Collaborative Strategies in the Event of Technological Discontinuities: The Case of Nokia in the Mobile Telecommunication Industry

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ABSTRACT. The paper examines the extent to which collaboration between large and small companies has been able to deal with the effects of discontinuous technological change. In applying an evolutionary perspective, the paper examines the process by which technological competencies and resources of large firms evolve and its effects on the characteristics of their collaboration with smaller companies. In focusing on the issue of complementary between local and international sourcing of capabilities and resources in the mobile telecommunication industry, it combines an empirical analysis of the structure of Finnish Science Parks with an examination of internationalisation strategies of large Finnish companies. The paper shows that Nokia has increasingly become engaged in sourcing capabilities internationally, this might, however, pose some long-term problems for the local embeddedness of the company in Finland.

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1. Introduction

Collaboration between large and small companies has been a response to discontinuous technological change in high technology industries. Large companies have been disadvantaged because they are less capable of smoothly responding to this change than their smaller counterparts. The incompatibilities with existing technologies and competencies imposed by discontinuity typically reduce the value of incumbency. They open alleys for the entry of new (mostly small) entrepreneurial companies that challenge the market position of established (mostly large) firms in the industry. This argument lies in the centre of the Schumpeterian model of innovation related to small firm growth (Schumpeter, 1912). However, as Schumpeter (1942) furthermore proposed, incumbency might also create advantages due to sheer market size and existing resources of research and development (R&D). The latter model of innovation has been related to the growth of large firms. The dichotomy between the effects of different types of companies on innovative progress (Freeman and Soete, 1997; Nelson and Winter, 1982) has extensively been discussed in the literature. Most research has developed its particular view on technological progress by resting on one of these models.[1] Recently, some studies have started to combine these models by examining industries exposed to rapid technological change.[2] The focus of studies on these industries has been, in particular, on the extent to which collaboration between large and small companies has been able to deal

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with the effects of discontinuous technological change.

In expanding the analysis beyond the Schumpeterian dichotomy, the paper demonstrates that large companies respond to discontinuous technological change by collaborating with smaller firms with the objective of combining the innovative advantages of both types of companies. In high-tech industries, such as mobile telecommunications, these collaborative efforts have especially been important due to the rapid pace of technological change, requiring companies to generate a constant stream of product innovations in order to sustain their competitive advantage in the industry. In applying an evolutionary perspective, the paper examines the process by which technological competencies and resources of large firms evolve and its effects on the characteristics of their collaboration with smaller companies. In examining the corporate strategy of Nokia, the large Finnish telecommunication manufacturer, the paper shows that the particular form of local innovation networks in Finland has effected the organization of international collaboration of Nokia. It seems that the local production networks in Finland can, on their own, rarely provide the advantages needed to facilitate the rapid technological change in the mobile telecommunication industry. Therefore, Nokia has pursued an internationalisation strategy that is complementary to its local integration with the aim of avoiding obsolescence of innovation potential.

In section two, the paper examines the problem of discontinuous technological change in a high-tech environment. Based on an evolutionary approach, the discontinuity of technological change is characterised and its effects on the obsolescence of accumulated firm-internal resources and competencies are studied. In section three, technological change in mobile telecommunication is linked to the evolution of the Finnish telecommunication industry, in particular with respect to its embeddedness in regional systems of innovation and the internationalisation strategy of its leading company Nokia. Finally, some tentative conclusions are presented in section four.

2. Theoretical perspectives: Discontinuous technological change in an high technology environment

2.1. *The economics of technological trajectories*

Evolutionary theories have made some progress in linking technological change to the growth of firms. They emerged as a reaction to orthodox theories that have been criticised as lacking the "descriptive realism in the characterisation of behaviour and events" and that were insufficiently equipped to deal with uncertainty and change in advanced theoretical work and many applied contexts (Nelson and Winter, 1982). Based on an evolutionary approach, researchers have focused on asymmetries and variety among companies and the role of technology in explaining these asymmetries. As originally proposed by Dosi (1982, 1988), these asymmetries are effected by changes in technological trajectories in the industry, i.e. technological progress along particular technological parameters defined by a technological paradigm. In analogy with Kuhn's definition of a scientific paradigm and inspired by Rosenberg's "focusing devices", Dosi (1988) defined a technological paradigm as "a pattern of solution of selected techno-economic problems based on highly selected principles derived from the natural sciences, jointly with specific rules aimed to acquire new knowledge and safeguarding it, whenever possible against rapid diffusion to the competitors". The establishment of a new paradigm entails a "communis opinio" about the nature of the solutions of selected techno-economic problems (Dosi, 1988). Technological paths or trajectories are shaped by selection or focusing mechanisms, which guide technological progress in certain directions. Along these technological trajectories, companies choose technologies according to particular technological parameters.

