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NOKIA IN THE FINNISH INNOVATION SYSTEM

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ABSTRACT: The report looks at Nokia in the Finnish innovation system. Nokia serves both as a user and as a producer in the innovation system. Nokia has had a remarkably positive impact on Finland's very high ratio of R&D expenditure to GDP. Moreover, at least partly due to Nokia, Finnish exports of high-tech products are notably greater than high-tech imports. Nokia co-operates with companies, universities and research institutes. Our interviews suggest that, due to co-operation, knowledge has flowed from one party to another. In addition to R&D co-operation, recruitment from universities to companies and vice versa has served as another important knowledge transfer channel. Although R&D co-operation has functioned well in most cases, in some cases problems have emerged. According to some of our interviewees, the allocation of intellectual property rights (IPR) has been troublesome. Another concern was related to the retaining of universities' high knowledge level in the future.

KEYWORDS: Nokia, innovation system, Finland, R&D, research and development, education, knowledge, technology.

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TIIVISTELMÄ: Tutkimuksessa tarkastellaan Nokiaa osana Suomen innovaatiojärjestelmää. Nokia toimii sekä innovaatioresurssien käyttäjänä että uusien resurssien tuottajana. Nokialla on suuri vaikutus siihen, että Suomen tutkimus- ja tuotekehityspanostukset suhteessa BKT:hen on maailman kärkiluokkaa. Yhtiö on myös keskeisesti vaikuttanut siihen, että Suomen korkean teknologian tuotteiden ulkomaankauppa on tuntuvasti ylijäämäinen. Nokia tekee yhteistyötä niin yritysten kuin korkeakoulujen ja tutkimuslaitostenkin kanssa. Tämän tutkimuksen aikana tehdyt haastattelut viittaavat siihen, että yhteistyön seurauksena tietotaitoa on levinnyt eri osapuolille. Tutkimusyhteistyön lisäksi rekrytointi korkeakouluista yrityksiin ja joissain tapauksissa yrityksistä korkeakouluihin on toiminut tärkeänä osaamisen siirtokanavana. Vaikka tutkimus ja tuotekehitysyhteistyö on toiminut pääasiassa hyvin, joissain tapauksissa siitä on myös aiheutunut ongelmia. Osa haastatelluista koki erityisen ongelmalliseksi aineettomien oikeuksien (IPR) jakautumisen. Toinen huolenaihe koski korkeakoulujen osaamistason säilyttämistä tulevaisuudessa.

AVAINSANAT: Nokia, innovaatiojärjestelmä, Suomi, T&K, tutkimus- ja tuotekehitys, koulutus, osaaminen, teknologia.

FOREWORD

Nokia has a significant impact on the Finnish economy. The company's operations affect the Finnish exports, gross domestic product, and their growth rates.

In addition to these, Nokia has an important role in the Finnish innovation system. To evaluate this role, in this study we have examined Nokia's influence on other companies and universities as well as on public sector income and expenditures. Both official statistics and interview material have been used as source data.

However, we have only begun the research in this interesting area. The objective of further research is to analyse the interviews more deeply and thus obtain more detailed knowledge of the interaction between Nokia and the rest of the society.

We would like to thank Petri Rouvinen, Pekka Ylä-Anttila and Ari Hyytinen for their valuable comments. We also thank all the interviewees and other people, who have helped during the course of this research. We are also grateful to Lotta Väänänen for translating this study (published in Finnish as ETLA keskusteluaihe no 799).

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June 2002,

Jyrki Ali-Yrkkö ja Raine Hermans.

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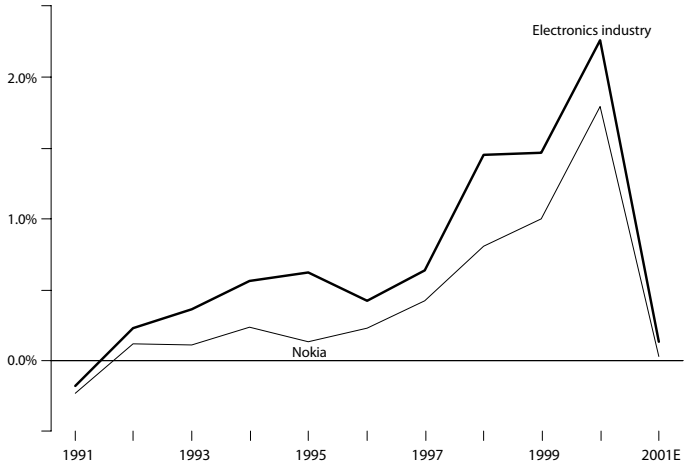
1. INTRODUCTION

This report examines Nokia's role in the Finnish innovation system. Innovation system refers to the operation and interaction of universities, research institutions, other public sector organizations, and private businesses, which together influence the creation, diffusion, and utilisation of novel know-how.

Nokia has a two-way role in the Finnish innovation system. On one side, Nokia utilises resources from the innovation system. At the same time the company produces innovation resources that diffuse outside the company.

In Finland Nokia has benefited from innovation resources such as the educational system, skilled labour, and Tekes' research and development (R&D) funding, to name a few. Similarly, Finland has reaped benefits from Nokia. The latest knowledge in the field has passed onto universities through Nokia. Know-how has also spread to Nokia's partners owing to its policies of networking. Nokia's international research projects have also gained in significance as a result of the company's global mode of operating.

Figure 1.1. Effects of Nokia and the electronics industry on the Finnish GDP growth.



Authors' own calculations (Sources: Nokia Oyj, Statistics Finland, National Board of Customs).

NOKIA'S IMPACT ON THE FINNISH ECONOMY

In the past ten years, Nokia's role in the Finnish economy has grown in importance. Nokia's share of the total Finnish exports is currently close to one fourth. This figure refers to Nokia's direct exports, which go through its own accounts. It, therefore, does not include exports of Nokia's partners.

Nokia has a significant impact on the Finnish gross domestic product (GDP), and its fluctuations. In 2001 Nokia's share of the Finnish GDP was 2.8 percent. Changes in GDP further emphasize Nokia's impact. In 2000 Nokia's contribution, that is its effect on GDP growth, was 1.7 percentage points, when the total GDP growth was 5.6 percent. [1]Consequently, Nokia was responsible for almost one third of the total GDP growth in 2000. Conversely, in 2001 the Finnish GDP growth stayed below one percent and Nokia's contribution to this growth was close to zero (figure 1.1).

Nokia's R&D spending has grown rapidly. In 2001, Nokia's share of the total R&D spending in Finland was close to one third, and approximately 47 percent of the total private sector R&D spending. Moreover, taking into account Nokia's foreign R&D investments, the group's R&D spending was close to 18 billion FIM (3 billion Euros) in 2001. The magnitude of this figure becomes evident when comparing it to the total private sector R&D spending in Finland, which was slightly above 21 billion FIM (3.5 billion Euros) in 2001.

Nokia's impact is therefore highly significant in comparison to the Finnish domestic product, GDP growth, value of exports, and R&D spending. On the other hand, its effect on employment is less significant. The company has about 24 000 employees in Finland, which represents about 1.1 percent of the total Finnish workforce. However, in addition to this direct effect, Nokia also has indirect influences on employment.

The significance of Nokia's position in the Finnish economy is rare even in international comparisons. Although some relatively large companies exist in other small countries as well, they tend to face different circumstances. Usually these large companies operate in low technology industries. In Finland, the situation is quite contrary. Nokia operates in a technology-intensive field, which requires large research and development investments.

