruun and Wallén (2000:37) report that Kairamo's vision was "to see a Finnish name in the passenger list every time an airplane crashes somewhere in the world".

[12] Thanks to the very lucrative exports of DX 200 telephone exchanges to the Soviet Union, it is likely that the share of profits was significantly higher, but there are no detailed data on Nokia's earnings from Soviet trade.

Televisions

Although Nokia's Electronics division had recorded some success in the development of computer terminals and monitors for industrial customers in the mid-1970s, Nokia turned down an offer to buy the debt-ridden television producer Salora in 1977. The main argument against the deal was that Nokia lacked experience from Salora's main business area: consumer electronics. The Electronics division was used to producing, marketing, and selling customized solutions to large industrial clients – mass production and marketing to hundreds of thousands of private customers were not on the agenda. However, times changed rapidly. Nokia's successful development of stationary and portable PCs introduced new marketing challenges. The success of the NMT system pushed Nokia in the same direction: although mobile phones were sold in tens of thousands rather than hundreds of thousands of units, most customers were private consumers buying a single set rather than companies or institutions buying larger amounts.

After the establishment of the Mobira joint venture in 1979, Nokia had also learned more about Salora. When a new offer to buy Salora came up in 1984, it was therefore decided that Nokia would enter the consumer electronics field at a large scale. Salora was not the only acquisition in this field. In rapid succession, between 1984 and 1987, Nokia bought three other television producers: Swedish Luxor, French Oceanic, and German Standard Elektrik Lorentz. By 1987, consumer electronics accounted for more than a quarter of Nokia's turnover Nokia was Europe's third largest and the world's ninth largest producer of television sets. As in the mobile phone business, Kairamo argued that it was imperative for Nokia to internationalize rapidly and to meet the main competitors face on.

Nokia's activities in computers and information technology expanded in the same way. The main acquisition in this area was the take-over of Ericsson Information Systems in 1987. The Ericsson division had itself acquired companies like Facit and Data-Saab some years earlier. The new company, Nokia Data, was one of Europe's largest computer companies, employing over 8,000 people and accounting for over 20 percent of the Nokia group's aggregate turnover.

The heavy investments in consumer electronics and information technology suggest that Nokia's management saw this as the company's future core business. This was a massive miscalculation. The European market for television sets was saturated, and in particular the German Lorentz was generating large losses. Other backlashes followed. Several leading members of the mobile phone division left the company in 1988, after a conflict with the CEO, Kairamo. Rumors about a merger with Volvo, or even a sale of the telecom operations, flourished. The return on the investments in the US market was falling. The suicide of Kairamo in December 1988 seemed to be the low point in the company's history. But things became worse.

Although Nokia's mobile phones and telephone exchanges generated substantial profits during the following years, the expenditures were also huge. The losses from the consumer electronics division were as large as the profits from the telecom side. In addition, massive R&D expenditures were needed for the development of the digital GSM system. The period from 1989 to 1992 can be characterized as a struggle for survival, which culminated in 1991. That year was not only marked by the beginning of the severe banking and financial crisis in Finland, but also by the collapse of the Soviet Union. This cut severely into Nokia's cash flow,

and forced the new CEO, Simo Vuorilehto, to extreme measures. In principle, all of Nokia was put up for sale. Thus, Nokia's Paper division was sold to the American JA/Mont in 1991. The Rubber division was also sacrificed. The tire production was sold to Japan's Sumitomo, while footwear production was spun off into a separate company. To cover the losses in the consumer electronics division, Nokia Data was sold to the UK-based company ICL (owned by Fujitsu) in 1991. The rest of the company was offered to Swedish Ericsson for a fraction of Nokia's present market value. Ericsson was willing to acquire Nokia's mobile phone and telecommunications divisions, but eventually declined the offer when it was told that consumer electronics – read televisions – must also be included in the agreement. All in all, Nokia shrunk from 44,000 to 22,000 employees during Vuorilehto's three and a half years as CEO, from the beginning of 1989 to middle of 1992, when he was succeeded by the current company president, Jorma Ollila.