In an evolutionary framework, the direction of technological progress is characterised by irreversibility and path-dependency.[3] Although irreversibility is generally associated with acquired system-scale economies or prior investments in education and equipment (Griliches, 1998) often the focusing capabilities of the prevailing technological paradigm are much more important, in the sense that while technological progress is locked-in a specific path, previous technologies are disregarded and eventually forgotten (David, 1985).[4] Although technological paradigms may be very strong for a considerable period of time, technologies do not follow the same technological path forever. Kuhn argued that "novelty emerges only with difficulty, manifested by resistance, against a background provided by expectation" (Kuhn, 1970). Thus, a change of regime may arise whenever there are diminishing returns in improving the basic technological characteristics over time or when other technological developments give way to a change of the characteristics of a design. Change can, however, also be induced when there are significant changes in the nature of the selection environment, which favour other technological alternatives. Technological paradigms often evolve from a conception of vague ideas into very strong paradigms, which blindfold technicians from pursuing other more uncertain directions. This can be critical for companies if these new directions of technological progress represent a challenge to the accumulated resource and capability base of a company (Christensen, 1998).

Based on new technological trajectories, technological discontinuity can emerge given that the new technologies are not easily compatible with the previous generation of technology and with pre-existing competencies within a company. Even further, technological discontinuity leads to a process in which the previous generation of technologies might increasingly become non-competitive, and many of the competencies that companies have previously accumulated based on previous generation technologies become useless. There is a high chance that irreversible investment in plant capacity and R&D, special licenses, contracts for special materials or services may become obsolete (Afuah and Utterback, 1997).

In their attempts to successfully adapt to processes of rapid technological change, companies have to make choices about the geographical dispersion of their production and innovation facilities. The key question is where companies can attract required competencies and resources that sometimes include even local tacit advantages (Cantwell and Santangelo, 1999). The re-orientation of production and, in particular, innovation networks of companies has been central in the process of adaptation. It has been demonstrated that increasing internationalisation of companies has taken place through the international expansion of these networks (Cantwell and Janne, 1999; Zander, 1999). However, the extent to which process of international expansion has been a supplement or a surrogate to the national (or regional) integration of companies in innovation networks has extensively been discussed in the literature (Cantwell and Santangelo, 1999; McKelvey and Texier, 2000). Studies on changes in these networks as a result of rapid technological change have rarely been undertaken. The analysis of Nokia's production and innovation network allows us to examine the issue of complementary between local and international sourcing of capabilities in one of the most dynamic industries (mobile telecommunications) in more detail. Let us first describe the dynamics in the mobile telecommunication industry before focusing on the specifics of this industry in Finland.

2.2. *The Technological trajectory in mobile telecommunications*

Within the mobile telecommunication, the pace of technological improvement has been rapid in the past twenty years.[5] At the beginning, the growth of the mobile telecommunication took place rather isolated from changes in other segments of the industry. With the introduction of radio technology around 1915–1925 in the United States, mobile technologies represented a fragmented technological trajectory in the industry. With the transition to the second generation of mobile phones, the separation and fragmentation of this trajectory continued (Kavassalis et al., 1996).

During the transition to the second generation of mobile technologies, technological discontinuity emerged. The second (digital) generation of mobile telecommunication technologies required a different set of competencies in particular in the areas of R&D and manufacturing compared to those required for analogue technologies. Although the design of telecommunication switching technology remained rather unchanged, radio technology was undergoing some fundamental changes from the analogue first-generation. In addition to a change in the basic design of the handset, other parameters became important for the new generation of mobile telephones such as the growth in bandwidth and network intelligence. Software development for the second-generation mobile phones became much more essential for further technological change. The growing significance of software development compared to the hardware side of mobile technology required telecommunication manufacturers to attract a different set of firm-internal competencies as accumulated during the previous generation of analogue mobile technologies (Bekkers and Smits, 1999).

During the current transition to the third generation in mobile telecommunications, the mobile technological trajectory increasingly provides the potential for convergence with other trajectories in the industry.[6] Some technologies utilized in the second generation mobile phones have been compatible to the third-generation because of the implementation of non-proprietary standards. However, a whole set of new competencies is needed for the distinctively different and integrated services that can be provided through third-generation mobile technologies. These new mobile technologies should not just be able to offer new services, but also substitute for traditional network services. In order to enhance the mobility functions of the third-generation mobile systems it has been necessary to enlarge the current intelligent network functionality of mobile technologies (Bekkers and Smits, 1999). Currently it is, however, unclear to what extent the mobile telecommunication trajectory will be the winning one in local access competition due to technical discontinuity that might cause some creative destruction in the telecommunication sector as a whole (Kavassalis et al., 1996). In the following section, the focus is on the current effects of this trajectory on the reorganisation of the Finnish telecommunication sector.

3. The development of the technological trajectory in mobile telecommunications and the role of Nokia

3.1. *The emergence of the technological trajectory in mobile telecommunications in Finland: The NMT standard*

The development and early adoption of the Nordic Mobile Telephony (NMT) standard established by the telecommunication administrations in Sweden, Norway, Finland and Denmark in the early 1980s has been considered as a re-birth of the Finnish Information Technology (IT) industry and the beginning of the mobile technological trajectory in Finland.[7] From the onset, the creation of appropriate competencies and resources has been central to the development of the NMT standard. These resources were initially created based on the collaboration between the telecommunication suppliers and Public Telephone Operators (PTOs). In 1981, the Nordic (state-owned) PTOs developed the Nordic Mobile Telephone system (NMT) as a standard for automotive mobile telephones. This standard was promoted and introduced by the Scandinavian telecommunication equipment industry. Although the NMT standard was initiated and developed by Ericsson and the Swedish PTO, it was soon adopted and co-developed by Nokia. In other words, Nokia was already at a very early stage engaged in shaping the technological trajectory in mobile telecommunications.