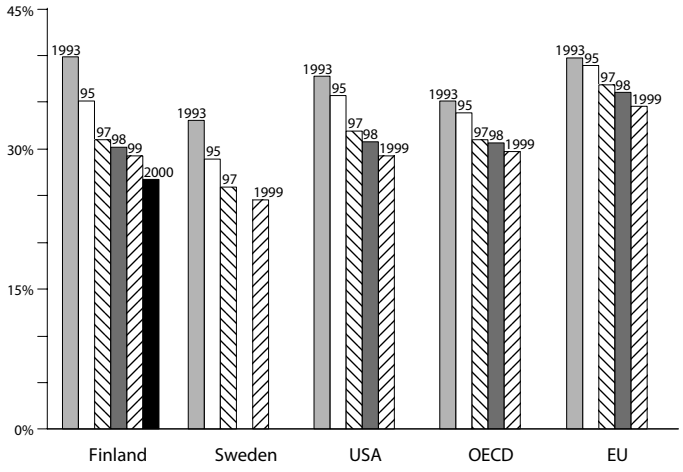
PUBLIC FUNDING OF R&D

In all industrialized countries the public sector takes part in research and development activities. R&D activity is seen to be a significant promoter of potential future economic growth. The role of the public sector in R&D activities varies by country (figures 1.2 and 1.3).

The share of public funding of the total R&D spending varies considerably by country and region. In 1999, on average almost 35 percent of R&D expenditures in the EU countries was financed by the public sector. This is clearly more than in the whole OECD area on average, where the respective figure in the same year was 30 percent. In Finland and in Sweden the share of public finance is even less. According to the latest information available, the public sector funds about one quarter of R&D in Finland and in Sweden. The public sector finances both its own R&D activity (e.g. universities and government owned research institutions) and the private sector research activities (figure 1.3).

There are big differences between countries and regions in the share of public funding of the private sector R&D. The comparison is made more difficult by the fact that in some countries the government funds the private sector development of military technologies.

Figure 1.2. Share of public finance of total R&D spending in 1993-2000.



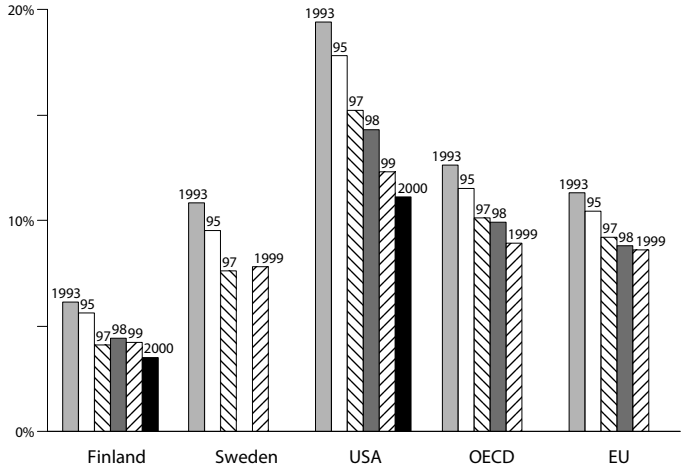
Source: OECD Main science and technology indicators.

Contrary to the previous comparison in figure 1.2, here the share of public finance (of the private sector R&D) in the EU countries is less than the OECD average. Therefore, on average the companies in the EU countries self-finance a larger share of their R&D than in the rest of the OECD countries. A second important observation concerns the role of the public sector in the United States. There the public sector finances evidently more of the private sector R&D than in the rest of the countries. This is partly due to the public financing of development of military technology in the private sector. It may also be a signal that in the United States companies are encouraged to invest in higher risk R&D projects.

In Finland and in Sweden the public sector finances a significantly smaller share of the private sector R&D than in the OECD and EU countries on average. In Finland only just over 4 percent of the private sector R&D is financed by the public sector. Excluding Nokia from the figures, in 2000 the share of public sector funding of the total private R&D expenditure would be approximately 5.8 percent.

Both of the above comparisons show that the private sector has a clearly more central role in research and development financing in Finland than in many other countries. On one hand, this can be seen as Finland's strength and a signal that companies are willing to invest in risky projects with own finance.

Figure 1.3. Share of public finance of private sector R&D spending in 1993-2000.



Source: OECD Main science and technology indicators.

On the other hand, one may ask whether the private sector R&D projects are directed towards too short-term R&D investments. Projects financed by the public sector are often longer-term ventures, which aim rather at research than product development. The potential benefits from these projects are only reaped over a long period of time.

RESEARCH OBJECTIVES

This study aims to provide answers to the following questions:

- How has Nokia influenced the know-how and innovation activities of universities in Finland?
- How has Nokia influenced the know-how and innovation activities of other companies?
- How has the public sector promoted Nokia's innovation activities?
- What has been the role of the public sector in Nokia's R&D projects?
- What is the impact of Nokia's partner network on innovation activities?

RESEARCH METHOD AND STRUCTURE OF THE REPORT

A variety of data sources will be used to answer the research questions. One important data source is official statistics. These are utilised especially when looking at the financing of R&D, and the foreign trade of high technology in different countries.

The study also makes use of information in the book on Nokia's history (Häikiö 2001) and in its annual reports. In addition to the book on Nokia's history, numerical data relating to Tekes has come directly from Tekes.

In addition to these, interviews conducted while this research was going on are used as qualitative data. There were 42 interviews made, of which 19 were with employees of Nokia, 13 with representatives of research institutions or universities, and 10 with people employed by companies cooperating with Nokia in R&D. All of the interviewees at Nokia were involved with R&D activities. The interviewees from the universities, research institutions and Nokia's partner companies had been part of R&D projects with Nokia. The interviews were conducted in December 2001 and January-March 2002. To protect the anonymity of the interviewees, their identities are not published.

The interviewees being quoted directly are divided into three groups[2]:

– R&D manager, Nokia,
– R&D manager, Nokia's partner company,
– Professor, university/research institution.

Interviews are especially utilised where quantitative data is not available or is not measurable. In addition, interviews are used to deepen the analysis of numerical information.

The report is structured as follows: Chapter 2 moves on to examine "what Nokia has got from Finland". Benefits reaped by Nokia in terms of the innovation system form the framework for analysis. Chapter 3 looks at the other side of the matter, that is "what Finland has got from Nokia". Chapter 3 provides a summary and conclusions.

2. FINLAND'S INVESTMENTS IN NOKIA'S GROWTH

R&D FUNDING BY TEKES

Tekes (the National Technology Agency) is an organisation under the Ministry of Trade and Industry (MTI), through which the government supports and funds technology development in Finland. In the 1990's Tekes has increasingly directed its funding (grants and loans) towards companies in the information and communication technology industry. In 2001 about one-third of the funding by Tekes was targeted at the information and communication industry.

Nokia, too, has received public funding for its R&D activities. The amount of Tekes finance received by the company has varied considerably. When in 1969 Nokia received 200 000 FIM (34 000 Euros) from the Technology Office of the Ministry of Trade and Industry (Tekes' predecessor before its founding), in 1999 the respective figure was 108 million FIM (18 million Euros) Tekes-funding. In 2000 Nokia received Tekes-funding worth 47 million FIM (8 million Euros).

In the 1990's Nokia received more Tekes-funding in nominal terms than in the previous decades. On the other hand, when compared to Nokia's total R&D expenditures, the share of Tekes finance has decreased significantly (table 2.1). Thus, we can conclude that while the amount of funding to Nokia by Tekes has increased, Nokia's own expenditure has grown more strongly.

In the 1970's the share of the MTI Technology Office (Tekes' predecessor) funding of Nokia's total R&D expenditures was 7 percent on average. In the first two years of the 1980's Tekes funding gained a significant position in the finance of Nokia's R&D. In 1980 over 25 percent of the company's total R&D was financed by Tekes, and in the following year the share remained at about 15 percent. After these peak years, the share of Tekes' funding of Nokia's total R&D spending decreased significantly.

During the recession in the beginning of the 1990's the importance of Tekes' funding grew again. With the support of public funding Nokia Research Center managed to sustain the

continuity of its research activities even through the most difficult years of the economic slump (Häikiö 2001, pg. 96). In the second half of the 1990's the share of Tekes finance of Nokia's total R&D expenditure has been around 1.5 percent on average. When the amount of Tekes finance is compared relative to Nokia's R&D activities in Finland, then the share of Tekes finance is slightly below two percent over the same time period.