Nokia's recovery: GSM and design

The turnaround for Nokia came with the breakthrough of the digital GSM technology in 1991 and a simultaneous turnaround in Nokia's mobile phone design strategy. Nokia had begun the development of its first GSM network (largely on the basis of the DX 200 switchboard) in 1987, when it entered into an alliance with Alcatel and AEG. The first orders came from France and Germany in 1988, with operators in Austria, the Netherlands, and Finland following the year thereafter. By 1990, new orders were flowing in. European integration was an important factor in enlarging the market for Nokia. The Single Market program stressed the need to raise the level of competition in Europe, and most countries licensed several operators for the new GSM systems, all of whom needed to set up their own networks. Increasing openness in public procurement also contributed to enlarge the international market.

The first of these new GSM networks was inaugurated in Finland in July 1991 by Nokia, and the first phone calls were made with Nokia's new digital cell phones. The following year, Nokia delivered GSM systems to 7 European countries as well as Australia, New Zealand, and Hong Kong. At the same time, orders for the old NMT systems continued coming in, mainly from the former Soviet Union and the East and Central European transition economies.

It was clear that the construction of new networks would also lead to increased demand for phones. At the end of 1991, there were an estimated 13 million mobile phones in the world, and Nokia's forecast was that the number would double each of the following years. More capacity was therefore needed. Nokia has already set up a new production line adjacent to the Lorentz factory in Bochum, Germany, and now British Technophone, Europe's second largest mobile phone producer, was also acquired. Several new products were also introduced.

Up until about this time, Nokia's advances in mobile phone production had largely been driven by technological progress. The size of phones had been reduced at a steady rate, from the large and clumsy "luggable" car phones of the early 1980s to "transportable" phones in the mid-1980s, and hand portable phones shortly thereafter. Each new model had been smaller than the previous, and therefore "more" mobile and portable. By the early 1990s, the size of mobile telephones had been reduced to a few hundred grams, with most manufacturers focusing their marketing efforts on the size and technical characteristics of their product. With its NMT 101 phone that was presented in January 1992, Nokia made a U-turn in its marketing strategy. Design and aesthetics were the new sales arguments, and Nokia started

targeting the mass market rather than the professional businessmen ("yuppies") that had been the standard customers.[13] Optional colored phone covers were introduced later the same year. The phone became a great success, and helped Nokia recover the market shares that had been lost during the preceding difficult years. Several new models of GSM telephones, typically with innovative design and strong focus on consumer needs, were introduced during the following years, and by the mid-1990s, Nokia had managed to transform the mobile phone from an exclusive capital good to a differentiated consumer good. To begin with, Nokia had little competition in the GSM phone market. Motorola maintained a focus on analogue technology several years longer than the European producers. A British attempt to establish a new manufacturer, Orbitel, failed. The toughest European competitor, Ericsson, focused more on systems than phones. Arguably, Nokia's head start in the GSM field gave it the advantage necessary to become the market leader for the remainder of the 1990s. Nokia has not recorded any losses since 1992.

Under Ollila's management, Nokia has continued focusing on telecommunications. The Cable division was sold in 1996 to the Dutch NKF Holding. The production of televisions was rationalized. In 1992, Nokia's television production had employed 6,000 people in 6 factories. By 1994, only two establishments remained, in Turku, Finland and Bochum, Germany, with some 3,000 employees. In 1996, the Bochum establishment was closed, and the Turku factory was finally sold, to Hong Kong-based Semi-Tech. The only part of Nokia's consumer electronics investment remaining in the company is a multimedia production unit in Turku. The four divisions that make up today's Nokia are Nokia Networks, Nokia Mobile Phones, Nokia Ventures Organization (financing various applications and software development for Nokia's products) and Nokia Research Center. The focus on telecommunications has been an enormous success. By the year 2000, Nokia had grown to more than 55,000 employees throughout the world. The stock market value of the company had increased from around 1 billion USD in 1990 to over 230 billion USD in 2000, totally dominating the Finnish corporate sector: Nokia alone accounted for over 60 percent of the value of the entire Helsinki stock market, and nearly a quarter of the country's exports.