Nokia-Mobira became world leader in the marketing of mobile handsets that were, at that time, mainly used in cars. In 1982, Nokia-Mobira introduced its first mobile phone. Within two years, Nokia-Mobira launched the first transportable telephone, which took the company into new markets such as the United Kingdom and United States. In 1986, Nokia was able to provide telecommunication switches that could be used in mobile networks. In contrast to other analogue systems, NMT technology included an important feature, namely the possibility of international roaming, at least to the neighbouring Scandinavian countries. This network feature increased the flexibility for residential and business users due to the larger size of the network.

In moving with NMT from the 450 MHz band (NMT 450) to the 900 MHz band (NMT 900), the mobile telecommunication equipment industry gradually improved the quality of the network. This transition to the 900 MHz band was due to congestion problems that occurred during the mid-1980s in the 450 MHz band. It fostered the need for a system with higher capacity. The Nordic PTOs introduced this new NMT 900 system after some discussion about the future of mobile telecommunications in 1986. The NMT 900 was, in principle, based on the NMT 450 technology. It offered, however, a higher functionality with respect to portability of telephones and increased capacity – mainly because of the higher frequencies used. Another distinguishing feature of NMT was the open interface between switches and radio base stations that enabled more flexibility in network design configurations. These interfaces allowed operators to reduce their switching costs by contracting alternative suppliers and minimising the risk of "lock-in" constellations between suppliers and PTOs.

3.2. *The emergence of technical discontinuity: The GSM standard*

In 1989, the European Telecommunications Standards Institute (ETSI) defined GSM[8] as the internationally accepted digital cellular telephony standard. The GSM system was scheduled to commence operation on July 1, 1991, but most operators did not launch their systems until 1992. The first GSM network operator was the Finnish Oy Radiolinja Ab. Nokia had been one of the developers of the system. Again, the company was one of the first entering this new phase in technological development in mobile telecommunication. As an illustration, the first GSM telephone call was made with a Nokia phone. The GSM system increased the network effects for users even further by providing roaming capacity in initially 12 countries.[9] Due to the higher frequency (900 MHz band), the bandwidth quality increased.

In order to respond to the increasingly rapid pace of technological change in the industry, the Finnish telecommunication industry had to develop new competencies and resources in the area of digital mobile technologies (Keil et al., 1997). GSM was based on open interfaces, which allowed other than established manufacturers to provide telecommunication equipment. This encouraged new entry of suppliers and facilitated experimentation by forcing suppliers to differentiate their products while competing within a common industry standard (NMT). This allowed systems firms to focus on only those elements of the product, in which they had specialised skills, purchasing all other components externally. Major firms in the industry, such as Nokia, were developing their competencies and resources by building up innovation networks. By focusing on their core competencies and purchasing the remainder from specialist suppliers, they created a network system that spread the costs of developing new technologies, reduced product-development times and fostered reciprocal innovation (Keil et al., 1997).

In summary, a major factor in the development of technical discontinuity in the telecommunication industry of Finland was the transition towards GSM. The incompatibilities between NMT and GSM technologies rendered not only customer equipment and existing network infrastructure capacity obsolete but also specialised equipment provided by suppliers, and knowledge and skills necessary to manufacture and implement GSM networks. These trends were reinforced with the gradual introduction of new platforms based on TCP/IP (Transmission Control Protocol/Internet Protocol) and the transition to the third generation of mobile telecommunication.

3.3. *Towards third generation of mobile telecommunication: UMTS and beyond*

The new technological challenge for the development of third generation mobile telecommunications has been the extent to which these technologies can provide personal multimedia.[10] Based on new wireless data applications and innovative terminal types, completely new markets are expected to develop. In this context, compatibility of mobile technologies with TCP/IP and ATM (Asynchronous Transfer Mode) is vital. Stepping stones in achieving compatibility have been standardisation efforts in the area of Wireless Application Protocols (WAP). The WAP forum, established by Ericsson, Nokia, Motorola and Unwired Planet (now Phone.com), was founded in 1997 in order to promote and develop a new standard for third generation mobile telephony. In more general terms, WAP can be considered as a variant of TCP/IP with an attached radio element.

Another decisive path of current technological development in the area of mobile telecommunications has been related to the *de facto* operating systems (EPOC) for mobile wireless information. After introduction, the EPOC 32 operating system has also been licensed to handset manufacturers and it is likely to encourage independent software vendors to produce EPOC-based applications. The development on the EPOC system takes place in the framework of a joint venture called Symbian established in 1998, in which Nokia, Ericsson and Motorola teamed up with Psion. In 1998, Matsushita joined the venture. Bluetooth applications[11] have been another decisive technological path in the development towards personal multimedia. These applications have been developed within the Bluetooth interest group consisting of Ericsson, IBM, Intel, Nokia and Toshiba with the aim to produce an open standard for short-range voice and data transmission via wireless devices. The participation of Nokia in the WAP Forum, Symbian venture and the Bluetooth interest group demonstrates that the company has at a very early stage been involved in the technological trajectory in third generation mobile telecommunications.

