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Towards a better understanding of innovation and industrial renewal in Finland - a new perspective

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FOREWORD

This paper describes the background, aims and the approach of the ’Finnish innovations’-project (Sfinno) and discusses theoretical and empirical issues related to innovation studies. The basic idea of the project is to deepen our understanding on the development processes taking place in Finnish industry. After the deep economic recession in the early 1990s, the Finnish economy is back on a positive growth track. The telecommunications industry has grown exceptionally fast. As a result, the telecommunications industry has quickly become Finland’s third mainstay, alongside the traditionally forest-based and engineering industries. What is behind this transformation? How sustainable is the growth in the telecommunications? What is the innovation capacity and growth potential of the more traditional industrial sectors? These questions are the focus of Sfinno.

In addition, Sfinno is developing new approaches and methods for innovation studies in general. The basic methodological approach of Sfinno is to study innovations at the micro level in their specific contexts. Most of the recent innovation studies are based on surveys, case studies, and indirect indicators. These studies have accumulated knowledge on many aspects of innovation activities, but even at their best many of the studies have remained either too general or too narrow. The only way to solve these methodological deficiencies is to study concrete innovations in their environments. This is Sfinno’s mission and its challenge.

The Sfinno project was started in mid 1997 by Mr. Tarmo Lemola and Mr. Christopher Palmberg. Mr. Ari Leppälahti and Mr. Hannes Toivanen joined the team in mid 1998. Mr. Christopher Palmberg has been the project manager since August 1998. The project is financed by the Technology Development Centre of Finland (Tekes).

Espoo, June 1999

Tarmo Lemola

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1. Introduction

One of the most fundamental trends in all advanced economies has been the accelerating rate of innovation and technological change, driven by intensified competition in most product and service markets. In Finland, technological change and innovation has played a major role in industrial renewal starting from the mid 1970s. In the late 1970s and 1980s, investments in R&D increased rapidly. The annual growth rate of the R&D volume was approximately 10 percent on the average in the 1980s, the highest rate of any other OECD country. However, in spite of the efforts to develop existing industries, to widen the industrial base, and to create new industrial opportunities, rapid growth in the 1980s ended in a deep recession.

After the dismal beginning of the 1990s, manufacturing picked up, reaching a growth rate of 12 % in 1994. Behind this sudden upturn has been reviving exports of forest-based industries, engineering and metal products, and telecommunication machines and appliances in particular. The primary social concern, however, is that the positive trends in industrial output and exports have not yet lead to very significant improvements in unemployment. Figure 1 presents the changing structure of Finnish exports as changes in the relative share of different industries to total exports.

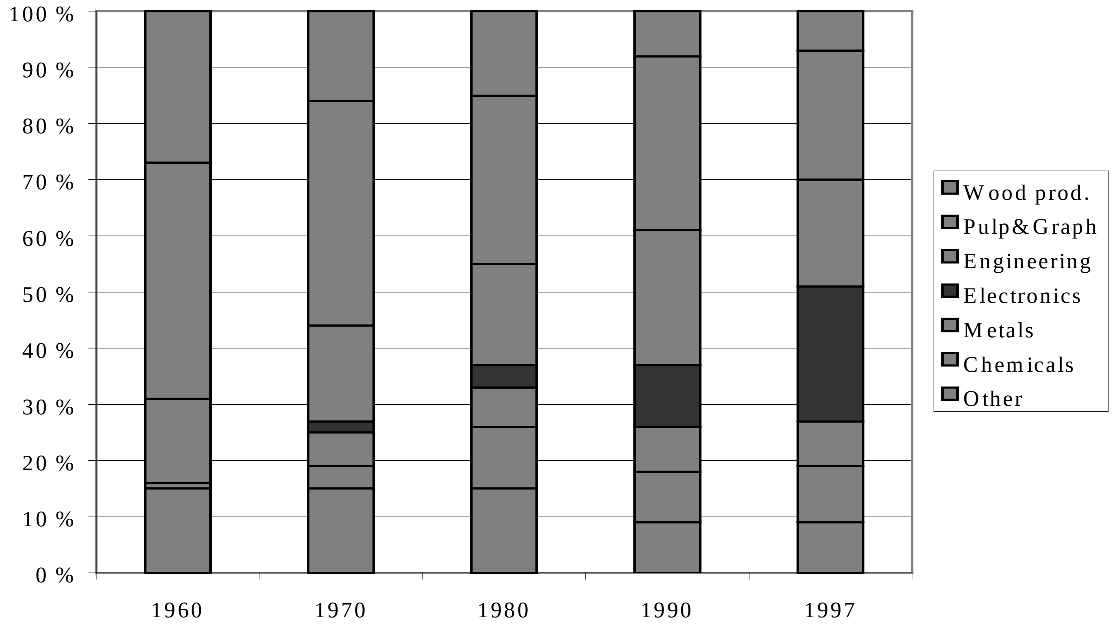

Figure 1. The changing structure of Finnish exports 1960-1997 (% of total exports).