Ollila also brought back some of the focus on human resource development and life-long learning that was lost during the crisis years before 1992. As a result of the structural changes in the company – the expansion of the telecom activities and the sale of everything else – Nokia has managed to raise the average education level (and reduce the average age) of its staff dramatically. The recruitment of skilled engineers to the expanding telecom divisions has been facilitated by close collaboration between Finland's universities and Nokia (as the former CEO Kairamo demanded). The risk that Nokia may concentrate its strategic activities outside Finland if it cannot find enough skilled professionals in Finland has been used to justify heavy investments in higher technical education. Nokia has also contributed significantly to the external financing of university research. In fact, while most academic areas have barely recovered from the budget cuts made during the Finnish crisis years in the early 1990s, there has been massive expansion in electrical engineering, information technology, and related areas.

[13] An illustration of this is Nokia's campaign for the NMT 101 in the US. "The Japanese made the smallest. The Americans the lightest. But the Finns made the best." See Pulkkinen (1997:119).

Success factors

Summarizing some of the determinants in Nokia's transformation from a raw material based to a knowledge based high-tech company, it appropriate to put particular emphasis on two factors that were noted already in the discussion of the forest industries' long-term sustainability. Firstly, it is clear that the acquisition of knowledge and skills has been of central importance for Nokia's breakthrough. Unlike the mature forest industry, where much of the skill and knowledge is created in the industry's knowledge clusters, the telecommunications industry has not developed any similar institutional structure yet. Nokia has therefore been forced to internalize these processes, systematically acquiring the skills needed for further stages in research and product development. At the same time as new knowledge has been brought into the corporation, there have also been comprehensive efforts to raise the educational level of existing staff. The establishment of *Nokia University* in the 1980s and the emphasis on individual development and life-long learning during the past two decades have been essential for the diffusion of new technology throughout the company.

It is not until the second half of the 1990s that the telecommunications industry in Finland is beginning to develop the institutions for a knowledge cluster. Very substantial public investments in relevant higher education, the establishment of formal linkages between universities and industry, and industry-financed research organizations are contributing to the creation of a knowledge cluster. It is possible that this pattern – with in-house knowledge development in the early stages, and more focus on institutions and collaboration in later stages of an industry's development – can be generalized from the Nokia case to other instances where new technologies and new industries are established.

The investments in education and knowledge creation have also led to the establishment of several production clusters focusing on telecommunications and information technology. Although many of the new companies that have been established in these clusters are presently sub-contractors to Nokia, they may in the long run create a strong enough competitive advantage to reduce Finland's dependence on the market leader, Nokia.[14] In fact, Finnish innovation and technology policy is today considered among the most advanced in the world, partly because of Nokia. Finnish authorities have for a long time been concerned about how the national business environment affects the competitiveness of individual dominant companies like Nokia, at the same time as the have encouraged diversification and development of innovations and new companies.

The other central factor has been internationalization. Being a small country, it has been clear from an early stage that the domestic market is not large enough to support the development of a high-tech industry like telecommunications. In particular, it has been clear that the small domestic (or Nordic) market would not be able to carry the costs for the increasingly expensive R&D programs necessary to remain competitive. The need to aim for the international market was therefore recognized early on. A side effect of the outward oriented strategy has been the need to measure up to foreign competition, which has pressured

[14] Nokia has itself been important in creating these clusters: the explicit aim of the Nokia Ventures Organization, one of the four divisions of today's Nokia, is to identify and support innovative companies in the telecom and information technology cluster.

Nokia to utilize its resources efficiently. It has also been a precondition for acquiring the technological assets necessary to establish its own capacity in technology development.

There are also some more specific determinants of Nokia's success story. Pulkkinen (1997:164-165) emphasizes the relatively slow development of the cellular mobile phone market, which made it possible for a relatively resource-poor newcomer like Nokia to acquire the skills needed for sustainable success in the industry. For instance, Pulkkinen shows that the market penetration rates of video recorders and televisions reached around 20 percent 10 years after their first commercial launch. For cellular mobile phones, the market penetration rate in the US was still only 5 percent in 1994, 10 years after its first commercial launch.