The central question in the evolution of this trajectory has been the extent to which the convergence of future mobile technologies with other trajectories in telecommunications will take place and, therefore, whether mobile technologies will become the winning contender in the local loop. If the technological trajectory in mobile telecommunication will continue, than the third generation technologies could be the long-term solution to overcome the bottleneck at the customer interface with the telecommunication network. In this case, this technological trajectory could create sufficient market potential for the growth of large telecommunication companies in Finland. If other local loop technologies, such as upgrading of fixed access or cable connection, will dominate, this might create problems in terms of competitive advantage for mobile telecommunication manufacturers. In this context, the organisation of innovation networks in the Finnish telecommunication industry and, in particular, of Nokia will be critical to deal with the challenges imposed by technological discontinuity in mobile telecommunications.

4. Technological change in the Finnish telecommunication industry

4.1. *Opportunities for inter-firm collaboration*

Increasing internationalisation has been an essential characteristic of firm strategies in the Finnish telecommunication industry in the 1980s and 1990s. As in other industries, telecommunication companies were benefiting from strong growth of industrial investment in Finland. This growth was partly caused by a rise in fixed domestic investment, but partly also, in particular in the 1990s, by a strong growth of industrial investment abroad. In 1998, foreign investment by Finnish companies accounted for more than one-third of total industry investment (Finnfacts, 1999a). As Table I shows, Finnish companies primarily invested in other countries of the European Union (EU). The most important target countries for investment have been Germany, Sweden and the United Kingdom. Investment spending in other countries than Finland exceeded 9.5 billion FIM in 1998, which equals EUR 1.51 billion.

The reasons behind foreign investment of Finnish companies have been twofold. Firstly, the domestic market became too small, in particular for companies in sectors with a high market growth such as mobile telecommunications. Secondly, foreign investment was increasingly

TABLE I
Industrial investment spending abroad (billion FIM)*

	1996	1997	1998
EU, Finland excluded	4.75	5.11	5.77
North America	0.16	3.77	0.66
South and Central America	0.20	–	0.08
Russia	0.10	0.19	0.38
Eastern Central Europe	0.10	0.18	0.24
Baltic countries	0.19	0.19	0.50
Asia	0.29	0.27	1.10
Others	0.10	0.62	0.80
Total	5.89	10.33	9.53

Source: Finnfacts, 1999a, p. 5.
* These figures include foreign acquisitions where at least a 10% stake has been obtained.

considered as a more cost-effective method of company growth compared to exporting of goods and services. It allowed Finnish companies to be closer to foreign markets and to source capabilities abroad (Finnfacts, 1999a).

In the following part, we would like to explore the question to what extent the internationalisation strategies of major companies in the industry have, in fact, been complementary to their embeddedness in local production and innovation networks in Finland. Before looking at the internationalisation strategy of the most successful Finnish IT company: Nokia,[12] the type of industrial activities in three major Science Parks in Finland, in particular in the area of information technology (IT) is examined. Based on these activities, Science Parks provide opportunities for major companies to attract particular resources and capabilities locally.

4.2. *The importance of SMEs in IT industries: Science Parks in Finland*

Local communities as well as the national government, in particular through the National Technology Agency (TEKES), have been important facilitators for the development of Science Parks in Finland. The main policy objectives for creating Science Parks have been to disseminate R&D spillover from existing universities and research institutes to new SMEs and research units. The idea of fostering the participation of SMEs in technological collaboration led to the establishment of Science Parks in Finland. Based on these objectives, the parks were aimed at fostering strong collaboration between firms, universities and research institutes (Finnfacts, 1999b). The first Science Park in Finland has been Technopolis in Oulu, founded in 1982. Technopolis has been set up as a regular firm with shareholders.[13] The other two Science Parks investigated in this paper are Innopoli in Otaniemi/Espoo and Turku Technology Centre in Turku.

In characterising the Finnish information technology (IT) industry as a whole, Table II shows that large companies in IT manufacturing have generated the largest share in employment. Only 16 percent of total employment in IT manufacturing came from SMEs. This percentage has been lower than for the manufacturing industry in total, where SMEs provided about 32 percent of total employment. In IT services, the trend has been more in line with total industry employment. Almost half of the employees involved in IT-services worked in SMEs. However, telecommunication services showed a pattern that was distinctively different from IT and other services. In this industry, large IT companies provided almost 90 percent of total employment.

The major industrial sectors represented in the large Finnish Science Parks were similar to the sector characterisation of the Finnish industry as a whole, although the ranking of clusters was slightly different.[14] The information technology industry has been the most important sector in the Science Parks (Table III). This has been most

TABLE II
Employment by enterprise size in percentages (in percentages), 1997

	Enterprise size (Number of employees)						Total
	0	1–9	10–19	20–49	50–99	100+	
IT manufacturing industry	0.1	3.6	2.5	5.6	4.3	83.9	100
IT services total	0.6	18.9	9.1	11.3	6.3	53.7	100
Of which:							
Wholesale	*0.6*	*26.0*	*14.2*	*15.7*	*9.1*	*35.4*	*100*
Telecommunications	*0.0*	*1.3*	*1.0*	*4.2*	*4.3*	*89.2*	*100*
Consultancy services	*1.1*	*26.0*	*9.6*	*12.0*	*5.8*	*45.5*	*100*
Total manufacturing industry	0.4	9.7	5.2	9.0	8.0	67.7	100
Total services activities	1.3	30.8	8.8	9.3	5.7	44.2	100
Total NACE 15–37, 45, 50–74, 92, 93	1.1	24.2	7.8	9.3	6.5	51.1	100

Source: Nordic Council of Ministries, 1998, p. 29.

