The role of the government sector in the breakthrough and growth of the Finnish telecom industry

Lemola, Tarmo (1); Lovio, Raimo (2)

1: University of Tampere, Finland; 2: Aalto University

This paper is dealing with the role of the government in building the base for the breakthrough of Finnish telecom or more specifically telecommunications equipment industry. Because of a dominance of one giant company, Nokia, in this sector, the focus is on relationships and linkages between Nokia and the various actors of the Finnish public sector. The fabric of policy instruments has been manifold. In addition to better-known science, technology, innovation and education policies, public procurement, regulation, standardization, liberalization, privatization, and trade policy have contributed to the developments.

1. Introduction

One of the biggest changes in Finnish industrial history or economic history more generally has been the rapid emergence and growth of the Finnish telecom[1] sector in the 1980s and 1990s. When the proportion of this emerging industrial sector of Finnish exports was practically nonexistent at the turn of the 1970s, it grew up to one third by the beginning of 2000s. Finland's rise from a natural-resource-exporting country to a technology intensive knowledge economy was considered not only in Finland but even more outside Finland remarkable in the speed and success of the transformation (Dahlman, 2007). In a short time, the country, which was thought of being among the latecomers in Europe, had become a forerunner and a model country.

Broadly understood, the telecom sector includes digital content provision and packaging, network infrastructure, equipment manufacturing and operation, and end-user terminals and portals. In early 2000s the Finnish telecom sector comprised of approximately hundreds or even thousands of firms. However, the contribution of one company, i.e. Nokia, to this industrial transformation and growth was in a class of its own, directly, and indirectly through the outgrowth of networks of suppliers and subcontractors in telecom and closely related fields (Palmberg, 2003). In early 2000s Nokia accounted for two thirds of total turnover, more than 80 percent of the total exports, and a lion's share of total R&D expenditure of the domestic and foreign telecom companies operating in Finland. Nokia's share of the total R&D expenditure of the Finnish business sector was almost half, and one third of total national R&D.

The core business group of Nokia in telecom and through Nokia the whole Finnish telecom sector has been *telephone or telecommunications equipment* which can be divided into network infrastructures (exchange equipment, base stations, networks, platforms) and handsets (radio phones, professional mobile radios, mobile phones). Over the decades, as a result of permanent

[1] For the sake of clarity the words *telecom industry* or *telecom sector* is used throughout this paper to refer to telecommunications equipment industry. Another name with almost the same content is ICT industry or sector. In older publications the word electronics industry was commonly used to refer to telecommunications equipment industry and other electronics product groups. Also the word information technology and corresponding sector has been used in these contexts. Differences in concepts may lead and have led to differences in statistics, but this should not be a problem for this paper.

evolution through some radical and a great number of incremental innovations the content of the telecommunications equipment sector has changed remarkably. Even today, after the sale of its mobile devices division in 2013 to Microsoft, Nokia is a company strongly focused on telecom, and closer to its telecom roots in Finnish Cable Works in the 1960s than ever before.

The focus of this paper is on the role of the state or the public sector in the breakthrough and growth of the Finnish telecom industry. Because of a dominance of Nokia, a proper understanding of the emergence and fast growth of the sector must therefore be based on relationships and linkages between Nokia and the various actors of the Finnish public sector. The fabric of policy instruments has been manifold. In addition to better known science, technology, innovation and education policies, public procurement, regulation, standardization, liberalization, privatization, and also trade policy have contributed to the developments. The paper covers the three decades from late 1960s to the turn of 2000. These three decades, and not only the years of Finnish telecom breakthrough in 1990s were years of active construction of the Finnish telecom industry.

2. Roles of the state

The state has a great number of mechanisms and instruments to influence the rate and direction of scientific, technological and industrial change. There is variation from time to time, country to country, sector to sector in how and how effectively the instruments are used, but they have been used and are used in all deveveloped as well as in developing countries. The choice of instruments is a crucial decision for the formulation of policies. Systemic policy approaches suppose that policy instruments are combined in policy mixes with possible complementary/synergetic/contrasting effects between them (e.g. Borrás and Edquist, 2013). As the case of the breakthrough of the Finnish ICT custer presented in this paper demonstrates, development of new industrial sectors takes time and includes not only intended systematic policy approaches but also uninteded and unrelated, occassionally conflicting development paths. A special feature of the Finnish story is the dominant role of one company, an old established Nokia with a lot of bargaining power in relation to the Finnish state and its various agencies.

The main state mechanisms analysed in more details in the paper are as follows:

Rsearch and education: The state carried main responsibility for creation, maintenance and upgrading of basic capacities through universities, particularly technical universities and the public Technical Research Centre of Finland throughout the whole development process, as well as securing availability of advanced ICT experts in the hottest years of ICT growth.

State owned companies: The Finnish ICT industry and the key product groups of Nokia originate from a few state owned companies. The state was a strategic partner with Nokia in the consolidation and later privatization of the main building blocks of the ICT sector.

Public procurement: In the early phases of development of the Finnish ICT sector procurements from the telecommunications administrator and a couple of other government agencies created seminal foundations for more fundamental inventions and innovations.

Standardisation: Involvement of the public Finnish telecom agency in early standardization of mobile telecommunication along with other Nordic sister organisations offered to Nordic companies (Ericsson in Sweden and Nokia in Finland) a very important competitive advantage in accelerting global competition,

Opening markets: Of two choices, state monopoly or monopolies, or opening competition through private domestic and foreign companies, the Finnish state chose the latter one. This was traditionally the case in telecommunications equipment market, and gradually it was extended to telecommunications services. Liberalization of capital market was of great help for Nokia and the emergence of new companies in the years of rapid growth and internationalisation.

Focused support to technology and innovation: A distinctive pattern of policy activities called nowadays innovation policy has contributed significantly to a renewal of the Finnish economy in general and particularly to the emergence and success of Nokia and other Finnish telecommucations companies.

The paper covers the three decades from late 1960s to the turn of 2000. A key finding is that development of the Finnish telecom sector with Nokia as the major operator has not been a result of an intentional private or public plan. It has been very much a long, organic and decentralized process with several public and private actors with a great number of informal and formal linkages between them. However, the state has had an important role and in some phases even a decisive role at catalyzing and accelerating the growth of Nokia, but even this has comprised decentralized activities without focused, consistent planning or centralized coordination.

3. The Finnish telecom industry

The seeds of the Finnish telecom industry date back to three companies (Table 1). *Salora*, established in 1928, was a manufacturer of TV and radio sets. It began the development of radiophones in 1964. The second seed, *State Electric Works*, established in 1925 as the radio laboratory of the Ministry of Defense, was founded to strengthen national development and production of radio technology. It was in 1962 merged with the R&D unit of the public Post and Telegraph Office (PTT), which had a dual role as a regulator and operator of all forms of Finnish telecommunications. The State Electric Works was renamed *Televa*. In 1976, Televa was organized as a state-owned limited liability company (Lemola, 1996).