Some specific characteristics of the Finnish (or Nordic) home market have also been important. Finland and Sweden have constantly been the top countries regarding the market penetration of mobile phones, which has naturally benefited the local producers. One reason is the peculiar institutional setup in the telephone markets in Finland. Rather than having only one national telephone operator (as most other Western European countries until the 1980s), Finland had numerous local telephone companies, and telephone subscriptions very extremely expensive in many locations. For instance, in Helsinki, a subscription could cost thousands of USD still in the 1980s, with long waiting periods. The emergence of the cellular phone introduced an attractive alternative: although the early generations of handsets were very expensive, they were still less costly than regular fixed line subscriptions. Another advantage in the Finnish market was the prohibition for domestic cellular operators to subsidize the handset (in many other countries, a handset may even be included without extra cost when new subscriptions are made – the costs will of course be paid through higher monthly fees). This encouraged Finnish consumers to be more sensitive to the cost, design, and performance of the handset, forcing Nokia to focus on these characteristics much earlier than producers in other countries (where consumers were less discriminating because they did not buy their phones directly). Hence, although most product markets today are highly globalized, it seems that local conditions and the local environment are still important determinants of where and how new industries develop.

Having said this, it is appropriate to note that Nokia's breakthrough in telecommunications also illustrates the element of chance and unpredictability that is an inevitable part of most (if not all) great industrial success story. The investments in learning, education, and internationalization that were made in the 1970s and 1980s did not aim primarily at launching Nokia as one the main players in the international telecom market. Instead, Nokia's management had its eyes set on the great consumer electronics markets, where televisions and computers were the main products. Most of Nokia's acquisitions during the 1980s aimed to strengthen the consumer electronics division, and much of the research effort was directed to the same area, e.g. to develop the high-definition TV technology. Most of these investments turned out to be disastrous, costing Nokia billions of USD in losses until the mid 1990s when the production of televisions was sold off, but they contributed to the development of the skills and the knowledge – both in production technology, marketing, and design – that were necessary to excel in the mobile phone industry. The tentative conclusion from Nokia's experience is that success is perhaps a mix of systematic creation of skills and knowledge and random technological innovation. Although it is impossible, at least for relatively small players, to plan major technological breakthroughs in advance, it is possible to

create an environment where the firm is well positioned to adjust to changing conditions and to benefit from innovations and market opportunities.

5.2 Ericsson

Unlike Nokia, its Swedish competitor Ericsson had firm roots in the telecommunications business when the modern cellular mobile phone technologies began to emerge in the 1970s. The company was founded already in 1876 by Lars Magnus Ericsson to produce telephones and switchboards. It became a multinational already in the 19th century, with Finland and Russia as the first foreign customers for its telephone systems.

During the first three-quarters of the 20th century, Ericsson´s core business areas were consistently telephones and switchboards for fixed networks. This background generated, of course, some knowledge to be used in the development of the mobile telecommunications area. However, important knowledge and experience also came from another industrial areas where Ericsson entered at an early stage: radio technology. In 1919, Ericsson formed, together with ASEA (now ABB) and AGA (gas equipment), a company called Svenska Radio Aktiebolaget (SRA). Radio broadcasting was starting in Sweden and SRA´s initial business was to build radio transmitters (see Meurling and Jeans, 1994). In 1921, SRA also began to make radio receivers for home use and it started its own radio broadcasting service (which had to close when the government broadcasting company was formed). SRA continued to build radio receivers into the 1950s, but also became involved in other applications of radio technology, both civilian and military. An airborne transceiver was build as early as 1920 and television-broadcasting experiments were carried out in Stockholm in the mid-1930s.

In the early 1960s, SRA sold off the radio and television production operations and concentrated on the defense business, with radar, troop radio, and land mobile radio business. Ericsson was the driving force behind these changes and became increasingly involved in the company's management. In 1983, SRA became a fully owned company within the Ericsson group and changed its name to Ericsson Radio Systems AB, referred to as ERA.

In the development of the Swedish mobile phone industry, Ericsson was not alone. Another important player was "Televerket", the Swedish Telecommunications Administration, which was a state-owned company. In the 1950s, Televerket not only owned and operated everything in Swedish telecommunications, but was also manufacturing many of its own products. Televerket and Ericsson had over the years worked very closely together in developing telephone equipment, and this cooperation was also crucial in the development of Ericsson's mobile phone division.