TABLE III
Firms and institutes per industry cluster (in perentages), 1999

	IT and electronics	Forestry, pulp and paper	Machinery	Medical, chemical and biotechnological	Other	N.A.
Innopoli, Otaniemi (*n* = 116)	36.2	5.2	3.4	3.4	49.1	2.6
Turku Techno. Centre (*n* = 191)	22.5	0.5	1.6	25.1	44.5	3.1
Technopolis, Oulu (*n* = 187)	44.9	1.1	2.7	10.2	28.9	11.8

Source: Science Park web-sites and business reviews (1999).

obvious in the Science Park of Oulu, where over 44 percent of the firms have been a part of the IT industry. At Innopoli, the share of the IT industry has also been rather high. More than one third of all companies in Innopoli were related to the IT industry. The exception in this overall picture, is the Turku Technology Center, where one quarter of all firms were part of the biotechnology industry, which makes the sector more important than the IT sector.[15] The traditional focal sectors of the Finnish economy, i.e. forestry (wood) and machinery, have been of less importance in the large Science Parks.

Table IV shows the core activities of companies in Science Parks in three main areas: services, manufacturing and technology.[16] The fourth category, defined as "other", contains activities that cannot be categorised in one of the other three categories.[17] In general, most firms performed service-related activities, which were, on average, over 55 percent of all activities. At Innopoli (Otaniemi), 69 percent of all companies delivered services. In Technopolis (Oulu) and Turku Technology Centre, nearly 50 percent of firms' activities were in the service area. The figures in Table IV demonstrate the importance of services, in particular in Innopoli. In this Science Park, consultancy firms have been much more prevalent than in the other two Science Parks.

On average, one fifth of the activities of companies have been technology related. Almost one-third of the firms and institutes of the Science Park in Turku were performing technology-related activities, like research and development. For the other three parks, these figures were significantly lower with 15.5 percent for Innopoli and 12.3 percent for Technopolis. Another important industrial activity in Science Parks has been manufacturing. On average, slightly more than 18 percent of all activities were related to manufacturing. In Oulu, more than one quarter of all companies considered manufacturing as their core activity. A smaller number of firms in the Science Parks of Turku and Otaniemi regarded manufacturing as their main objective, namely 15.7 percent and 12.1 percent. In general, technology and manufacturing taken together accounted for a lower number of industrial activities in the Science Parks compared to services.

A description of company activities in the information technology (IT) sector is shown in Table V. At the Science Park in Innopoli, more than 70 percent of the IT-activities were in the service area. These services included sales offices of large companies, such as 3Com and Texas

TABLE IV
Core activities of firms and institutes (in percentages), 1999

	Services	Manufacturing	Technology	Other
Innopoli, Otaniemi (*n* = 116)	69.0	12.1	15.5	3.4
Turku Techno. Centre (*n* = 191)	48.7	15.7	31.9	3.7
Technopolis, Oulu (*n* = 187)	48.7	26.7	12.3	12.3
Average	55.5	18.2	19.9	6.5

Source: Science Park web-sites and business reviews (1999).

TABLE V
Activities of IT firms and institutes (in percentages of total), 1999

	Services	Manufacturing	Technology
Innopoli, Otaniemi (n = 116)	71.4	16.7	11.9
Turku Technology Centre (n = 191)	40.4	29.8	29.8
Technopolis, Oulu (n = 187)	44.0	40.5	15.5
Average	51.9	29.0	19.1

Source: Science Park web-sites and business reviews (1999).

Instruments, delivery of IT security systems and smart cards (Bull), and 3D simulations and Internet design. Manufacturing has mainly been done by SMEs, although some large manufacturers also have subsidiaries at Innopoli. In total, manufacturing accounted for nearly 17 percent of all IT activities. The most well-known manufacturers in the park have been the U.S. companies Lucent Technologies and Verbatim. Only 12 percent of the companies in Innopoli had technology-related activities in the core of their business. Neither Nokia nor Sonera nor any other large Scandinavian telecommunication company has branches at Innopoli. In this park, the large IT companies were all foreign and mainly from the U.S.

The activities of the firms and institutes at Turku Technology Center have been slightly different compared to the Science Park in Innopoli. Here, a small majority of companies considered IT services as their main activity (more than 40 percent). A substantial proportion of firms has been involved in manufacturing and technology (both account for nearly 30 percent).[18] The R&D activities in the IT area have been undertaken by two large companies and the university of Turku. One major company, Benefon Oyj, has its R&D centre in Turku. This company, a Nokia-Mobira spin-off, considers mobile telecommunication based on NMT 450 and GSM standards as its main activity.[19] Another large company with an R&D laboratory in Turku has been Ericsson. None of the SMEs considered R&D in information technology as their primary activity.