The third company, the *Finnish Cable Works*, founded in 1917, was a producer of telecommunications cables. It was merged with Nokia when *Nokia Corporation* was formed in 1967. In addition to Finnish Cable Works, Finnish Rubber Works (est. 1889) and Nokia (a forest products company, est. 1865) were merged under the same conglomerate. All these three companies had for long time been jointly owned. Although the forest-based company lent the name to the conglomerate, the cable company provided the core knowledge base for Nokia to diversify into telecom and other electronics.

Although the foundations of domestic equipment manufacturing were laid in the 1920s, the foreign manufacturers, Siemens and LM Ericsson and ITT dominated the market of the telecommunications product group until the 1980s. Foreign firms had established manufacturing units in Finland in order to avoid import regulations, to provide after-sales services to their customers, public and private telecommunications operators, and also because of relatively low labor costs in Finland at that time. Domestic demand was steadily growing in the 1960's and 1970s, but the few small Finnish companies were not able to compete with the few big international corporations (Lovio, 1993).

In the 1970s, Nokia became a central force in the consolidation of the domestic industry. By the late 1980s, a big part of the Finnish telecom industry had been merged into Nokia. In early 1970s the state owned Televa had begun to develop completely digital telephone exchanges. About the same time Nokia had acquired knowledge in digital communications by purchasing a manufacturing license for Alcatel's digital exchange in 1977, and it also began its own research and development project on digital exchanges.

It turned out very soon that Televa needed a bigger partner for commercializing digital exchanges. Nokia had already for some time had a great interest to have an access to Televa's technical know-how, experts and most probably also to its market share. After multistage preparations Nokia and Televa decided to join forces by setting up a jointly owned company *Telefenno* in 1977 to coordinate research and development as well marketing activities of the two companies related to digital exchanges for fixed networks in the beginning (Koivusalo, 1995, Sandelin and Partanen, 2015).

In 1981 the state decided to sell 51 percent of Televa's shares to Nokia (including Telefenno). The new company was given the name *Telenokia*. Six years later the state allowed Nokia to acquire Telenokia completely. In this way, after intensive debate, lobby, and other preparations of several years Nokia had managed to create a firm foundation for successful further development of its whole mobile network business which still forms the core of Nokia of today. Televa's key product, the digital telephone exchange, a product called DX 200 and expertise related to that was more advanced than Nokia's. The DX 200 has later been characterized as "Nokia's jewe"l (Sandelin and Partanen, 2015). A happy marriage to Nokia.

A very similar path as in telephone exchanges was followed when Nokia started to develop its other core business of the future, mobile phones. A small group of engineers at Nokia Cable Works began development of radio phones (VHF phones) in early 1960s. The scale was small in terms of production and demand. At the same time a privately owned Finnish company Salora developed its own radio phone, and seven years later Finland's first auto radio phone. As a couple of years earlier with Televa, Nokia created in 1979 with Salora a 50-50 owned joint venture named *Mobira* to market and develop radio technology, especially new NMT phones.

Formation of the alliance was assisted by the PTT. A stronger expression of the assistance is that the public sector deliberately pushed Nokia into becoming the channel of this expertise (Castells and Himanen, 2002). Again Nokia's motivation to ally, this time with Salora was understandable: Salora's portable mobile phone and its technical and other expertise was more advanced than Nokia's product and expertise, and Salora had a stronger foothold in the market of mobile phones than Nokia.

Nokia acquired Salora (including Mobira) in 1984. Two years later Mobira was renamed *Nokia-Mobira* to show Nokia's sole ownership of the company, and in 1989 Nokia-Mobira was named *Nokia Mobile Phones*, NMP which soon became well known also globally. Here ended the consolidation process of Finnish telecommunications equipment industry which had started ten years earlier. Nokia had managed to collect the key Finnish expertise and main Finnish domestic competitors in the telecommunications equipment industry.

Nokia weathered a crisis in the late 1980s as the company tried to cope with the growth and diversity, not only in telecom but even more in other parts of electronics, particularly in televisions and micro computers. The crisis was so severe that Nokia's owners considered selling the company to Ericsson (Sölvell and Porter, 2011). Consequently, in a short time at the turn of 1990 Nokia went through a comprehensive metamorphosis. Nokia acquired new companies as has been presented above, but even more it sold all its original business units (Cable Works, Rubber Works, Forest Products) as well as consumer electronics industry which was among the main reasons to Nokia's serious problems in early (ei late) 1990s. The heavy divestment program reflected in the number of employees which decreased from 45 000 to 15 000 between 1989 and 1993 (Ali-Yrkkö, Paija, Reilly and Ylä-Anttila, 2000).

From a conglomerate with a high number of different business lines Nokia transformed into a pure telecommunications company. Nokia was organized into two main business groups: Nokia Mobile Phones (manufacturing mobile communication devices) and Nokia Networks (building mobile communication networks and offering related services). Mobile phones accounted for 72 percent of revenues in 2000, and was the most profitable of the two groups. They both had around 25 000 employees. Since the heavy lay-offs around the turn of 1990 Nokia created 9 500 jobs in-house between 1992-1999.

Already in the early 1990s, Nokia controlled about 12 percent of the global market for handsets. By the end of 1990s Nokia became the world leader in digital mobile phones with a market share of 31 percent in 2000. An illustrative example of Nokia's rapid success in digital mobile phones is the model Nokia 2100. It was Nokia's first consumer-targeted model and was launched in 1994. It was selling 20 million units compared to a goal of 400 000. Nokia's sales increased close to 40 percent annually over the latter half of 1990s (Ali-Yrkkö et al., 2000, Sölvell and Porter, 2011). Nokia's first exports of digital exchange systems were to the Soviet Union, which quickly became an important market for the firm who appreciated not only Finnish technical innovativeness and flexibility, but also Finland's political neutrality in the postwar era (Sandelin and Partanen, 2015). In less than a decade Nokia became in 1990s a major multinational company with operation in more than 130 countries all over the world

In early 2000s Nokia's share of the total ICT sector's (consisting of components and contract manufacturing; telecom systems, equipment and related services: and telecom operations and value added network services) sales in Finland was around 50 percent. Of the telecom systems, equipment and related service production Nokia accounted for two thirds. Nokia was responsible for one-fifth of Finland's total exports and around 3-4 percent of its GDP, making it the biggest company in the country.

Nokia's role was even more important in strategically important activities such as research and development as well as internationalization of business operations. It accounted for 45 percent of total business sector research and development in Finland, and a third of total national research and development. In 2003 more than 60 percent of Nokia's research and development (3.8 billion euro) was conducted in Finland. Nokia employed about twenty thousand people in Finland (total

employment 51 359), of whom more than half were in research and development (Hyytinen et al., 2006).