In the 1990's, most of the Tekes funding received by Nokia has been directed towards Nokia Research Centre projects. In the years 1993-2001 the share received by the Research Centre of the total Tekes finance to the whole Nokia group was 55 per-

Table 2.1. Nokia's R&D activities and Tekes funding.

	Nokia's R&D exp., FIM mill.	Percent of total sales	Tekes funding, FIM mill.*	Percent of Nokia's R&D exp.
1969	9.0	1.6 %	0.2	2.1 %
1970	12.0	1.6 %	0.9	7.8 %
1971	15.0	1.9 %	0.8	5.3 %
1972	20.0	2.3 %	1.6	8.0 %
1973	29.0	2.7 %	2.5	8.5 %
1974	38.0	2.3 %	2.9	7.7 %
1975	47.0	2.8 %	2.4	5.1 %
1976	55.0	3.1 %	2.4	4.4 %
1977	55.0	2.9 %	5.0	9.0 %
1978	59.0	2.3 %	4.1	6.9 %
1979	72.0	2.3 %	4.0	5.6 %
1980	95.0	2.1 %	25.0	26.3 %
1981	172.0	3.0 %	25.0	14.5 %
1982	212.0	3.3 %	10.0	4.7 %
1983	267.0	3.8 %	17.0	6.4 %
1984	355.0	3.8 %	28.0	7.9 %
1985	456.0	4.1 %	8.0	1.8 %
1986	539.0	4.5 %	23.0	4.3 %
1987	581.0	4.2 %	26.0	4.5 %
1988	795.0	3.6 %	36.0	4.5 %
1989	950.0	4.2 %	18.0	1.9 %
1990	1164.0	5.3 %	30.0	2.6 %
1991	933.0	6.0 %	47.0	5.0 %
1992	1113.0	6.1 %	57.0	5.1 %
1993	1472.0	6.2 %	73.0	5.0 %
1994	1900.0	6.3 %	64.0	3.4 %
1995	2531.0	6.9 %	65.0	2.6 %
1996	3514.0	8.9 %	62.0	1.8 %
1997	4560.0	8.7 %	74.0	1.6 %
1998	6838.0	8.6 %	79.0	1.2 %
1999	10442.0	8.9 %	108.0	1.0 %
2000	15375.0	8.5 %	47.0	0.3 %

* Based on Tekes' funding decisions. Data before 1983 is from the Ministry of Trade and Industry Technology Office.

Authors' own calculations (sources: Nokia's annual reports, Häikiö (2001).

cent on average (Häikiö 2001). As a summary, we can conclude that although the amount of finance granted to Nokia by Tekes has increased in nominal terms in the 1990's, its share of Nokia's total R&D expenditure has decreased.

In many interviews, it was stated that the effects of Tekes funding reflected on the length and determination of the R&D projects. One interviewee described the impact of this finance as follows:

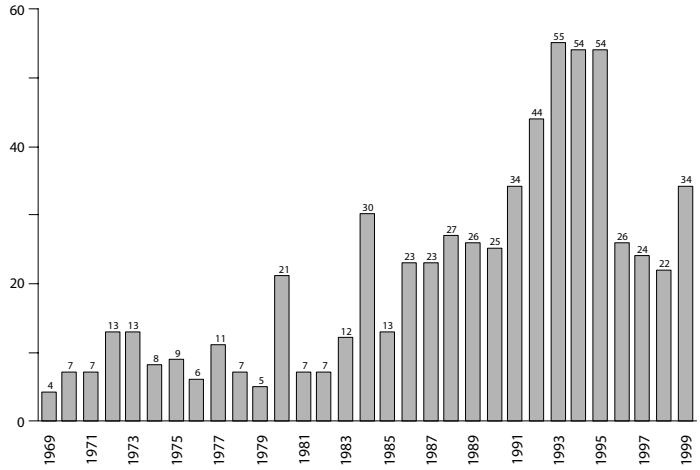
> Tekes is a binding force, which stabilises research activity in this turbulent environment. If a decision has been made to start on something, it is out of the question to change direction or start doing something else. It does not do, because we have a deal [with Tekes]. (R&D manager, Nokia)

It is difficult to estimate how much of Nokia's R&D is research and how much is product development. It is, however, very likely that most of the company's R&D is applied research and development activity. Basic research is mostly done at Nokia Research Centre and in cooperation with universities.

The nominal amount of Tekes funding to Nokia has increased at the same time as the number of R&D projects has increased (figure 2.1).

In the 1970's, Nokia received Tekes funding for an average of 9 projects annually. In the 1980's, the number of projects receiving Tekes funding grew to nineteen on an annual basis. In the 1990's the number of projects receiving Tekes funding has con-

Figure 2.1. Number of Tekes projects at Nokia annually.



Source: Häikiö (2001).

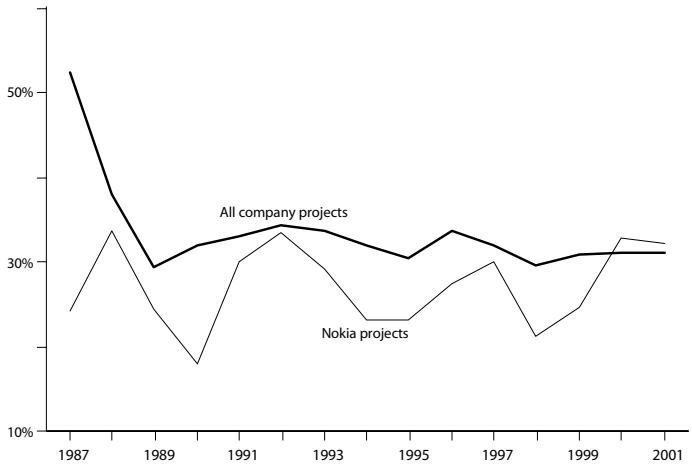
tinued to grow. On an annual basis, an average of 37 projects at Nokia have received R&D funding from Tekes. Taking inflation into account, the average size of Tekes' Nokia projects has stayed almost the same with the exception of two time periods. A number of extensive projects were initiated over the turn of the 1970's, which, for example, laid the basis for the GSM technology and developed the IT systems. The second exception to the even size of projects is the growth in size that took place at the end of the 1990's. This is partly a result of the TLX and ETX research programmes (see chapter 3.1) initiated by Tekes, in which Nokia has been involved.

Tekes finances only a part of the costs of companies' research and development projects (so-called company projects of Tekes). Usually, most of the costs of company projects are financed by the company or group of companies. Figure 2.2 examines the share of Tekes finance in all company projects, and separately in Nokia projects.

Figure 2.2 shows that Tekes' share of finance in company projects has decreased towards the 1990's. Tekes' financing share of the company projects has been 32 percent on average. Around 70 percent of the finance has come from other sources, mainly from the companies themselves.

The share of Tekes finance in Nokia projects has been smaller than in company projects on average. In the 1990's Te-

Figure 2.2. Share of Tekes finance in all company projects and Nokia projects.



Data source: Tekes.

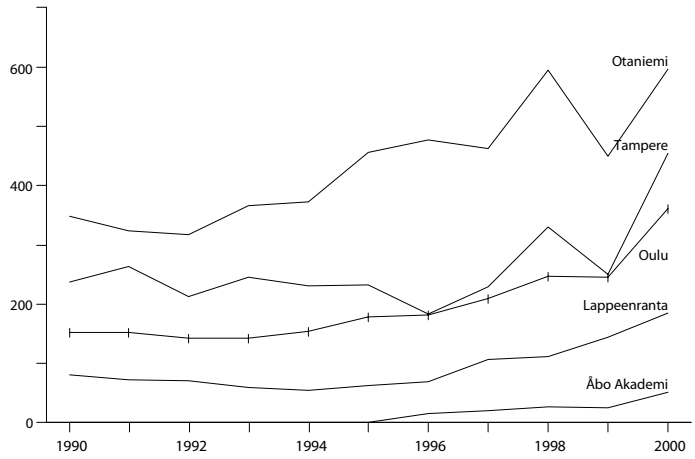
kes financed 26 percent of Nokia projects on average, while the share of other finance, primarily Nokia's own share has been about three fourths of the project's total costs. In 2000 and 2001 Tekes' share of finance in Nokia projects has exceeded 30 percent, and has thus been above the average share of financing in company projects. Historical analysis shows that Tekes' share of Nokia project finance has varied a great deal, and thus it is likely that the current rise is only temporary.