As in the other two Parks, the majority of IT organisations of Technopolis in Oulu have been concentrated on services and software activities. Services activities were performed by SMEs as well as by some large companies (Nokia, Sonera, Tieto corporation and Compaq). The Finnish firms, Elektrobit and Extrabit, provided software for Nokia's Mobile Phones. In addition, manufacturing has been an important activity within this Science Park. The manufacturers at Technopolis have been either internationally oriented Finnish companies or subsidiaries of large foreign corporations. Examples of Finnish manufactures at Technopolis have been Indesco and Nemo Technologies. This latter company is a joint venture of Elektrobit and Nokia, established in 1996. The large foreign IT-producers have been Hewlett-Packard, 3M, Sun Microsystems and Tellabs. Nokia Telecommunications and the University of Oulu have been the most important contributors to IT-related R&D at Technopolis. None of the other organisations or subsidiaries of large companies had R&D as a core activity.

Based on the integration in local innovation and production networks in the Science Parks, major companies in the Finnish mobile telecommunication industry such as Nokia have been able to expand and to acquire capabilities internationally. An international sourcing of capabilities has increasingly become necessary to facilitate the adaptation of these companies to the technological trajectory in mobile telecommunications. These capabilities were rarely available within the Finnish Science Parks. The rapid pace of technological change, in particular technological discontinuities, seems to have reinforced problems with competencies and resources that could be attracted locally. These problems were related, firstly, to scarcity of skills and competencies usually provided in Science Parks, and secondly, to the decreasing competence of the subcontracting industry to provide inputs required for further innovation in mobile telecommunications. This is a first indication that the Science Parks might not be able to fulfil the promises of facilitating the discontinuous shift along the mobile telecommunication trajectory. Let us turn to the alliance strategy of Nokia to analyse the extent to which these capabilities could have been acquired internationally.

4.3. *The internationalisation of a major firm in the Finnish IT industry: The case of Nokia*

In the Finnish IT industry, internationalisation has been a dominant industrial trend at least since the late 1980s. In its internationalisation strategy, Nokia has been a trendsetter for the industry as a whole (Keil et al., 1997). Since the mid 1990s, the alliances of Nokia have mostly been international (95 percent).[20] The majority of international alliances occurred in the area of manufacturing, less than 30 percent were technology alliances, and only around 10 percent were international service-related collaborations. In general, these alliances were related to GSM-based technologies ranging from building networks to adding new services and technologies to mobile handsets. A majority of international alliances involve large American IT companies, like Motorola, IBM, Lucent Technologies, AT&T, 3Com and Intel. Other international alliances were based on collaborations with Japanese companies such as NTT and Toshiba. The alliances with European partners mostly involved collaborations with telecommunication operators, such as Deutsche Telekom, British Telecom (Quadrant Consortium), France Telecom and the Dutch KPN. The Scandinavian alliances were dominated by the collaboration with Ericsson. Other Scandinavian alliances involved companies like Telenor, Telia, TeleDanmark and the Finnish-Swedish MeritaNordbanken. In the latter venture, Nokia and the bank have been aiming at providing banking services on mobile handsets. This new form of electronic banking allows clients to check their accounts and make transactions using their cellular telephones.

There have been national alliances mostly with Sonera (the former Telecom Finland), except for one alliance with a smaller Finnish company called Seiren Solutions. This company produces Waplook, software for applications using the Wireless Application Protocol. Waplook for MS Exchange is a personal organiser program designed to work in WAP-compatible devices such as the third generation cellular telephones to be launched later this year.[21] The company markets the application to telecommunications companies and operators to be included in their services. Seiren Solutions collaborate with Nokia Telecommunications to develop value-added services for mobile operators as a member of the Nokia Artus Developers Program. The company has benefited from funding of TEKES.

In Table VI, some indication is given on the status of Nokia as a partner for development of services, manufacturing and technology. Our analysis shows that Nokia has been an alliance partner for joint development in 75 percent of the collaborative agreements (characterized in the row labelled "Partner") In more than one fifth of the agreements with other companies, Nokia has been a preferred or exclusive supplier of equipment (see rows "Supplier" and "Manufacturing"). The provision of service usually occurs in a partnership and only in 2.5 percent of the cases, Nokia deliv-

TABLE VI
International alliances of Nokia (in percentages, $n = 80$), November 1996–November 1999

	Services	Manufacturing	Technology
International	11.25	55.00	28.75
National	1.25	3.75	0.00
Partner	10.0	36.25	28.75
Supplier	2.50	22.50	0.00
Equity	0.00	3.75	13.75
Non-equity	12.50	55.00	15.00

Source: Communications International, Communications Week International, Total Telecom, 25 November 1996–25 November 1999 (www.totaltele.com).

ered services as a supplier. In all technology alliances, Nokia has been a partner, meaning that the company has not performed research and development for third parties.