It is clear, that Nokia functioned as an exceptionally important engine of growth and change for the whole Finnish telecom industry. Nokia engaged the majority of the Finnish telecom companies – directly and indirectly – in its production processes. In early 2000s the number of first-tier Finnish subcontractors was estimated to some 300 companies. In 1998, the estimated share of the partnership outsourcing was around 14 percent of the Finnish subsidiaries' sales, and the first-tier subcontractor employment reached some 14 000 employees in Finland (Ali-Yrkkö et al., 2000). Nokia's role in Finland and in the Finnish innovation system has been so big that it has been mentally easier for Finns to understate ("it is not only Nokia") than to overstate it.

Nokias' transformation and rapid growth in the 1990s was naturally reflected in restructuring and growth of the whole Finnish industry and economy. Telecom was by far the fastest growing industrial sector in the 1990s. By 2001, Finland had become one of the fastest growing and most competitive economies in the world (Sölvell and Porter, 2011). By all the traditional criteria, the Finnish economy was very dynamic during the years 1996-2000. The annual growth of the Finnish GDP in this period was faster than that of the United States, Japan, and the average for the EU. Labor productivity in the Finnish business sector grew by an annual average of 3.5 percent, and in the manufacturing sector the growth was 7 percent. The value of the stocks on the Helsinki Stock Exchange climbed by 894 percent in the five-year period between 1996 and the end of 2000 (Castells and Himanen, 2002).

4. Main phases of the role of the state in the breakthrough of Finnish telecom

Starting from the 1960s as has been done in this paper, Finland accumulated technical expertise and skills in radio and telephony through an uncoordinated but informally linked activities of telecom experts of public agencies, foreign and domestic firms, research institutes and universities. The PTT was the key public actor, a technologically sophisticated lead user and nodal point, as a big operator, powerful regulator and a source of expertise, and domestic and international links. Important instruments for promotion of development of telecom equipment were R&D, public procurement and standardization.

The 1970s was very much the decade of intensive and extensive standardization. The PTT maintained its position as the leader of the orchestra. As described above, in this decade the state was also actively involved in reorganization of the company structure of the telecom sector.

In the 1980s, the Finnish state invested heavily in development of domestic technology and production capabilities by funding industrial R&D, and collaborative R&D among companies, research institutes, universities and public agencies. Information and communications technologies were given special attention and funding. The major state actor was the National Technology Agency (Tekes) with technology programs of new generation. Finnish firms, particularly Nokia benefited from this competence building and networking. The 1980s was also the decade of deregulation and liberalization.

The 1990s was the decade of Nokia's rapid growth and internationalization. Of the state activities high on the agenda was provision of skilled labor force to Nokia and other companies of the telecom sector, not only in the long term but also and particularly in the short term. This raised the importance of education and training at tertiary and university education levels in information technology fields.

In the 2000s, first manufacturing, and in the wake of manufacturing also part of research and development started to move abroad. However, for long time Finland remained as a home-base of Nokia's headquarter and strategic research, but in the 2000s Nokia's connections to Finnish research communities and subcontractors were little by little diminishing. A major part of what Finland was able to give to Nokia had been given in previous decades.

5. Technical universities and VTT as creators of knowledge base

The level of research in Finnish universities and research institutes was in the 1960s and 1970s modest both quantitatively and qualitatively. This was true of research in most fields of science and technology, and it was also true of telecommunications technologies. The major university in technical research and education was the Helsinki University of Technology, established in 1849 as a "manufacturer and handicraft school". The University had developed research and education in transmission and radio technology from 1960s onwards. This was complemented with cellular and digital radio technology in late 1970s and early 1980s. The education and research was foremost focused on the digitalization efforts of the PTT during the modernization of the fixed networks. At the University of Oulu, established in 1958, research and education in the fields of electronics was started in the late 1960s and early 1970s in new microprocessor technology and systems software development methodologies (Palmberg and Martikainen, 2003, p. 22).

The role of the Technical Research Centre of Finland (VTT), established in 1942, started to grow in Finnish industry and economy in the 1970s after reorganization of the institute. When the total number of VTT's personnel was around 700 in 1970, it had grown to 2700 by the year 1990. VTT's research, testing and inspection activities covered practically all fields of technology relevant to various industrial sectors in Finland, including telecommunications technologies. During the 1970s, the early application of digital technology was related to collaboration between the VTT Telecommunications Laboratory, the Helsinki University of Technology, Nokia Electronics, and some of the private telcos. This collaboration had an origin in the pre-competitive research consortium for the ISDN standard (Integrated Services Digital Network), but subsequently evolved towards transmission technologies and fixed exchange systems. This later led to VTT's involvement in European collaboration for the application of the open systems interconnection model (OSI) in a transmission and switching environment (Palmberg and Martikainen, 2003).

Another important initiative was the establishment of VTT Electronics laboratory in 1972 in the city of Oulu to strengthen the local education and research milieu which was born around the University of Oulu and its technical faculty. The VTT Electronics Laboratory specialized in tailor made projects for companies in embedded computer control and software design. Nokia (Nokia Cables) had several factories in Oulu region, and in the late 1990s Nokia started to strengthen also its research

and development activities in Oulu in close collaboration with the university and VTT. The innovation community in Oulu became the Finnish forerunner in building up local and regional innovation ecosystems. The Oulu Technology Park was established in 1982 as the first of its kind in the Nordic countries. All the characteristics of more famous science park environments existed there: a mixture of research units of large corporations, small high-tech firms, various applied and basic services, university and research institutions and concentration of knowledge/research intensive sectors (Vuori and Vuorinen, 1994).

The third Finnish technical university of importance to Nokia and the telecom sector has been the Technical University of Tampere, founded in 1965 as a branch of Helsinki University of Technology and became an independent university in 1972. The Technology Center Hermia, located next to the university was established in 1986 by a group of local public actors. In 1988 Nokia established in Hermia a unit specialized in digital signal processing which later became one of Nokia's technological core competencies. In a short time Hermia expanded a technology and innovation center and a home for 150 companies and research organizations, including VTT. The Nokia Communicator, a famous series of business-optimized smartphones as well as Nokia's first camera phone were developed in Hermia.

In the mid-1990s Nokia's and its Research Centre's cooperation with foreign universities and research institutes intensified along with globalization of the company. At the beginning of 2001, Nokia had fifty-five research and development units in fifteen countries, linked very closely through the concept of virtual laboratories (Castells and Himanen, 2002, p. 37). The units were located in countries and places where they were close to customers, top universities and other sources of special expertise needed in continuous development of Nokia's businesses. However, all these years Finland was the home base for Nokia's Research Centre and its research and development in general.