HIGHLY QUALIFIED PERSONNEL FROM FINLAND

As the significance of research activity has grown, Nokia has tightened its links to universities and research institutions. As also the need for highly skilled labour has increased, Nokia has attempted to influence the level and direction of higher education (Häikiö 2001, pg. 87).

Nokia's role in education politics became more effective as the need for qualified personnel grew in the 1990's (Häikiö 2001, pg. 98). Through the Federation of Finnish Electrical and Electronics Industry Nokia strived to increase the number of university starting places available in the fields of electronics, telecommunications, and information technology. In many universities the number of study places have been increased (figure 2.3).

Figure 2.3. Study places in fields of electronics, telecommunications and information technology in universities in Finland.



Data sources: University of Technology, study office. Statistics on applications for technical sciences.

The number of study places available in technical education has increased at an average annual rate of 2.5 percent over the 1990's. In the beginning of the 1990's, the number of places was reduced due to the state of the public finance. At the same time the number of people willing to study was above the normal level, because the demand for labour fell considerably during the recession. Student potential was left unused. Because the average time to graduate from a technical university is 6-7 years, the graduation of those students who started in the beginning of the 1990's took place during the fastest growth phase of the economy. At the end of the decade, as the Finnish economy had fully recovered, there was a shortage of technically skilled labour.

In 1997, Nokia estimated that over the years 1997-2000 the need for technically skilled labour would be about 6500 people (Häikiö 2001). This figure is about two thirds of all the graduates (in Finland) in fields that Nokia considers relevant. In the fields that are central to Nokia, i.e. electronics, information technology and telecommunications, the number of university starting places available began to grow in the middle of the 1990's. From the mid 1990's to the year 2000, the number of places increased most in the large universities in Otaniemi, Tampere and Oulu in absolute figures. Then again, the relative growth in the number of starting places was highest in the smaller universities, in Lappeenranta and Åbo Akademi.

Nokia has played an active role in research projects with the universities of technology. In addition to the acquisition of research information, the projects have served as an important form of recruitment. Nokia has obtained novel know-how through research and development projects focused on its own fields of interest.

> Especially during these times after the mid-1990's we [at Nokia] had very frequent recruitment and then all one could get was students about to graduate, or even third or fourth year students, with whom we usually or almost every time ended up with thesis work here. (R&D manager, Nokia).

> We do have 43 nationalities here [at Nokia Research Center] and quite many of them have come through university networks and university cooperation. (R&D manager, Nokia).

FINLAND AS THE TEST LABORATORY FOR LATEST TECHNOLOGY

The government had a large role especially in the early phases of the development of mobile communications. At the turn of the 1960's, Nordic postal and telecommunication companies began planning a pan-Nordic automatic mobile communication network, NMT[3]. Open standards and equipment compatibility were focused on in the planning of the NMT. These actions aimed at promoting competition between equipment manufacturers (Häikiö 1998, pg. 32).

Nordic Telecommunications Administrators therefore guaranteed competition between manufacturers, from which the whole industry subsequently has benefited. In the beginning of the 1980's the Nordic NMT network remained as the world's most extensive mobile network measured by the number of users (Paija 2001). It was also a network where roaming had been contracted for, and a number of operators from various countries took part. Nordic equipment manufacturers got invaluable experience from manufacturing NMT networks and phones, which they have later utilised.

The government also had a significant role in the creation of the pan-European GSM standard[4] in the turn of the 1970's. In Finland, the Post and Telegraph Office financed GSM research by industry players and technical universities, the first of which was conducted in 1981 (Häikiö 1998, pg. 39). Also Tekes financed the activities, the benefits of which were only realised years later.

> The first large programme by Tekes was The Convergence of Information Technology [part of a larger whole called "The Development Programme for Information Technology"] in 1984. …In that programme, those protocol and database tools were made by teams, which went to Nokia and made GSM. (Professor, university/research institution).

In 1987 thirteen European countries signed a contract where the implementation of the GSM system was agreed on.

In addition to standardizing these systems that cross borders, governments had another important role in the development of mobile communications, which was the freeing of competition. Finland among other countries deregulated the telecommunications industry, which led to more open international competition.

As a summary we can state that Finland's early presence in the international mobile networks has created a good test field

for Nokia. Firstly, NMT was the world's first automatic mobile network covering several countries. The experiences gained from it could later be utilised. Secondly, the step-wise process to free competition in the telecommunications industry led to the founding of Radiolinja Oy. In 1991 Nokia sold its first GSM network and the customer was Radiolinja. Radiolinja opened its GSM mobile network as the first operator in the world, and the event received a great deal of publicity in the world (Häikiö 1998, pg. 130). Opening the world's first commercial GSM network brought Nokia an important reference for future.

The research investments in the beginning of the 1980's have benefited Finland through the success of the GSM. One interviewee presented it as follows:

> If we looked at where all those people came from, and then the tools and the know-how, which were developed in the 1980's, Tekes' programme [The Convergence of Information Technology] has given birth to incredible results, combined with the business know-how and the competence in NMT-centres and terminal equipment that Nokia then had. It was the combination of these competencies. …And the result of this combination is now visible to us. These would never have been accomplished without Tekes. (Professor, University/research institution).

In addition to the development of NMT and GSM, Finland has probably acted as a pilot country for Nokia in other ways too. In Finland the mobile phone penetration has been one of the highest in the world for a long time. One can presume, that the high penetration has partly enforced Nokia's beliefs that it will rise to similar figures in the rest of the world. Faith in high growth rates has possibly also ensured that the company has invested enough in research and development.

3. NOKIA'S INFLUENCE ON THE FINNISH INNOVATION SYSTEM

TRANSFER OF KNOW-HOW TO OTHER COMPANIES

Nokia's own operations are reflected on other companies in Finland. The most central channel concerning the innovation system is Nokia's cooperation with other companies. Nokia cooperates both in production and in research and development with numerous companies. In 2000 there were about 300 companies in Nokia's "first tier" partner network. There were from 18,000 to 20,000 employees in these companies, who worked with products delivered to Nokia (Ali-Yrkkö 2001). One can roughly estimate that, taking into account Nokia's partners, Nokia's share of Finland's employment is slightly below 2.5 percent.

Most of the cooperation with companies has aimed at production and manufacturing operations. However, over the past years cooperation has increasingly extended to operations relating to research and development. Cooperation in R&D can be examined by analysing Nokia's cooperation in R&D projects financed by Tekes.

Tekes' data set contains information on various dimensions of cooperation.