Another way of looking at alliance activity has been to characterize the agreement in terms of equity/non-equity forms of inter-firm cooperation. Table VI shows that non-equity forms of alliances have been the majority of agreements. One quarter of alliances has been established in the form of a non-equity customer-supplier contract (see rows "Supplier"). The majority of equity agreements are related to technological activities. An example of an equity technology alliance is the Quadrant consortium with British Telecom, Motorola and TWR. Only a few of the equity agreements are related to manufacturing. A good example of an equity agreement in manufacturing is Symbian, a joint venture of Psion, Nokia, Motorola and Ericsson, established in 1998. Symbian seems to be rather successful in the development and exploitation of their EPOC software, since Microsoft is loosing ground with their Windows CE for GSM and other portable applications.

In terms of interdependence and internationalisation, non-equity agreements have mostly been used in order to attract capabilities that are not available within the firm, but complementary to existing competencies within the firm. They have especially been applied in sectors where the external environment has been highly turbulent. Furthermore, these alliances have been established to create network effects, i.e. to increase the willingness to pay among users and the market price because of the high expected sales given the product succeeds (Economides, 1996). Examples of such consortia to build up competencies and to increase network effects have been the WAP Forum and the Bluetooth consortium.

5. Summary and conclusions

Increasing globalisation and rapid technology change have been key characteristics of the mobile telecommunication industry in Finland in the 1980s and 1990s. Large companies in the industry such as Nokia have been successful in driving technology change to facilitate their internationalisation strategy. They have been able to adapt to the rapid technological change characterising the technological trajectory in mobile telecommunications during the 1970s and 1980s. Accumulated resources and competencies in the information technology sector in Finland facilitated this adaptation process. The sectoral reorganisation of the IT industry based on the introduction of the NMT standard has been a major example of this.

With the emergence of technical discontinuity in the mobile technological trajectory in the 1990s, new competencies were needed in the Finnish industry to deal with Internet technologies based on TCP/IP in terms of technological skills and capabilities as well as inputs from supplying industries. In order to develop these competencies, large Finnish companies such as Nokia have increasingly sourced these capabilities externally, mostly through forming international alliances. The internationalisation strategy of Nokia poses, however, also some risks with respect to the sectoral development of the national IT industry in Finland. It may lead to lesser integration of Nokia in local production and innovation networks in Finland.

In contrast to the successful adaptation process of large Finnish IT companies, it seems that their smaller companions in the national Science Parks were rarely involved in processes of technological change. An analysis of the structure of Science Parks showed that collaboration in Science Parks has mostly been at the level of IT services, to a lesser extent in the area of IT manufacturing and R&D. These results indicate that Science Parks in Finland have become less important for the growth of resources and competencies of large companies such as Nokia required for the next generation of mobile technologies. As demonstrated in the different examples, Nokia has become involved in several local networks of companies, through alliances, spin-offs and the mere presence of affiliates in Finnish Science Parks. However, if the tendency towards internationalisation proceeds, there might be some long-term problems for Nokia and other large companies in the Finnish IT sector. These companies could potentially undermine their locally accumulated resources and competencies by exclusively focusing on international collaboration and engaging in the race for global standards in mobile telecommunications. In this respect, technological discontinuity might become a threat rather than an opportunity for the national IT industry in Finland.

In summary, the early evidence from SME activity in Science Parks in Finland suggests that SMEs have not been as much involved in sectoral reorganisation of the Finnish IT industry as their larger counterparts. It seems, in contrast, that large companies such as Nokia and Sonera, which have become increasingly engaged in R&D activities abroad, used Science Parks to a lesser extent for technological collaboration than for outsourcing of certain business service activities.

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Appendix 1: List of acronyms

AMPS	–	Advanced Mobile Phone System Application Protocol
ATM	–	Asynchronous Transfer Mode
Bluetooth	–	specification describing they way in which mobile computer-telephones with wireless access
CEPT	–	Conférence Européenne des Administration des Postes et des Telecommunications (European Conference of Postal and Telecommunications Administration)
D-AMPS	–	Digital Advanced Mobile Phone System
ECSD	–	Enhanced Circuit Switched Data
EGPRS	–	Enhanced General Packet Radio Service
EPOC 32	–	32-bit multitasking operating system
EPOC	–	operating system designed for small, portable phones, computers, and personal digital assistants can easily interconnect with each other
ETSI	–	European Telecommunications Standards Institute
FISPA	–	Finnish Science Park Association
GSM	–	Global System for Mobile Telecommunications
ISDN	–	Integrated Services Digital Network
IT	–	Information technology
MBS	–	Mobile Broadband System
MHz	–	Megahertz
MoU	–	Memorandum of Understanding
NMT	–	Nordic Mobile Telephony
NMT 450	–	Nordic Mobile Telephony standard 450 MHz
NMT 900	–	Nordic Mobile Telephony standard 900 MHz
PTO	–	Public Telephone Operator
R&D	–	research and development
SME	–	small- and medium-sized enterprises
TCP/IP	–	Transmission Control Protocol/Internet Protocol
TEKES	–	Teknologian kehittämiskeskus (National Technology Agency)
UMTS	–	Universal Mobile Telecommunications System
WAP	–	Wireless Application Protocols
Waplook	–	Software for applications using the Wireless

Notes

[1] See for example the special issue of *Industrial and Corporate Change* (Vol. 6 No 1. 1997) on industry structures and dynamics.

[2] The favoured industrial sectors characterised by rapid technological change have, in particular, been telecommunications, biotechnology, microelectronics and new materials.