Televerket and SRA jointly developed the first Swedish mobile phone systems already in the 1950s, to be set up in Stockholm and Gothenburg, and continued refining its radiotelephone technology throughout the 1960s and 1970s. Yet, the big breakthrough did not come until the establishment of the NMT system in the 1970s. Some enthusiastic engineers from Televerket and SRA had in 1969 proposed the idea of a Nordic standard in the mobile area and the managed to get the governments in Denmark, Finland, Norway and Sweden to accept their proposal. The pan-Nordic automatic cellular mobile telephone system, which was an analog system, took ten years to complete, and required a committed financier along the way. Ericsson was not very interested in investing in a "public good" (which is one way of looking at NMT and later generations of mobile systems), but Televerket was. With the

exclusive rights to the market, Televerket could spend ten years in planning and developing a new mobile network. As noted earlier, parallel development work was underway in Finland and other countries.

The second-generation wireless standard, the digital GSM system, was the one that would make Ericsson a real world player. A research group, once again jointly set up by Ericsson and Televerket (and four of Sweden's major technical universities) was created in 1977 and during the next ten years the specifications for GSM was developed. Again, parallel processes were set up by Nokia and its collaborators on the European continent. The "mobile group" inside Ericsson, however, was not well recognized by the top management and the rest of the company. ERA lived its own life inside Ericsson, run by a small group of entrepreneurs (internally called "cowboys") that nobody in the company cared about. As one quote says: "So we didn't really know much about ERA. And we didn't care!" (Meurling and Jeans 1994: 48). ERA was even located far away from the rest of the Ericsson group – in Kista, north of Stockholm – so there was no day to day contact between them. Despite the neglect by the headquarter, the development of GSM was completed in 1988, but mobile phones were still considered a side-show within Ericsson – a product line kept in being by the need to support sales of mobile systems.

In the 1990s, with the breakthrough of the GSM technology, the top management finally recognized ERA and the importance of mobile handset production and started to invest heavily in developing new equipment. R&D spending jumped.from 11 percent of sales in 1990 to 24 percent in 1991 (Åsgård and Ellgren 2000). As a result, Ericsson generate exceptional growth during the 1990s. Annual net sales increased from SEK 45.7 billion in 1990 to SEK 215.4 billion in 1999 and worldwide employment grew from 70,000 to 103,000 employees (Meurling and Jeans 2000:393). In 1990, the business area of mobile telephone systems (including mobile phones) accounted for some 25 percent of the company's sales; in 1999, this had risen to 40 percent. Today, Ericsson has become one of the worlds leading suppliers of cellular infrastructure, mobile telephones (where actual production has recently been outsourced), and switching systems and fixed networks, with operations in more than 140 countries.

As was the case for Nokia, it is clear that part of Ericsson´s success in the mobile telephone business was related to its rapid internationalization. By adapting its equipment to different standards used in various countries, it could begin to look abroad for expansion. It managed to enter the US market very early and in 1998, it had become one of the three top cellular infrastucture suppliers, with about 30 percent of the US market (Meurling and Jeans 2000). The US success was repeated in the UK, Italy, Germany and Japan and soon Ericsson became a major player all around the world. This, of course, resulted in very significant economies of scale as well as a very competitive entrepreneurial climate: the entry into the largest foreign markets also meant that Ericsson chose to compete directly with its main rivals.

Trying to generalize Ericsson´s success in the development of digital mobile systems and terminals, it possible to outline at least four other factors that have been important for its success:

- Ericsson's early experience with telephone and radio systems led to the accumulation of skills and competence in the relevant technology. At the same time, it should be noted that the lack of prior experience with consumer electronics and mass marketing may be one of

the reasons why Ericssson's performance in mobile telephone handsets is weaker than its success on the systems side.

- The close cooperation with Televerket, a state owned company, facilitated the long-term financing of the research and development costs for both the NMT and GSM technologies at their early stages of development, when risks were high and rewards were uncertain.
- Very substantial amounts have been invested in R&D once technology standards have been established.
- A few outstanding entrepreneurs have made significant contributions to technology development.