6. Public procurement and standardization in the early phase of development

It is very much conventional wisdom in Finland and part of the common narrative of the Finnish success that public procurement in a form of a call by the Finnish army in 1963 for tenders for a battlefield radio initiated or at least catalyzed the development process which ten years later lead to the emergence of Finnish mobile phone business (Koivusalo, 1995, 1995, Lemola, 1996, Hyytinen et al., 2006). Ultimately the army did not have the resources to purchase the radio, but the prototypes served as important forerunners of commercial portable phones. Other state agencies with demanding communications requirements such as the telecommunications administrator, the railways, and the coast guard also had a major influence on companies' product development efforts.

Another similar example is the Auto Radio Puhelin (ARP, Car Radio Phone Network), developed under the PTT. ARP was introduced in 1971 as the first mobile telephone network in Finland to provide nationwide service. Although ARP did not turn mobile communications into a major business, by standards of its time it was a success with more than 35 000 users in 1986. The ARP service eventually became too congested and was gradually replaced by the modern NMT

technology. However, ARP provided significant experience and customer interfaces for PTT, research organizations, and Finnish companies such as Salora, Nokia and Televa. It also indicated that there was commercial potential in mobile services (Koivusalo, 1995, Hyytinen et al., 2006). The ARP network was closed at the end of 2000 with NMT 900.

Hyytinen et al. (2006) consider that telecommunications standardization in the Nordic and European contexts may be the single biggest explanatory factor behind Finnish telecom success. The Finnish PTT played a key role with other Nordic public telecom companies in the development of a new transnational analog mobile phone standard (NMT). Joint development which started in 1969 created the basis of future success for Nokia in Finland and Ericsson in Sweden. The common standard gave the companies a unique opportunity to develop an advantage in mobile communications expertise (Lovio 1989 and 1993, Castells and Himanen 2002, Hyytinen et al., 2006).

In the early 1980s, the Nordic countries formed the largest mobile communication market in the world in terms of the number of subscribers (60-70 percent of the worldwide subscription). Mobira, a joint venture of Nokia and Salora, supplied the first NMT portable phones in the world. In contrast the Finnish companies (Televa and Nokia) were neither ready nor willing to supply network technology at the starting phase of the NMT project. Eventually, under pressure from the PTT, which wanted to curb the market power of the Swedish firm Ericsson and equipment prices in general, Mobira and Televa started to manufacture network equipment (Palmberg, 2002, Hyytinen et al., 2006).

The Nordic companies had home ground advantage, when the first NMT based networks were opened in the Nordic countries in 1981-1982, but in fact the NMT standard was open to companies outside the Nordic area. This made development highly competitive: Nokia and Ericsson had to compete with each other and with other big companies like Motorola, Mitsubishi, Panasonic, Nec and Siemens (Castells and Himanen, 2002).

The telecommunication authorities of European community launched in 1991 the GSM (Digital Global System for Mobile Communication) standard. The Nordic actors had already in early 1980s been active at initiating the pan-European standard for digital mobile system. Upon transition to digital technologies, Nokia bet heavily on GSM as the second-generation (2G) standard which eventually commanded three-quarters of the worldwide user base. Nokia managed to capitalize on its early lead in both GSM networks and handsets.

The fact that mobile telecommunications standards were agreed upon beforehand rather than being completely or partly determined by market forces clearly aided entrants and market creation. The settlement of standards was based on demonstrations where the benefits of a given technological solution could be shown. Nokia was successful in these open competitions and thus able to contribute to the formation of these standards (Hyytinen et al., 2006).

The examples given above about procurement and standardization is just a peak of the iceberg. Actually, development and implementation of telecom equipment, systems, platforms, and networks comprised already this time a great number of bigger and smaller projects, specifications, tests, first prototype orders, large-scale equipment orders etc. carried out jointly with several public

and private actors. Moreover, public procurement and standardization are often closely related. Hence, the PTTs large-scale equipment orders during of the hectic years of mobile telecommunication in the 1970s and 1980s provided exceptionally important business opportunities for the Finnish companies (Palmberg, 1998).

7. Liberalization for open competition

In Finland, the telecommunications equipment market has always been open to domestic and foreign competition. Unlike in many other countries, there has not been an exclusive relationship between a monopolistic national manufacturer and a monopolistic public telecom operator. Foreign manufacturers, like Siemens, ITT-Alcatel and LM Ericsson have had production facilities in Finland.

Open market and free competition among manufacturers have had three kind of dynamic effects on the evolution Finnish telecommunication field (Paija, 2001). First, highly competitive markets put an immense challenge on national actors. Secondly, presence of production facilities of foreign companies functioned as a channel for technology transfer and diffusion. Thirdly, in a free supply of equipment, it was advantageous for the operators to enhance independence on suppliers. To be able to match a variety of incompatible equipment, the operators had a strong need to develop their technical knowhow.

There was an additional distinguishing feature in the market structure of the Finnish telecom sector: from the years of Finland's independence in 1917, the public PTT had had a dual role as regulator and operator of all forms of Finnish telecommunications. By 1935, the almost all Finnish long distance telephone traffic was transferred to the control of the PTT. This regulated telecommunications monopoly continued in Finland over 50 years. In 1981 the Finnish state began to prepare for an eventual deregulation of the operator sector. Six years later, in 1987, the legislation (telecommunications services act) geared towards quickly turning the PTT into a limited liability company (Katila et al., 2007).

The first step in a long and occasionally disruptive deregulation process was to transfer regulatory authority from the PTT to an independent body under the Ministry of Transport and Communications. The second step was the actual formation of the state-owned limited liability company called Telecom Finland, which operated on more commercial terms than its predecessors. In 1998 Telecom Finland renamed Sonera was listed on both the Helsinki Stock Exchange and on the NASDAQ. The next step was taken in 2002 when the Swedish and Finnish telecommunications companies Telia ja and Sonera were merged TeliaSonera.

However, in spite of strong position of the PTT, the state never had in Finland a total monopoly in telephony operation. In addition to the PTT, which was primarily in charge of long-distance and international operation, licenses were held by a large number of private companies that operated local networks. Many scholars have with one voice come to the conclusion that the dual market structure created fruitful tensions, competition, and threat of losing locally strong market position (see e.g. Paija, 2001, Castells and Himanen, 2002, Hyytinen et al., 2006, Sölvell and Porter, 2011).

The decisive stimulus and pressure for continuing liberalization of telecommunications services did not come from the government, but it mainly came from private operators. The telecommunications

services act not only separated the regulatory and operator functions of the PTT but it also established the right of private companies to offer mobile communications network services. The PTT had for some time had a monopoly over the first generation mobile network on the NMT technology. Private companies had previously been refused due to the supposed social benefits arising from a "natural monopoly".

However, after a long, occasionally hot political controversy, it was the privately-owned Finnish Radiolinja, established in 1988 by the private camp, who was the first operator in the world to launch a commercial GSM network in July 1991. Nokia made its international GSM call on the same occasion with Radiolinja's network. In answer to Radiolinja's challenge, Telecom Finland brought forward the launch date for their GSM services. Here ended a long political dispute over state-owned monopoly in telecom services (Paija and Rouvinen, 2004, Hyytinen et al., 2006, Sölvell and Porter, 2011).