[3] The combination of an evolutionary perspective with path-dependent approaches provides a framework to understand and to model the effects of history on the behaviour of agents. This evolutionary perspective is therefore also complementary to theories on path dependence where the focus is on the major events or parameters that decisively influence the outcome of technological competition. In this context, path dependence defines the set of dynamic processes where small events have long-lasting consequences that economic action at each moment can modify, yet only to a limited extent. Path-dependence is caused by the overlapping of irreversibility, indivisibility and structural action of agents as opposed to parametric behaviour (Antonelli, 1997; David, 1985; David, 1987).

[4] However, unlike biological evolution, technical evolution can in some instances be characterised by partial reversibility to previous technologies. Nonetheless, reverting to previously abandoned technologies is often very difficult and seems to be very rare in practice.

[5] Commonly three periods in the development of the mobile technological trajectory are distinguished: The first generation based on the breakthrough of mobile telecommunications related to early analogue systems such as NMT (Nordic Mobile Telephony) or the U.S.-American standard AMPS (Advanced Mobile Phone System), the second generation based on cellular mobile telecommunication related to standards such as GSM or D-AMPS (Digital Advanced Mobile Phone System); and the third generation based on high-speed mobile telecommunications related to standards such as the European third-generation standard UMTS (Universal Mobile Telecommunications System) or MBS (Mobile Broadband System). A full list of acronyms is provided in Appendix 1.

[6] Technological progress in the equipment industry has continuously improved the functionality to allow for high-speed data transmission, video and multimedia. Central here has been the compatibility with ISDN and packet-switched protocols such as ATM and IP.

[7] There are definitely early examples of the mobile trajectory reaching back to Alexander Graham Bell's discoveries, but a further historical analysis would go beyond the scope of this paper (Bekkers and Smits, 1999).

[8] GSM originally stood for Groupe Spéciale Mobile and was later renamed into Global System for Mobile Telecommunications.

[9] In 1987, 13 telecommunication operators and administrators from 12 areas in the CEPT signed the Memorandum of Understanding (MoU) "club" agreement.

[10] There have been some attempts to modify the GSM standard to support higher data rates with a somewhat reduced coverage using a new modulation system. Current systems already enable cellular operators to offer higher than 9.6 kbps data rates to their subscribers for new data applications. The ECSD (Enhanced Circuit Switched Data) and EGPRS (Enhanced General Packet Radio Service) solutions offer data services comparable to third generation levels with considerably fewer radio resources than in standard GSM.

[11] The proposed standard uses a short-range, low-power radio link in the 2.45 GHz band to exchange information between devices within a radius of about 10 meters. Such enabled devices will not need to rely on line-of-sight communications and will maintain connections while moving. When the technology enters the commercial market by 2000, the device will be fully integrated onto a single 9 mm^2 chip.

[12] For an analysis of spillovers of parent firms to new, technology-based firms in the Finnish biotechnology sector, see (Autio, 1997) and (Autio and Yli-Renko, 1998).

[13] The main shareholder has been the city of Oulu that owns the majority of all stocks. Other shareholders have been Nokia and the University of Oulu. Other Science Parks followed this model. The communities have been main shareholders and usually the university and a few other organisations own the other shares. For instance, the city of Tampere owns more than 95% of all shares, while the Finnish research institute VTT and the university together own less than one percent of the shares (Finnfacts, 1999b). With the growing number of Science Parks in Finland, a new co-ordinating body was required to facilitate the growth and creation of Science Parks. As a result, the Finnish Science Park Association (FISPA) was founded in 1988. The FISPA currently has ten members. A significant number of SMEs has been located in Finnish Science Parks. Currently, Finland has 17 Science Parks with approximately 1,000 companies and 10,000 employees. Most parks are situated in close proximity to universities.

[14] The industries are based on collaborative schemes as indicated by the data available.

[15] The Biotech cluster includes biotechnological, medical and chemical technologies.

[16] Services include all services delivered to other companies or customers. Examples are maintenance services, travel agencies and restaurants. In our definition, software is either part of services, manufacturing or technology, depending on the nature of the activity. Manufacturing consists of the production of goods and software, if not software consulting or research and development of software. Technology contains all research and development activities and alliances to set standards.

[17] In most cases, this will mean that the exact core activity is unknown.

[18] Two large firms (Nokia and Siemens) contributed a large share to manufacturing in this Park. Therefore, it may be that these two companies over-proportionally contributed to the value-added of SMEs in manufacturing. However, it currently is rather unclear to what extent these companies contributed to total employment and production in this park.

[19] The company was established in Salo in late 1987 by Jorma Nieminen, the first president of Mobira. In 1999, it had almost 300 employees. One-third of the company's personnel is involved in R&D. Furthermore, R&D accounts for 17% of net sales. The firm is internationally oriented and has been engaged in a number of strategic partnerships.

[20] As we discussed earlier, the Finnish industry has been internationalising at high pace. A good example of interna-

tionalisation is Nokia, the world's largest mobile phone vendor. Our database on alliances of Nokia is especially suited to demonstrate Nokia's strong involvement in the global IT industry. Since the database is obtained from international telecommunications journals, the bias will be towards international as opposed to national alliances.

[21] Source: http://www.seiren.net/news/press_release.htm.

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