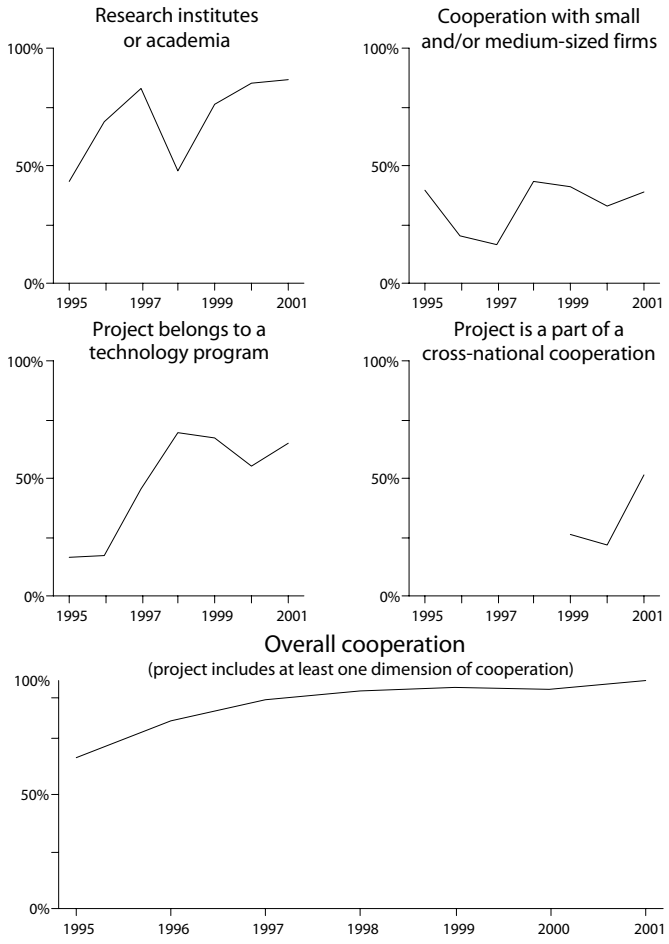
In most of the Tekes' Nokia projects there have also been other partners. The projects have not only involved Nokia's internal research and development, and most of the time other parties have been engaged as well.

The share of cooperative projects has increased continuously. Currently there are at least some partners involved in almost all of the Tekes-financed Nokia projects. Compared to the mid 1990's, especially the cooperation with research institutions and universities has increased. The cooperation with small and medium enterprises (SMEs) in Tekes-financed projects fell in 1996 and 1997. After this SME cooperation has increased back to the year 1995 level. There is no information available on the

share of international cooperation for the years 1995-1998, but from the information on 1999-2001 it would seem that increasingly there is at least some level of international cooperation involved in Tekes-financed Nokia projects. We can also see from figure 3.1 that a growing part of Nokia's Tekes projects are part of Tekes' technology programmes. In the technology programmes companies, research institutions and universities work together in the planning-, implementation-, and monitoring phases of the programme.

With the help of research and product development cooperation, know-how diffuses from one party to the others. Exter-

*Figure 3.1. Cooperation in Tekes-financed Nokia projects.**



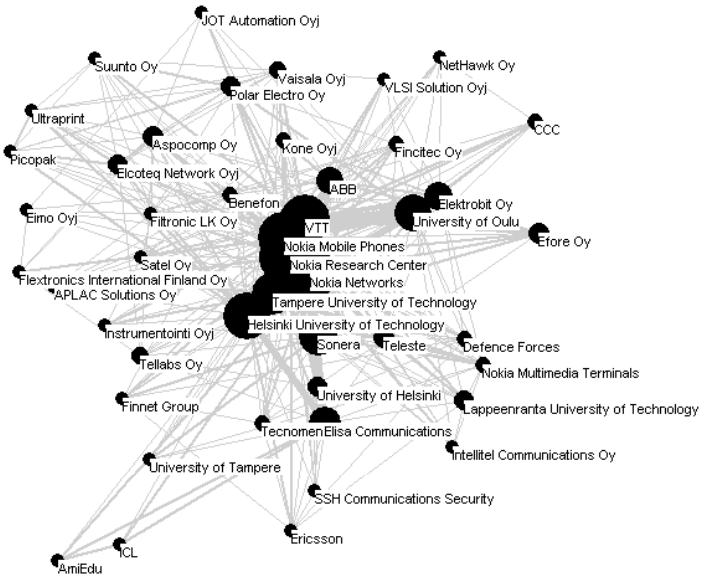
* Percentage of projects.

nalities from R&D activity, that is the diffusion of know-how from one party to others, have a great significance for the society. Public grants, directed to research and development, are usually argued by these externalities.

The following figure (3.2) examines Tekes' latest programmes, which concern the information and communication cluster. The programmes included in the figure are: Electronics for the Information Society (ETX), and Telecommunications: Creating a Global Village (TLX). Both programmes include business projects as well as research projects. The figure includes those Nokia's partners, which have at least three cooperative projects with Nokia.

The figure shows that many companies and universities have cooperated with Nokia. There are both small and big companies amongst the partners. Also the partners' industries vary a great deal. There are component and part manufacturers (like Eimo, Aspocomp and Filtronic), contract manufacturers (like Elcoteq and Flextronics), software houses (e.g. Aplac, CCC and SSH Communications Security), production automation

*Figure 3.2. Nokia's cooperation network in Tekes' ETX and TLX programmes.**



* The figure includes both company ventures and target research projects. Included are partners with minimum of 3 projects with Nokia. Information is based on the end reports of the ETX- and TLX- programmes. The figure is interpreted so that the more projects the organization is involved in, the larger is its circle and the closer it is to the centre. The figure was drawn in the course of the "Evaluation of Finnish R&D Programmes in the Field of Electronics and Telecommunications (ETX, TLX and Teletronics I)" project.

manufacturers (e.g. JOT Automation) and operators (e.g. Finnet, Sonera, and Elisa). In addition to the companies shown in the figure, Nokia has cooperated with many other parties regarding the TLX and ETX programmes. These organizations have been involved in less than three projects with Nokia, which is why they are not included in the figure. Among those left out of the picture are both large and small companies. Many of the small companies are young.

Based on the interviews, cooperation with Nokia has had various influences. For many SMEs, Nokia works as a systems provider, into whose solutions their products are incorporated. One Nokia partner summarised the significance of cooperation as follows:

> We saw it, that we can make the technology, but without the help of Nokia and its brand in the market, we cannot survive alone. Nokia worked as a marketing channel, and in this Nokia was our most important customer, and so we thought that Nokia manage the distribution of these products. (R&D manager, Nokia).

Although many companies in the ICT-cluster operate globally today, there is still much to develop in this aspect. The lack of marketing know-how and channels complicates and inhibits SME internationalisation. One interviewee presented it as follows:

> If I look at this problem of being Finnish, then … we have a very thin internationalisation. People who have international experience, fluent language skills, ability to work with foreign cultures, active relations in other countries. There are too few of these. It shows in business [and] it shows in the academic side. Being top of the observation class, … it is not quite enough. (Professor, University/research institution).

On the other hand, the incorporation of the SME products into Nokia's products has caused problems in some cases. These companies have not created their own brand, and not always own the intellectual property rights, which could be marketed or utilised together with other companies. This may complicate the future growth possibilities of the companies in question, and make the expansion of their customer bases difficult.

The cooperation clause set by Tekes for large companies came up in many interviews. The requirement has made an impact, as the following example shows.

> The starting point with Tekes has been that university cooperation and networking is a must… It has, that Tekes says we must create networks and maintain links to universities, become a significant reason that Nokia does it… It is one driver for us, that we remember to do it when in tough times it is easy to curl up in oneself. (R&D manager, Nokia).

On the other hand, in more than half of the Nokia projects being interviewed, cooperation would have taken place regardless of the cooperation clause. In these, it has often been the case of organizations already familiar with each other. The organizations had completed a number of projects together and the same configuration carried on to new projects as well. In many cases, the cooperation between the partners has long traditions.

> It worked well in Oulu then and it still works quite well, [the cooperation] we had with universities, Nokia, and few other local companies. This tradition of research cooperation with the university is very long. (R&D manager, Nokia).

> Mobira purchased much outsourcing from universities already in the beginning of the 1980's. It was quite open, and since they did not have the resources, they had much of the work done by universities. (Professor, University/research institution).

What came up in many interviews is that representatives of universities and research institutions felt that they did almost all the work related to the projects. Financing organizations take part in executive meetings but not in the actual substance of most of the projects. Many interviewees brought up the issue that business partners could play a more active role. The next quote describes these wishes:

> We would really greatly welcome more active company partners … That is the opportunity of the Tekes projects. That a company, which assigns a person there, who has the right competence, skill, background, commitment, time and who would stay on there. Not only become familiar with the material and come to the meetings prepared and so, but would maybe go and talk to the people there and work on a paper together and participate. This is extremely rare. (Professor, University/research institution).