Lack of capital and inefficient capital investments had turned out in the 1980s to be the Achilles' heel of the Finnish economy. Consequently, in addition to increasing competition within telecommunications services, liberalization of capital markets and EU membership tokk place in 1990s. Liberalization of capital markets which had begun in the 1980s continued in 1990s in many ways. Among others, access to foreign investors was facilitated, and restrictions on foreign ownership of the Finnish firms were removed. Consequently, constraints decreased and the efficiency of the allocation of capital improved which were instrumental to the revival of the economy and the emergence of new companies and industries. Finland's quick recovery from the deep recession in early 1990s would not have been possible in the financial markets like those of the past. "Even Nokia would not exist in its current form without having had access to external capital" (Paija and Rouvinen, 2004, p. 59).

In 1995, Finland became a member of European Union. EU membership brought further integration into the European Common Market, and harmonization many laws and regulations with the other European countries. With the opening toward the west, the Finnish economy attracted significant amounts of inward foreign direct investments (FDI). In 1985, the stock of Finnish inward and outward foreign direct investment had been 1.3 and 1.8 percent of GDP respectively. In 1998, these ratios had increased to 18.3 and 33.8 percent.

8. Innovation policy[2] as an instrument for renewal of Finnish industries: general features

There is a broad consensus among Finnish and foreign scholars and other experts that a distinctive pattern of policy activities called nowadays innovation policy has contributed significantly to a renewal of Finnish economy in general and particularly to the emergence of information and communications technologies and industries (e.g. Lemola, 2002, 2004, 2014, Dahlman et al., 2007, Castells and Himanen, 2002, Sabel and Saxenian, 2008) The two decades, the 1980s and 1990s can

[2] In Finland as in many other countries, the policy nowadays often called "innovation policy", has had even in the past different names. In the 1970s the policy was in Finland called "science policy", or "research policy" after Swedish "forskningspolitik". In the 1980s the name of policy was changed to "science and technology", and in the 2000s to "innovation policy". Innovation policy has been used in a wide meaning of the word, covering science, technology, innovation or various types of innovation, and sometimes also education.

be characterized as “golden decades” of Finnish innovation policy, but this policy, in the actual meaning of the word, did not begin in the 1980s. It began already in the 1960s.

More than ever before in Finland, science, technology as well as research and development and their economic significance became in mid-1960s a topic of debate and an area of government activity (Lemola, 2002). The main driver was intensifying internationalization and liberalization of trade. This placed new strains on Finland’s structure of production which was one-sided (high dependence on forest-based industry), and on its level of technology which was low compared with that of Finland’s main competitors. Investment in research and development and education was considered an important building block of the Finnish national modernization project.

This lead in short time to improvements in the capabilities and operating conditions of the universities by increasing their financial resources for research directly from the state budget and through the Academy of Finland (a system of research council for funding university research) which was reorganized in 1969; The Technical Research Centre of Finland (VTT), Finland’s biggest government research institute was comprehensively reorganized in 1972; the Ministry of Trade and Industry received appropriations for industrial research and development; the National Fund for Research and Development (Sitra) was established in 1967 to support firms’ research and product development; and a ministerial committee on science – the Science Policy Council renamed in 1987 Science and Technology Policy Council – had been established already in 1963 (Lemola, 2002).

The early years of Finnish innovation policy in the 1970s was characterized by a focus on the development of basic financial and other resources of research and development. A new era started in the 1980s. The focus of innovation policy was shifted to technology and innovation, and in technology particularly to information technology. The most visible achievement of innovation policy of this decade was establishment of Tekes under the Ministry of Trade and Industry in 1983 to boost science, technology and innovation based industrial and economic development (Lemola, 2014). In a short time Tekes became the central actor in the promotion of innovation related activities in Finland. This included provision of additional resources for technological research and innovation, improving interaction and cooperation between companies, research institutes and universities, and activities associated with technology transfer, diffusion and commercialization of science and technology. As much as the government can do, the seeds of Finland’s success in information and communications technologies and industries in the 1990s and 2000s were very much sown in the 1980s.

The architect of the new innovation policy was the broadly based Technology Committee appointed by the government in 1979 (Technology Committee, 1980). Broadly based meant experts representing political decision makers, the government sector, employers, employees and researchers. One of the motives to set up the committee had been a concern that new information technologies will significantly increase automation and unemployment in industries and services. The committee’s conclusion was that not even rapid development of automation would place any restrictions on social development in the 1980s. On the contrary, information technology and its application would be a resource opening up new opportunities. Consequently, the committee’s principal recommendations included allocating more public and private resources to research,

development and education in general, and particularly to various fields of new information technology. As a result of its analysis, the need for a conscious innovation policy with ICT as a key technology was increasingly identified (Lemola, 2003, Castells and Himanen, 2002).

During the 1990s, the changes in the innovation policy initiated in the preceding decade were accelerated. A belief in the importance of knowledge-intensive innovation-driven economic growth not only remained but increased among the policy makers and actors of the Finnish innovation system. The most important single act was the government's decision in 1996 to increase state funding for research and development by 250 million euros in 1997-1999. This meant an increase of about 25 percent in three years in the state's research appropriations from the 1997 level (Science and Technology Policy Council, 1996). Most of these additional funds were channeled to competitive research and development projects through Tekes and the Academy of Finland. The funds for the additional appropriations were obtained mainly from the partial privatization of some state-owned companies.

Initiated by the Science and Technology Policy Council headed by the Prime Minister, Finnish innovation policy adopted in 1990 a "holistic" approach, focusing on a broader "national innovation system" (Lundvall, 1992, Science and Technology Policy Council, 1990). In this view innovation is not generated by individual companies or state agencies, but instead innovation was considered to be embedded in a network of economic relationships, institutions and policies. Innovation policy this inspired to coordinate a diverse array of actors and issues in order to promote innovation restructuring industries (Schienstock and Hämäläinen, 2001).

It is difficult to say exactly how the ideas related to the concept of a national innovation system were implemented and what kinds of effects this had on the performance of the Finnish system. The concept was of great rhetorical and symbolic value in various policy contexts. Most probably it increased among policy makers and other actors of the system understanding of the whole set of factors influencing the development and utilization of new knowledge and know-how. It supported efforts to "join national forces" or to intensify national cooperation in research and development. More concretely, the concept gave arguments on the central role of research and development and innovation as a well as education in industrial and economic development (Lemola, 2004).