However, as in the case of Nokia, it is interesting to note that the outcome of all these efforts has not always been the intended one. When the entrepreneurs at Ericsson Radio System started to develop the NMT and GSM technologies, they were consistently ignored by the top management at the headquarters. The lack of interest in financing the development of the NTM system is perhaps understandable, considering the public good character of such a system. As soon as it is developed, many companies can deliver the equipment. But even after the system was invented, Ericsson was not very interested in the beginning to deliver the most modern equipment (Åsgård and Ellgren 2000). Instead, the focus of the company's operations remained in fixed line telephone systems. It was not until after Televerket threatened to buy the equipment for the NMT system from the Japanese that Ericsson reacted.

Earlier in this study we have pointed to the importance of clusters in the evolution of industrial competitiveness. It should be noted in closing that the Swedish success in the mobile telecommunication sector is also to a large extent a cluster phenomenon. When Ericsson Radio System moved to Kista in the 1980s, this was a remote and empty place north of Stockholm. In order to minimize risks and costs, all innovation companies like Ericsson outsource an important share of their operations, and in the wake of Ericsson´s move to Kista, several of its sub-contractors followed. Ericsson's success in the mobile phone industry meant that many of these firms were also able to expand at a rapid rate. Today, Kista has developed into one of Europe´s largest clusters in information and telecommunication technology, where many of the institutions necessary to develop a knowledge cluster of the type seen in the forest industry are presently emerging.

6 SUMMARY AND CONLUSIONS

The purpose of this paper has been to describe and analyze the evolution of industrial competitiveness in Sweden and Finland in a long-term perspective. Chapter 2 looked at the foundations for industrial take-off in Sweden, with some focus on the development of institutions for the creation and dissemination of the skills and knowledge needed in the emerging industrial sector. Chapters 3 and 4 narrowed the focus, and examined the development of the Swedish forest industry until the early 1990s, with particular emphasis on the factors allowing the industry to remain competitive for more than one century. Chapter 5 narrowed the focus further, turning to a discussion of the emergence of Finnish Nokia and Swedish Ericsson as market leaders in the high-tech mobile telecommunications industry. The emphasis here was on the transformation of Nokia from a producer of simple raw material based goods to a knowledge-based high-tech company.

Although the different chapters have examined industrial development at different levels of aggregation and at different points in time, it is still possible to point to some common findings and results. These include the following:

- Institutions and institutional reforms have played an important role for growth and development. Several examples have been highlighted throughout the report. For instance, the land reforms in the early 19th century were essential for the introduction of new technology in agriculture: the subsequent increase in agricultural productivity was a prerequisite for industrialization. Similarly, the introduction of laws to guarantee re-planting and to limit the concentration of forest ownership in the early 20th century were essential to create a sustainable resource base. More recently, various environmental regulations have forced the Nordic corporate sector to take a leading role in the development of environmentally sustainable production technologies. The role of various public or semi-public institutions to promote research and knowledge diffusion has also been emphasized repeatedly.
- The acquisition of relevant skills and knowledge has been an essential success factor. The Swedish industrialization process – as well as the early development of the forest industry – relied to a great extent on foreign technology and capital. Foreign direct investment in Sweden was important, but the international experience of Swedish entrepreneurs and innovators also contributed significantly. The foreign technologies that were transferred to Sweden were rapidly absorbed in domestic industry, since the level of education was relatively high. Over time, an increasing share of the forest industry's technology has been created in the sector's knowledge and skill cluster. This is made up of a multitude of institutions and organizations involved in the creation and dissemination of knowledge and skills. We have argued that this cluster is of essential importance for the Swedish forest industry's ability to adjust to a continuously changing competitive environment. In the telecommunication sector, the acquisition of knowledge has largely taken place at the firm level. Ericsson's long experience in the telecom business allowed it to develop much of the necessary competence within the corporation, although collaboration has become increasingly important in recent years, as technology has become more sophisticated. Nokia's limited experience in the telecommunications field forced it to acquire a significant share of the necessary assets by buying up local as well as foreign companies, but in-house training and education have been of central importance for Nokia's ability to absorb new technology. Both companies have also benefited greatly from public investments in higher education and research.
- Internationalization has been essential at all levels of development. The first stages of Swedish industrialization were clearly export-led, driven by the demand for forest products in Great Britain and other parts of Western Europe. In the forest industry, in particular the large-scale paper and pulp industry, growth has been based on access to the European and international markets. Internationalization has also been essential for the Nordic telecom producers to finance the large fixed costs related to research and development. In addition, a relatively open trade regime has been necessary for the acquisition of modern technology, both at the early stages of industrialization and in today's high-tech industries: many of the core patents in the telecom sector are held by US, Japanese, and continental European producers. The need to adapt technologies to

international standards and the continuos competitive pressure from other international producers have also been important driving forces in many industries, not least telecommunications.