DIFFUSION OF KNOW-HOW TO UNIVERSITIES

Nokia's cooperation with universities in Finland has mainly focused on the universities of technology and natural sciences. Most cooperation takes place, as is depicted in the previous figure (3.2), with the Universities of Technology in Helsinki and Tampere, and with the University of Oulu. In addition to these, Nokia cooperates with, for example, the University of Technology in Lappeenranta and with the Universities of Helsinki and Jyväskylä. Nokia also has extensive cooperation with VTT (Technical Research Centre of Finland).

Through cooperation know-how has spread to various parties. The exchange of information has been both-sided, that is, in many projects the know-how has diffused from universities

to Nokia and vice versa. The same concerns the partner companies. The following quotes from interviews describe the diffusion of know-how:

> The accumulation of knowledge in our organization has been very strong. In this project, almost all of our people are such, who are doing post-graduate studies and aiming at a doctoral dissertation. New theories have been developed and new results in different areas, thus knowledge at our organization has increased considerably. (Professor, University/research institution).

> From Nokia's perspective, they [at Nokia] were passed on such knowledge, which they had not created themselves but where their work had explored alternative solutions. This way their competence was complemented. (Professor, University/research institution).

> Concerning the technology, we learned a great deal [in this project]. …I suspect, that at this moment we have the world's top knowledge concerning this [the developed system], which we can present. We also learned about the markets. We acquired contacts in Finland as well as the rest of the world. (R&D manager, Nokia's partner).

> This [project] enforced in its part our conception of the fact that especially this university group is productive, and we can obtain this type of competence there. That way we had faith, when we later participated in similar projects, that it is worthwhile to get this sort of projects done here. (R&D manager, Nokia).

The spreading of know-how and competence is not always uninhibited. Especially in the case of an application close to commercialisation, the transfer of knowledge is carefully controlled. Some interviewees expressed doubts concerning the spread of know-how even more widely, as the following example shows:

> The requirement by Tekes, that there have to be [in large company projects] small businesses involved has caused the result that small slices have been outsourced to smaller companies or universities. The networking requirement has kept this option [Tekes' financing] open. But how much competence is transferred, that is probably quite little. (Professor, University/research institution).

A central distribution channel for know-how is recruitment. The most common way is that students move from universities to companies, and competence is transferred with them. Many of the interviewed company representatives stated the ability to recruit competent people in the future as an important motive for university cooperation. There has also been some transfer of personnel in the other direction. The following quotes exemplify the significance of recruitment:

> In this project, there has also been the kind of knowledge transfer that people from this project have moved to be employed by the financing organizations. Similarly it has been that people from the financing or-

> ganizations have come for post-graduate studies to work for us. (Professor, University/research institution).
>
> The development of universities is very important from the point of view of the companies, and at least we saw it as very important to be able to direct their research so that it would serve us best. And that the resources there would develop so, that we would able to recruit people from the universities in the future… We have recruited one person from this project from there [university]. (R&D manager, Nokia's partner).

In addition to the cooperation with universities and research institutions in Finland, Nokia cooperates with many universities abroad. Table 3.1 presents Nokia's most important cooperation universities.

In addition to these universities, Nokia has other cooperation universities. Cooperation at different levels takes place with over 100 universities. Nokia's cooperation with a wide university network poses Finland a challenge. A prerequisite for continuing the cooperation is, that universities are able to stay at the very front of the technological development.

> It sets us too with a tough challenge, that we need to choose the right areas and be the world leader in them. Because Nokia is so big, it can

Table 3.1 The most important cooperation universities of Nokia by country.

Finland	The United Kingdom
Helsinki University of Technology	Imperial College
Tampere Univ. of Technology	The University of Strathclyde
University of Oulu	University of Surrey
Denmark	The United States
Technical University of Denmark	Massachusetts Institute of Techn.
Aalborg University	University of California, Berkeley
	Texas A&M University
Germany	Stanford University
University of Dortmund	China
Aachen University	
	Beijing Univ. of Posts and Telec.
Sweden	Tsinghua University
Linköping University	Thailand
The Royal Institute of Technology	
	Asian Institute of Technology
Japan	
	Hungary
University of Tokyo	
Tokyo Institute of Technology	Budapest Univ. of Techn. and Econ.

Source: Häikiö (2001).

> take the world's best from wherever [in the world]. (Professor, University/research institution).
>
> Nokia is a large and international and demanding customer. It requires competence from its own contractors, it demands high competence from universities and research institutions, and it sets the standards high. That way the research projects borne at universities are such that we, and our kind of smaller companies, are able to utilise them. (R&D manager, Nokia's partner).

When examined more broadly, both company and university cooperation is based on the fact that each party feels they benefit from it. The main benefits to universities come from dissertations, academic publications and the accumulation of know-how. The latest theoretical knowledge is passed on to companies through the universities. While the business sector has been able to offer practical applications, where theoretical knowledge and basic research have been utilised in business.

The views of the interviewees regarding the utilisation of the results of cooperation and especially the division of intellectual property rights (IPR) are split in two. Some did not find the IPR problematic while some felt that the biggest challenges of all were related to IPR. The following quotations describe these views:

> Then when those departure or IPR-issues come up, they have been settled in the executive board. They have not caused any big difficulties, rather the opposite. But it requires that the one, who participates in the project, understands the rules and how the game is played. (Professor, University/research institution).
>
> The company concluded, that this project is not continued. That the company stated it is not continued, that can be permitted for the financing party. But what was sad about it, was that the [original] idea was that if they do not commercialise the product, then the university is left with the right for further development. Then we could develop something new based on the previous work. Now what happened is, that this permission was not granted. It ended where some researchers could not continue their doctoral dissertation work, because the work that they have done is based on what has been achieved in that project. Now that the company sits on these results and does not expose them, they cannot continue to work on their dissertation. (Professor, University/research institution).
>
> This crisis, which is here in this IPR matter, is extremely serious… It can consume the basis from this whole thing. (R&D manager, Nokia).

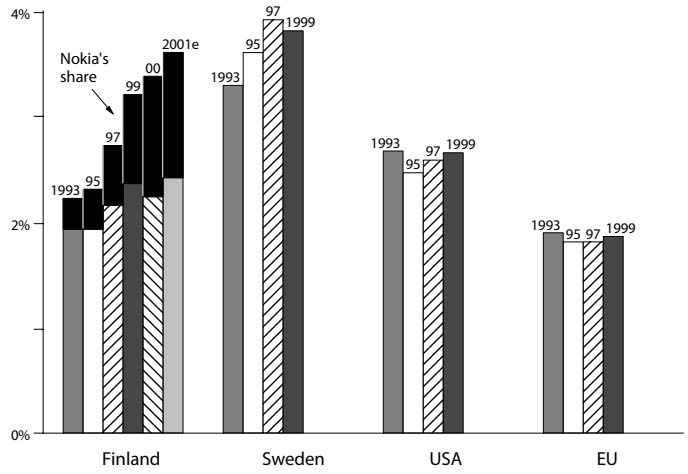
The interview quotes indicate that, in both companies and in universities/research institutions, IPR related matters are receiving central attention. Within this study there was no opportunity to focus more deeply on questions relating to intellectual property. The subject is therefore left for further study.

FINLAND'S REPUTATION AS A HIGH-TECH COUNTRY

The share of research and development expenditure of the gross domestic product has grown strongly in Finland over the past decades. Since the beginning of the 1990's, relatively more research and development was conducted in Finland than in the EU on average (figure 3.3). In the latter half of the 1990's Finland overtook the United States in R&D intensity. At the end of the decade, the share of research and development exceeded 3 percent of the gross domestic product, which equals the level of R&D in Japan. Relatively most is invested in research and development in Sweden, of all the countries in the study.