9. Tekes: the key planner and executor of the new innovation policy

Recommendations of the Technology Committee lead to the formation of Tekes (National Technology Agency) who became the key planner and executor of the new technology and innovation oriented policy aiming at creating new opportunities to the Finnish economy and society. Tekes did not need to start from scratch. It inherited a major part of its tasks carried out formerly, from late 1960s, by the Ministry of Trade and Industry (R&D loans and grants, appropriations for goal-oriented technical research). Tekes's task was to make sure that the additional resources which will be allocated to research and development in the coming years are directed better and used more effectively than until then.

As one of its first initiatives Tekes started to plan, organize and finance national technology programs of a "new generation". Similar programs had earlier proven their worth in such forerunner

countries of those years as Japan and Sweden (Lemola, 2004). Technology programs were used as instruments to concentrate resources to technological fields which were considered nationally especially important. In addition, national technology programs were regarded as effective instruments to increase interaction and cooperation between companies, research institutes and universities.

The Technology Committee had raised electronics, data communications, data processing, production control and automation technology as areas the significance of which were considered to be great to all industrialized countries, and in which technology was developing particularly rapidly. The Committee proposed that the implementation of new kind of programs should be started in semi-conductor components, information technology, automation and manufacturing and process industries, and biotechnology (Technology Committee, 1980).

The programs in semiconductor components, and information technology (FINPRIT) began practically immediately after the start of Tekes, and they became Tekes's pilot technology programs. Both of the programs were explicitly directed for building up new competences urgently needed by growing telecom companies, Nokia as a major player, and for improving interaction and cooperation between companies, research institutes and universities. Tekes funded 70 percent of the costs of FINPRIT, while the remaining shares were provided by the research institutes and industry.

The great importance of FINPRIT was in the fact that the program helped Nokia and other Finnish telecom companies to overcome the challenges related to a shift from analog (NMT) technology to digital (GSM) technology (Ali-Yrkkö and Hermans, 2004). Ali-Yrkkö and Hermans cite two of their interviewees:

The first large programme by Tekes was The Convergence of Information Technology (part of a larger framework called 'The Development of Information Technology') in 1984 …. In that programme, those protocol and database tools were made by teams, which went to Nokia and GSM. (Professor, university/research institute)

If we looked at where all those people came from, and then the tools and the know-how, which were developed in the 1980s. 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/industry)

Nokia has been an important participant not only in Tekes technology programmes but in monetary terms even more as a receiver of Tekes grants and loans for in-house research and development not engaged in technology programs. In 1980s and 1990s Tekes increasingly directed its industrial funding towards companies in the information and communication technology industry. As a consequence of these aspirations, in 2001 about one-third of the funding by Tekes was targeted at this industrial sector (Ali-Yrkkö and Hermans, 2004).

Nokia's public funding for research and development experienced a growing trend over the three decades 1970-1990 (Ali-Yrkkö, 2010). In 1969 Nokia received a total of the equivalent of 34 000

euros from Tekes's predecessor the Technology Office of the Ministry of Trade and Industry (MTI), while in 1999 the respective figure was the equivalent of 18 million euros of Tekes funding. In the 1970s the share of the MTI's funding of Nokia's total research and development expenditure was 7 percent on average and in 1980 as much as one quarter. In the following years the share of Tekes funding remained at about 15 percent.

After these peak years, the share of Tekes funding of Nokia's total research and development spending decreased significantly. In the end of the 1990s Tekes's share was around 1.5 percent of the company's sizeable total research and development investments (2584.0 million euros in 2000). Even though the share of funding from Tekes was decreasing from significant to insignificant, Nokia's share of Tekes's all company projects was in the 1990s one third on average (Ali-Yrkkö and Hermans, 2004).

In the 1990s, most of the Tekes funding received by Nokia was directed to Nokia Research Centre's projects. In the period 1993-2001 the Research Centre received 55 percent on average of all Tekes funding to Nokia Group. During the recession at the beginning of the 1990, the importance of Tekes funding was especially great. With the support of public funding, the Nokia Research Centre managed to sustain the continuity of its research activities even through the most difficult years of the economic slump (Häikiö, 2001, p. 96).

One of the main justifications of public support for a highly profitable global market leader given by researchers and public administrators has been, that Nokia's participation in collaborative technology programs has been crucial for the formation and development of the whole Finnish collaboration network in advanced information and communications technology. Over the years and decades, this has generated a great number of fruitful intended and unintended side effects of spillovers between participants (Paija and Rouvinen, 2004, p.58). Through co-operation knowledge and know-how has spread multilaterally between various parties, companies, research institutes, universities etc.

10. Case DX 200: "the biggest and most successful Finnish innovation project"

A product called DX 200, characterized before as Nokia's "jewel" has been one of Nokia's and Finland's biggest, most expensive and most successful innovation projects or more a complexity of several hundred interrelated projects from early 1970s until now. In the very beginning, DX 200 was a modest telephone exchange. Through a great number of incremental innovations and modifications DX 200 gradually developed first to a larger digital telephone exchange system and later to a complex platform for large mobile networks.

Development of DX 200 started at Televa, the Finnish state-owned telecommunications equipment producer, in the early 1970s. In 1977, further development and commercialization of DX 200 was transferred to Telefenno, a research, development and marketing company for telecommunications equipment jointly owned by the two companies. As mentioned before, Televa and Telefenno were moved in mid-1980s completely to Nokia's ownership.

The new company Telenokia received orders of the DX 200 for fixed networks from both the PTT and the local telcos, and in 1984 there were around fifty DX 200 systems in operation in Finland.

The same year the first systems were exported to the Soviet Union. Starting from 1985 export volumes increased significantly and at the end of the 1980s Scandinavia and the Far East had become the most significant markets. In 1986, the first DX 200 was delivered for a mobile NMT network, and in 1991 the world's first GSM call was made using Nokia's mobile phone. The core network components were based on Nokia's DX 200 platform.

Already the original digital DX 200 exchange system for fixed networks was technologically very complex and required sophisticated competencies, but complexity was increasing remarkably in the exchanges for mobile NMT and GSM networks. Particularly along with the third GSM based device generation the challenges in terms of technological competencies and research and development volumes raised in 1980s to a totally new level. Software development alone of new DX 200 versions required from Nokia an input of several thousand person-years (Sandelin and Partanen, 2014)

Because of high and strongly increasing R&D costs, public financing had from 1970s had important role as a sharer of the risk related to development and commercialization of totally new technological competencies and solutions. Televa and later Telefenno had received in 1970s support from The Ministry of Trade and Industry for the first phases of DX 200 project, and particularly important was the support as grants and loans which Nokia received in mid-1980s from Tekes for development of NMT exchange (DX 200 MTX), and in the end of the 1980s for development ISDN and GSM exchanges, and later for the network systems of the 4th generation mobile technology.

Sandelin and Partanen have estimated (2014, 459-460) that during of the years 1983-2002 the total amount of support that Nokia received from the Ministry and Trade and Industry and Tekes for more than one hundred projects was around 60 million euros. One third of this was for network exchanges. This is much but not so much if we take into account that the total research and development expenditure of DX 200 in 1970-2006 was 3.5 billion euros and the number of person years almost 50 000.