- The technological innovations underlying both Nokia's and Ericsson's breakthroughs were possible only thanks to long-term investments in R&D programs. In Nokia's case, early orders from the Soviet Union were essential to secure financing for technology development; in the case of Ericsson, support from the state-owned Televerket was instrumental. At the same time, it is clear that focused long-term research projects are high-risk ventures. Neither Nokia nor Ericsson prioritized the R&D programs that eventually generated the innovations necessary for the successful development of the GSM technology. For instance, Nokia's primary investment emphasis was instead on projects that eventually failed, such as the HDTV program. An essential success factor has therefore been flexibility: both companies were able to shift rapidly from other activities to the mobile phone industry when it took off in the early 1990s.
- While most of the industry's early development was based on in-house assets, it now appears that a knowledge and skill cluster is emerging in the telecommunication industry. It is possible that this suggests a general pattern in the development of new technologies or industry sectors. Intangible, firm-specific assets dominate the early stages of a technology's life cycle, whereas an increasing share of the essential knowledge and skills are of a "public good" character at later stages. Knowledge and skill clusters can arguably not emerge unless a large share of the essential knowledge and skills are available to most participants in the cluster. A central determinant of how "public" the knowledge and skills are may be the extent to which the public education system is involved the industry. In the forest industry, it obvious that the public higher education system plays a central role: this may be underway also in the telecom sector, as a result of the increased investments in relevant higher education.

A tentative conclusion from this report is that an industry's success is a mix of systematic knowledge creation and random technological innovation. It is not possible to systematically generate major technological breakthroughs, but it is possible to create an environment where firms or entire industries are well positioned to adjust to changing conditions and to benefit from innovations and market opportunities. In mature, raw material based industries – like paper or wood products – the innovations are likely to be incremental, and a large share may be related to changes in demand or international competition, rather than major changes in production technology. A solid knowledge base is, nevertheless, necessary to ensure the necessary flexibility and adaptability. In younger industries – like telecommunications – fundamental changes in technology will be more common, and the main challenges are related to the ability to acquire the technical skills necessary to remain competitive. Although mergers and acquisitions as well as various kinds of strategic alliances are likely to be important in these sectors, a solid knowledge base within is also essential to facilitate the dissemination and implementation of new technologies throughout the firm or industry.

These conclusions suggest an important role for public policy. The experiences discussed in this report suggest in particular that public policy should provide an appropriate institutional framework to facilitate the sustainable use of land, raw materials, and other resources and promote *learning* and *internationalization*. While most successful companies invest heavily in in-house programs for knowledge creation and human resource development,

it is essential that the public education system can also provide graduates with appropriate skills and knowledge. This is not only a prerequisite for successful life-long learning in the business sector, but may also provide a common knowledge base for the development of various networks and clusters in industry. Support for the development of industry level organizations, as outlined in the discussion of the Swedish forest industry's knowledge cluster, is also likely to be useful. Direct support to in-house commercial research, on the other hand, is more questionable. Although Ericsson's experience points to successful collaboration between the company and the Swedish public sector in the development of its NMT and GSM technologies, it is often a costly and inefficient way to promote a competitive business environment. One problem is that direct state intervention distorts competition. Another problem is the risk inherent in any long-term R&D project: failures are more likely than successes.

Internationalization is best supported through open and outward-oriented trade policies. It has repeatedly been noted that access to export markets is essential for small-country producers, but it should also be pointed out that access to imports at competitive cost is perhaps equally important. Few countries can rely exclusively on domestic resources for economic development. A significant share of the cheapest intermediates and best technologies for any industry, even in relatively simple raw material based sectors, is likely to be found abroad. Outward oriented trade regimes will promote the flow of information about these resources, both through trade and foreign direct investment.

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