Finland's high research and development intensity leans mostly on Nokia's extensive R&D activity in Finland (figure 3.3). If Nokia's share were taken out of the figures, in 2001 Finland's R&D spending would be about 2.4 percent of GDP. Yet, even then Finland's R&D intensity would be clearly above the average EU level. To summarise, we can conclude that more research and development takes place in Finland than in the EU countries on average, independent of whether Nokia is taken into account or not.

Figure 3.3. R&D expenditures relative to GDP.



Authors' calculations (Data source: OECD Main science and technology indicators).

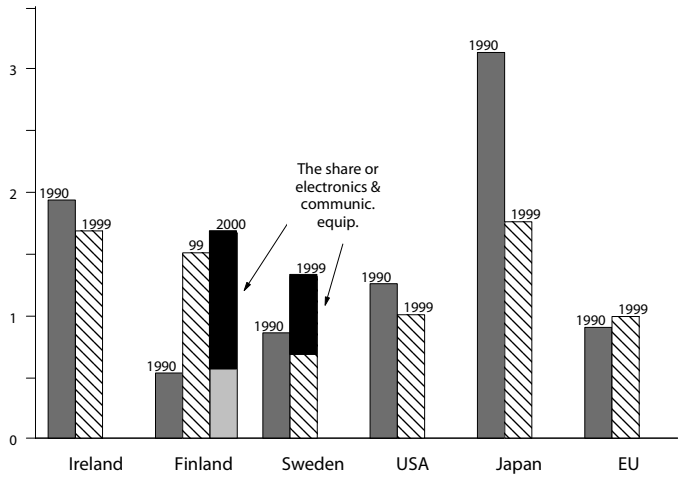
Nokia's R&D spending has increased strongly since the beginning of the 1990's. Although the company has increased its research and development abroad, R&D expenditures have also grown strongly in Finland. In 2001, the company's R&D conducted in Finland was approximately 47 percent of the total business sector R&D in Finland.

Research and development expenditures in different countries depict investments, which are made in hope of future income. Together with R&D investments, technological success of a country can be explored through the foreign trade in high technology.

Figure 3.4 shows the ratio of high-tech exports to high-tech imports. If the figure is below one, more high-tech products are imported than are exported. If the ratio is above one, more high-tech products are exported than are imported.

In 1990, Finnish imports of high technology were almost twice its high technology exports. Over the decade, the foreign trade in high-tech products turned into a surplus. Finland overtook Sweden, United States, and the EU average in the ratio of high-tech exports to high-tech imports. High technology exports grew faster than the imports, and the European "top country" Ireland has almost been reached when examined with this measure (figure 3.4). Contrary to Finland and Sweden, Ireland's export surplus is based almost completely on the exports

Figure 3.4. High-tech exports to high-tech imports in different regions in the 1990s.



Authors' calculations. Data source: OECD.

of multinational corporation's subsidiaries. About 90 percent of Ireland's high technology exports come from these subsidiaries.

What has caused the change described above? The structure of Finland's industries and exports has changed quite drastically, especially as a result of Nokia's strong growth. Finland's high-tech exports without electronics and telecommunications equipment remained below imports throughout the 1990's. The export intensity in high technology in Finland and in Sweden is mainly based on exports of telecommunications equipment. Their share of exports was almost one fifth of the total product exports in 2000.

MONEY FLOWS BETWEEN NOKIA AND THE PUBLIC SECTOR

Money flows between Nokia and the public sector are examined in the following. All figures are given in the year 2000 prices (nominal prices are deflated with the living cost index).

R&D grants from Tekes to Nokia totalled slightly below 500 million FIM (80 million Euros) over the years 1995-2000. Over the same time period, Nokia paid corporate taxes of 17.9 billion FIM (2.9 billion Euros). In addition, Nokia invested in the academic world by financing research and development projects as well as by donating equipment and software to universities. We estimate the total value of these investments to be about 100 million FIM (18 million Euros). The estimate is based on the research finance paid by Nokia to Tekes' ETX and TLX programmes (total of over 50 million FIM over the period 1997-2000). An estimate of research finance in the years 1995 and 1996 is added to this figure, plus an estimate of the value of equipment and software donated by Nokia.

Nokia's employees have paid income taxes worth 8.5 billion FIM (1.4 billion Euros) over the years 1995-2000, and taxes on management options worth 6.9 billion FIM (1.2 billion Euros). Over the same time period, Nokia has paid just below 7 billion FIM (1.2 billion Euros) of social security payments for its employees. Altogether, the income taxes, taxes on management options, and social security payments for the employees exceeded 22 billion FIM (3.8 billion Euros) over the years 1995-2000.

Nokia has, as have all other companies, benefited from free public services such as higher education. In addition, the companies' personnel use and utilise free services, transfer payments and infrastructure built by the public sector. The division of these costs, and their calculation for a specific company is considerably difficult. Therefore the following calculations should be looked at as exemplifying.

There are various methods to calculate the accounting value of the education of Nokia's Finnish workforce. One way of doing so, which we employ here, is to calculate it as the product of the costs of different qualifications and the number of Nokia's Finnish personnel with the respective education[5]. Calculated this way, the value of the education is 3.6 billion FIM (600 million Euros). This depicts the amount of money that was required in 2000 to produce the respective level of qualifications.

Similarly we can calculate how much of public sector spending and investments is directed to a company Nokia's size by the number of employees. In this calculation, public sector expenditures include public consumption, public investments, and transfer payments without personnel expenses. The figure obtained this way is then directed to Nokia's employees by dividing the figure by the number of people in the work-age and multiplying it by the number of people employed by Nokia in Finland the same year[6]. According to this mechanical calculation method, the value of public services and infrastructure directed to the employees of any company of Nokia's size would be about 9.4 billion FIM (1.6 billion Euros). Both this and the method used to calculate the accounting value of education should be considered as examples, as other methods exist as well.

4. CONCLUSIONS

PUBLIC SECTOR SHARE OF R&D RELATIVELY SMALL IN FINLAND

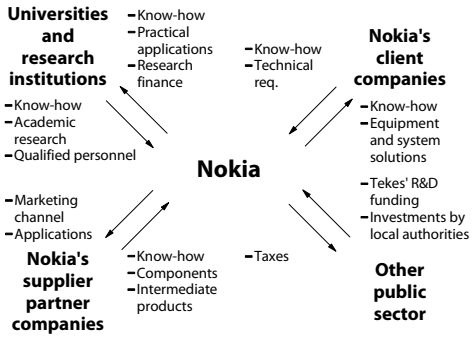
Research and development expenditures in Finland relative to the gross domestic product are among highest in the world. In 2000, R&D expenditures were 3.4 percent of GDP. Only in Sweden the share was higher (3.6%). According to preliminary information, the share rose to 3.6 percent in Finland in 2001. Also the R&D expenditures in Sweden rose in 2001.

The high R&D intensity in Finland is largely based on the private sector's research and development investments. The share of public sector of the total research and development activity is smaller than in most other countries. Also the public sector financing share (R&D support) of the private sector research activity is clearly smaller than in the comparison countries.

Nokia's impact on Finland's high R&D intensity is significant. When Nokia's R&D activity is deducted from the calculation, Finland's R&D expenditures relative to GDP are only 2.4 percent in 2000. However it must be noted, that even this share is well above the EU average.

Nokia, even when considered more broadly, has a significant position in the Finnish information and communication cluster's innovation system. Nokia operates in the cluster as both a user and a producer of innovation resources. The diagram depicts Nokia's position and relations in the national innovation system.

Figure 4.1. Nokia in the Finnish innovation system.



Regarding the innovation system, parties central to Nokia are universities, research institutions, other public sector organizations, and Nokia's suppliers and client companies. The key factors in the innovation system are the transfer of know-how, learning, and the quest for innovation. If the system functions well, the interaction of these factors reflects on the economy in the form of employment, exports, business profits and public sector tax income.