Financial contribution received from the Ministry of Trade and Industry and Tekes for DX 200 has been just part of the total national contribution. Televa and its predecessors had already in the 1960s had close links and cooperation with professors and other scholars of the Helsinki University of Technology (HUT). Actually the whole idea of development of a telephone exchange representing latest technology came from HUT (Sandelin and Partanen, 2014, 25). Professors of telecommunications technology encouraged their students and the representatives of the few Finnish companies in the field to apply in telephone exchanges microcomputers and commercial micro circuits.

The lively cooperation between the Finnish companies, universities and VTT continued and became even more intensive in later years of DX 200 development both directly and through national technology programs such as Finprit, described before, and its successors (Sensor Technology, 1985-1988, Microelectronics, 1987-1991, Design and planning techniques of electronics, 1991-1995, Electronics for the information society, 1997-2001, Telecommunications: creating a global village, 1997-2001, Telecommunications electronics, funded by the Academy of Finland, 1998-2000, and Miniaturising electronics, 2002-2005).

11. Securing availability of advanced experts in ICT

In addition to investment in research and development, a key factor in Finland's emergence as a successful wireless player was a good quality of education at various education levels, and a strong commitment of policy makers and institutions of higher education to respond to the demands of the telecom industry as to the content and volume of related education. "The main reason why Nokia thrives in Finland is that it can draw on the local environment of advanced expertise in ICT" (Paija and Rouvinen, 2004, p. 60).

Owing to several reforms in the Finnish education system in 1960s and 1970s, the younger generation of Finns was already in late 1980s among the most educated in the world. Education that would enhance technological change was prioritized in education policies. Among the OECD countries, the Finnish education system was in the 1990s lagging only the Korean and German systems in terms of its relative emphasis on the natural sciences and engineering (Hyytinen et al. 2006, p. 59-60).

During the most intensive growth period which started in the 1990s the supply of skilled labor force ran short of industry's demand. The government reacted quickly by increasing the number of openings in institutions of higher education. Between 1993-1998, the total intake of students in universities had been nearly doubled, and in polytechnics it nearly tripled. (Ministry of Education, 1997). During the second half of the 1990s, the intake in higher-level technical education increased to the extent that there were even concerns about watering down the level of education with excessive intakes and stagnant budget financing (Paija and Rouvinen, 2004, pp. 51-529).

However, the Federation of Finnish Industries, the Federation of Electronics and Electrical Industry with Nokia as an active actor of both federations pushed the government to intensify efforts to increase supply of trained experts in the fields relevant to companies such as Nokia. University graduates were estimated to be in particularly short supply. Nokia's estimate was that over the years 1997-2000 the need for technically skilled labor in Finland would be about 6500 people (Häikiö 2001, part 3. p. 91). This figure was about two thirds of all the graduates in Finland in the fields of electronics, telecommunications, and information technology. (Ali-Yrkkö and Hermans, 2004, p. 110)

As a result, the government launched in 1998 a program aimed at further increasing education in information technology between 1998 and 2002. The programme included both ad hoc measures for promoting know-how and increasing the number of graduates in the near future (professional upgrading programs), and permanent increases in the provision of university and non-university professional education. The program designated that enrolments in universities will be increased from the projected level of 3000 by 1000 new students by the year 2000, and between 1998-2002 a total of 5 150 new students to professional upgrading programs. Similar increases were designated to polytechnics but smaller to vocational institutes. The target groups of the upgrading programs were those who wanted to upgrade their degree either from a lower level (e.g. polytechnic) to a higher level (e.g. university) or from another sector to information and communications sector (Jonkinen, 1999).

The total expenditure of the government of the program in 1998-2006 was estimated to amount to 500 million euros. The industry contributed to the implementation of the program also called “Joint Venture” (Häikiö 2001, part 3, p. 92-93). Companies provided internships, encouraged and promoted their experts to participate in training and education in universities and polytechnics, and donated funds for necessary equipment. The intake of university undergraduate and graduate school students occurred faster than planned (Kivistö and Aarrevaara, 2005).

Educational resources allocated to science universities in Finland in the beginning of 1990s did not match the sizeable growth in enrollment, owing to the retrenchment in public spending, yet the tertiary level of the education system suffered relatively little from the government’s belt-tightening (Hyytinen et al., 2006). During the same period, the budgeting system for higher education shifted towards performance measures, and research funding of universities was based on competition for both public and private funds.

12. Conclusions

This paper has taken the stance that the story of Finland’s telecom breakthrough equals the story of Nokia’s breakthrough in telecom. Subsequently, also the role of the Finnish state in this breakthrough has been analyzed from the same perspective. Nokia has not been the only Finnish telecom company, but it has been and still is the biggest and most dominant one. There are in Finland’s telecom sector several small companies and a few bigger companies, but common to all these companies has been their strong dependence on Nokia and its success. When Nokia did well the whole Nokia community did well, but when Nokia failed as its Mobile Phones did starting from late 2010s, the whole Nokia community was in troubles, some less, many more.

The Finnish state has all reason to congratulate itself for its significant contribution to the Finnish telecom breakthrough and the Nokia success story. The value of the achievement does not diminish the fact that the outcome most certainly was a big surprise also to the state itself. The Finnish telecom industry, not to mention Nokia, was not a creation of the state. Market forces and private entrepreneurship in the form of an old, big and strong national player Nokia were in the driving seat, but the Finnish state did everything what a state of a small economy can do for industrial upgrading and renewal. This paper has been dealing with the telecom sector. The focus of policies was in the 1980s and 1990s on ICT and information technology, but innovation and education policies covered most other sectors of the Finnish economy as well. It was in these decades question about a comprehensive mobilization of national resources for knowledge-based innovation driven growth.

There has not been a systematic plan to build a globally competitive Finnish telecom sector with Nokia as a flagship or even as a national champion. One thing is however sure: the long-term strategic perspective of innovation and education policies were essential to Nokia’s and Finland’s emergence as successful telecom player. These policies were relatively consistent over the long term starting from late 1960s and were not dictated by short-term cyclical or political considerations. The breakthrough of Finnish telecom was very much an innovation driven breakthrough. Therefore the whole fabric of activities which various parts of the public sector

executed in education, science, technology and innovation made the state an important actor in this development.

The recent history of the Finnish telecom sector has been full of dramatic turns. The dominance of Nokia has drastically changed and its importance for the Finnish economy diminished. However, Nokia's collapse was not a total collapse for the company and neither for Finland, not to mention the fundamentals of Finnish innovation policy. The policy instruments which have been successfully used in Finland for upgrading and renewal of the telecom industry and other industrial sectors are still relevant for Finland or even more relevant than in the past. However, targeting "new Nokia" is not realistic, and it is not necessarily desirable either. Instead of one giant, a more diversified industrial structure with a bigger number of small and medium sized companies would fit best for Finland of the future.

References

Ali-Yrkkö, J. (2010). The role of Nokia in the Finnish economy. In: J. Ali-Yrkkö, ed., *Nokia and Finland in a sea of change.* Helsinki: Etla., pp. 9-36.

Ali-Yrkkö, J., Paija, L., Reilly, C. and Ylä-Anttila, P. (2000). *Nokia - a big company in a small country.* Vantaa: Taloustieto Oy.

Ali-Yrkkö, J. and Hermans R. (2004). A giant in the Finnish innovation system. In: G. Schienstock, ed., *Embracing the knowledge economy*. Bodmin: Edward Elgar., pp. 106-127.

Borras, S. and Edquist, C. (2013). *The Choice of Innovation Policy Instruments.* Centre for Innovation, Research and Politics, Lund University. Paper no. 2013/04.

Castells. M. and Himanen, P. (2002). *The information society and the welfare state. The Finnish model.* New York: Oxford University.

Dahlman, C (2007). Conclusions and Lessons from Finland's knowledge economy for other economies. In: C. Dahlman, J. Routti and P. Ylä-Anttila, ed., *Finland as a knowledge economy. Elements of success and lessons learned.* Washington D.C: The World Bank., pp. 99-110.

Dahlman, C.J., Routti, J., and Ylä-Anttila, P., ed., (2007). *Finland as a knowledge economy. Elements of successs and lessons learned.* Washington: The World Bank.

Hyytinen, A., Paija, L., Rouvinen, P. and Ylä-Anttila P. (2006), Finland's emergence as a global information and communications technology player. In: J. Zysman and A. Newman, ed., *How revolutionary was the digital revolution?* Stanford, California: Stanford University Press., pp. 55-77.

Häikiö, M. (2001). *Nokia Oyj's history 1-3* (in Finnish). Helsinki: Edita.

Häikiö, M. (2002). *Nokia, the inside story.* Great Britain: Pearson Education.

Jonkinen, J. (1999*). The public-private partnership to meet the demand for IT skills: programme for increasing education in the fields of information industry in Finland.* [pdf] Available at *http://www.oecd.org/finland/2100511.pdf*

Katila, V., Koski, H., Routti, J., Tiihonen, P., and Ylä-Anttila, P. (2007). Changes in the economic and institutional regimes. In: C. Dahlman, J. Routti and P. Ylä-Anttila, ed., *Finland as a knowledge economy. Eelements of success and lessons learned.* Washington D.C: The World Bank, pp. 25-37.

Kivistö, J. and Aarrevaara, T. (2005). *Review of the programme for increasing education in the information industry fields* (in Finnish). Publications of the Ministry of Education 2005:30.

Koivusalo, M. (1995). *The development and challenges of the Finnish radiophone industry* (in Finnish). Espoo: Cetonia Systems.

Lemola, T. (1996). Is three billion marks enough? (in Finnish), In: T. Lemola and R. Lovio, ed., *Why Nokia, Finland?* Juva: WSOY. pp. 144-173.

Lemola, T. (2002). Convergence of national science and technology policies: the case of Finland. *Research Policy*, 31, 1481-90.

Lemola, T. (2003). Transformation of Finnish science and technology policy. *Science Studies,* 16 (1), 52-67.

Lemola, T. (2004). Finnish science and technology policy. In: G. Schienstock, ed., *Embracing the knowledge economy.* Bodmin, Cornwall: Edward Elgar. pp. 268-284.

Lemola, T. (2014). Background: Evolution of Finland's knowledge economy policy. In: K. Halme, I. Lindy, K. Piirainen, V. Salminen, and J. White, ed., *Finland as a knowledge economy 2.0. Lessons on policies and governance.* Washington D.C.: The World Bank. pp. 29-43.

Lovio, R. (1989). *Finnish success story* (in Finnish). Helsinki: Hanki ja Jää

Lovio, R. (1993). *Evolution of firm communities in new industries.* Helsinki: The Helsinki School of Economics and Business Administration.

Lundvall, B-Å. ed., (1992*). National systems of innovation.* London: Pinter Publishers.

Ministry of Education (1997*). A programme for increasing education in the information industry fields* (in Finnish). Reports of the Ministry of Education 25:1997.

Paija. L. (2001). The ICT cluster in Finland. Can we explain it? In: L. Paija, ed., *Finnish ICT cluster in in the digital economy*. Helsinki: Taloustieto.

Palmberg, C. (1998). *Public technology procurement in the Finnish telecommunications industry.* [pdf] Available at *http://citeseerx.ist.psu.edu/viewdoc/download?doi=10.1.1.196.8416&rep=rep1&type=pdf*

Palmberg, C. (2003). *Turning opportunities into innovations.* Stockholm: Royal Institute of Technology.

Palmberg, C. (2002). Technological systems and competent procurers: The transformation of Nokia and the Finnish telecom industry revised. *Telecommunications Policy* 26: 129-148.

Palmberg, C. and Martikainen, O. (2003). *Overcoming a technological discontinuity. The case of the Finnish telecom industry and the GSM.* Helsinki: Etla.

Rouvinen, P. and Ylä-Anttila, P. (2004). Case study: little Finland's transformation to a wireless giant. In: S. Dutta, B. Lanvin, and F. Paua, ed., *The global information technology report, 2003-2004.* New York: Oxford University Press. pp. 87-108.

Rouvinen, P. and Ylä-Anttila, P., (2015). The historical evolution of the Finnish ICT sector. In: E. Giertz, A. Rickne and P. Rouvinen, *Small and beautiful. The ICT success of Finland & Sweden.*Vinnova Analysis 2015:06. Stockholm: Vinnova. pp. 51-61.

Sabel, S. and Saxenian, A. (2008). *A fugitive success. Finland's economic future.* Helsinki: Sitra.

Sandelin, M. and Partanen, J. (2015). *Nokia's jewel* (in Finnish). Porvoo: Bookwell Oy.

Schienstock, G. and Hämäläinen, T. (2001). *Transformation of the Finnish innovation system: a network approach.* Helsinki: Sitra.

Science and Technology Policy Council of Finland (1996). *Finland: a knowledge-based society.* Helsinki: Edita.

Sölvell, Ö. and Porter, M. (2011). *Finland and Nokia: Creating the world's most competitive economy.* Harvard Business School, 9-702-427.

Technology Committee (1980). *The report of the technology committee.* Helsinki: Valtion Painatuskeskus.

Vuori, S. and Vuorinen, P. (1994). Outlines of the Finnish innovation system: the institutional setup and performance. In: S. Vuori and P. Vuorinen, ed., *Explaining technical change in a small country.* Heidelberg: Physica-Verlag. pp. 1-42.