THE SIGNIFICANCE OF TEKES FUNDING

The share of Tekes funding of the total R&D expenditures of Nokia has varied over time. MTI's Technology Office (Tekes' predecessor) covered an average of seven percent of Nokia's R&D spending in the 1970's, eight percent in the 1980's and slightly below three per cent in the 1990's. In 2000 the respective figure was 0.3 percent. However, it must be noted that Tekes finance has had strategic and long-term influences. For example, MTI's Technology Office and Tekes financed the early development phases of Nokia's digital call centre system. In the early years of Tekes, considerable amounts were invested in the development of the GSM technology, software tools, and the protocol base at VTT (Technical Research Centre of Finland).

According to the book on Nokia's history (Häikiö 2001), Tekes funding during the recession in the early 1990's especially supported the continuity of the operations at the Nokia Research Center.

LEARNING AND THE QUEST FOR INNOVATION IN AN IMPORTANT ROLE

In addition to money flows, Nokia's activities are reflected on the Finnish innovation system through education, diffusion of know-how, other companies' R&D activities, and learning.

Nokia has numerous links to organizations that influence the birth and utilisation of innovations in both Finland and abroad. Cooperation network includes other companies (producer-user relations and research cooperation), research institutions and universities (research cooperation). In addition to the R&D cooperation in Finland, Nokia has numerous similar cooperation relations to foreign companies and universities.

Nokia was involved in research cooperation with universities already during the Nokia-Mobira times in the 1980's. Universities have conducted numerous cooperative projects concerning the development of mobile phones, networks and their software. Nokia's success is at least partly a sign that world's top class technology has been developed in Finland.

It seems that the cooperation between companies and universities/research institutions has functioned relatively well in Finland. The prerequisite for cooperation has been that both companies and universities have felt they benefit from the cooperation. Know-how and competence has transferred between companies and universities, which has enabled learning for both parties. Latest theoretical knowledge has been passed onto Nokia and other companies through universities. The business sector has been able to provide practical applications, where theoretical knowledge and basic research have been utilised in business. These issues are highlighted by the following example:

> For several years the situation has been such that the level of research in companies is the same as that in universities. It is however focused on quite short-term issues and concrete matters. Universities have a longer scope. That, which has been attempted to achieve, is to match these together. That is a motivator for us researchers. (Professor, University/research institution).

On the other hand, successful university cooperation and current high level of competence do not provide guarantees for the future. Some interviewees brought up their concern for the current state of universities. According to them funds are not directed to where they are needed. These views are evident in the following interview quotations:

> It would be a good message to truthfully bring out the kind of state our country is now in and where we are going to, because this is a distressing situation. …And then the Ministry of education states, that there are no problems and universities decide themselves on the distribution of funds, as we know and the consequences of that. So we maybe have five years of time to sustain and develop the competence, which we have. But after that we will not differ much from any other European state in this game. …So this is the current state of the Finnish innovation system. (Professor, University/research institution).

> What we are particularly concerned about is this deterioration of basic higher education. It is crucial that the [university] first and second courses are taught well. …And that is now partly deteriorating due to lack of funds and that is serious. (R&D manager, Nokia).

Nokia has had its influence on the fact that the number of university places in the ICT field has been increased strongly.

The company has also played a role in educational planning at universities, and through that influenced the direction of education. By these means Nokia has been able to recruit highly qualified personnel, especially for tasks related to research and development.

In addition to universities and research institutions, Nokia cooperates in research and development with other companies. The variety of partners is vast. The network includes component manufacturers, contract manufacturers, production automation manufacturers, software houses and even companies outside the ICT industry. As a result of the cooperation, know-how has flowed in both directions. Nokia has benefited from partner companies by acquiring components of the latest technology, intermediate products, and software modules for its own end products. This has benefited Nokia's R&D activity and production, as well as enabled Nokia to focus on its own core areas. Also the innovation activities of Nokia's partners have reaped benefits from the existence of Nokia. Nokia has offered applications for various companies' products. Furthermore, Nokia has served as an international marketing channel for companies. Particularly small firms' resources would not have sufficed for international operations had Nokia not worked at least partly as a marketing and distribution channel. Thus the products of many smaller companies are incorporated into Nokia's products.

Cooperation with both universities and companies has brought advantages, but problems have not always been evitable. One issue that raises discussion concerns the utilisation and ownership of the results of cooperation. These intellectual property rights (IPR) determine which party has the biggest possibilities to utilise the results in its business. However, the IPR issue could not be thoroughly explored within the framework of this study.

SUCCESS THROUGH INTERACTION

Although exact information on the amounts of public funding received by Nokia's competitors is not available, it is probable that Nokia has not received any more public funding than its competitors. Nokia has received public R&D financing in the early phases of some risky projects. A number of these projects have later proved to be very profitable.

To summarise, we can say that the public sector has been involved in the financing of many of the basic technologies important to Nokia. Furthermore, Nokia's own R&D and marketing investments have grown. At the same time Nokia's cooperation with other companies, universities and research institutions has made it possible for Nokia to focus on its own core competencies. It is probable, that without the interaction of these parties Nokia's know-how would not have realised the current level of returns.

FUTURE

As a result of Nokia's rapid growth, its position in the Finnish innovation system in the information and communications cluster has been highlighted. Latest knowledge in the field has also accumulated in other Finnish companies, universities, and research institutions. Nokia's cooperation with other Finnish parties depends on their ability to stay ahead of the development also in the future. The Finnish universities compete for the top positions with universities in the rest of the world. Currently Nokia cooperates with over 100 universities around the world, and it can choose its partners. Nokia's own R&D activity will become more and more global in the future. It is likely that the company's research and development activities will grow faster abroad than in Finland.

More detailed knowledge is required of Nokia's influences in the Finnish innovation system. One interesting question is, what benefits have Tekes' Nokia projects accomplished over the long-term. Some of the projects are directed more towards research than development activity, where the benefits only surface over a longer term. A second interesting issue to research would be the short-term benefits of Tekes' Nokia projects measured by, for example the number of patent applications, notices of invention, and dissertation work. A third issue requiring analysis concerns the influence of Nokia's networking on the future of its partners and the whole economy. The fourth interesting subject is based in the history. It would be important to study how the basic know-how and technology for the telecommunications industry was created in Finland at the end of the 1970's and beginning of the 1980's. This kind of a report on the contribution of various companies, universities, and research institutions as well employees of these organizations, to the development of the industry still needs to be done.

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ENDNOTES

[1] The calculation is based on Nokia's own report of the value of exports, which does not fully correspond to the official statistics.

[2] In Nokia and its partner companies people at different levels of organization were interviewed. To ensure the anonymity, everybody is given the title of "manager" independent of whether the interviewee was a project manager, in middle management or in top management.

[3] The abbreviation NMT came from the words Nordic Mobile Telephony

[4] The abbreviation GSM originally came from the words Groupe Spécial Mobile. Later the meaning of the abbreviation was changed to Global Systems for Mobile Communications.

[5] The educational distribution of Nokia's Finnish workforce is estimated as follows: university degree 36%, polytechnic university degree 30%, degree from institute of further education (e.g. commercial and technical colleges) or vocational school 30%, rest 4%. The costs of education are from figures in the Ministry of Education's KOTA and AMKOTA data bases on the number of graduates in 1995-2000 and the costs of budget financed activity in 2000. The calculation includes only qualifications higher than basic education, thus costs of basic education are not included.

[6] The value of public spending utilised by Nokia's personnel (G_{Nokia}) is directed to Nokia's employees so that public consumption and investment expenditures as well as transfer payments without pension and employment expenditures (G_{Total}) over the years 1995-2000 are divided by the number of work-aged people ($L_{WorkAge}$), which has then been multiplied by the number of Nokia's employees in Finland ($L_{NokiaFin}$). In other words: $G_{Nokia} = \frac{G_{Total}}{L_{WorkAge}} \cdot L_{NokiaFin}$