Despite the proliferation of new industries and the consequential effects to manufacturing output, forest-based industries and engineering have remained as the core of the Finnish industry, although to a lesser extent than before. This is especially true if one looks at the changes in production and export volumes rather than the relative percentage figures. Fortunately, high tech industries have been the most rapidly growing fields during the 1990s.[1] The major high-tech product group in Finland is telecommunications equipment. In 1998, these products accounted for 73 % of the total high technology exports. When we take one step further, we see that the success of the telecommunications industry has essentially one common denominator: Nokia (Lemola 1999).

Strenghthening existing industries, widening the industrial base, and creating new industrial opportunities will remain the focus of Finnish innovation policy also in the coming years. In the political rhetoric this need to renew industries and industrial structures towards high-tech has been expressed as a necessary transition towards the information society (Science and Technology Policy Council of Finland 1996). As a significant step towards these aims, in 1996 the Finnish government initiated a scheme to increase research funding with a view to raising R&D input from 2.35 % of GDP in 1995 to 2.9 % by 1999. One important means to this end has been a carefully - but not too narrowly - targeted allocation of public funding. According to the latest figures, with the joint efforts of the public and private sectors this aim will not only be achieved but even exceeded. Consequently, the Finnish R&D input of GDP in the beginning of the new millennium will be one of the highest in the OECD countries.

These ambitious aims also mean that a better understanding of the basic mechanisms of innovation and industrial renewal in Finland has become a critical asset. An increase in the R&D input may be a necessary but not a sufficient condition for the targeted change. It will also require a better micro-level understanding of the knowledge-base of the economy, and the interrelationships between R&D and other types of innovative activity, the emergence and growth of firms, industrial development and renewal in general. Hencefar, technological change and innovation within industry has mainly been studied from the perspective of industrial clusters and aggregate statistics (see e.g. Virtaharju & Åkerblom 1993, Leppänen & Romppanen 1995, Rouvinen et al. 1996, Vartia & Ylä-Anttila 1996, Mäkinen 1998). On the other hand, studies using firm-level data such as the Community Innovation Survey, suffer from the well-known fact that indirect or aggregate proxies are used to approximate the innovation output of firms. (see e.g. Husso et al. 1996, Leiponen 1996a, 1996b & 1999, Lehtoranta 1998 in Finland and Sirili 1998 for the methodological discussion in general). In

[1] Measurement of the technological intensity of industries follows the well-known OECD classification which is

order to shift the attention to the very core of technological change and industrial renewal - the commercialisation of innovations in their entrepreneurial context - the VTT Group for Technology Studies has initiated a novel research project named Finnish Innovations (Sfinno).

The aim of the Sfinno-project is to provide a deeper, and at the same time a more comprehensive understanding of recent industrial renewal processes in Finland from the point of view of individual innovations. For this purpose we are constructing a unique database consisting of some 2000 Finnish innovations commercialised during the 1980s and 1990s. The database contains basic data on the innovations and commercialising firms. It also contains data on the origin and diffusion of innovation, R&D collaboration, public support and the commercial significance of the innovation. Subsequently, this data will be used for more in-depth studies of both quantitative and qualitative nature, where the general aim of the project is broken down into very specific research issues related to the interrelationships between innovations and industrial renewal.

Apart from providing a deeper and more comprehensive understanding of recent industrial renewal processes in Finland, the Sfinno-project also contributes to the methodological discussion on the measurement of innovation, especially concerning the level of analysis. The firm is typically considered a natural and convenient unit of analysis, but our approach is different since we take the point of departure in the identification of individual innovations and thereafter link the data on the nature of specific innovations and innovation processes to the firm-level data. Therefore, our approach comes closer to measuring concrete developments within industry and the knowledge base of firms. This approach enables us to identify micro-clusters of innovations and firms that otherwise might remain invisible in aggregate statistics. Furthermore, we can provide a more thorough analysis of the origin, development, diffusion and distribution of different types of innovations across sectors and we can also reveal new perspectives on the contribution of different kind of firms to innovation in Finland, for example the contribution of Nokia.

This paper is the first report on the Sfinno-project and therefore focuses on definitional, theoretical and methodological issues which have shaped the overall design of the project. The purpose of the paper is to review some theoretical and methodological approaches that we feel are particularly relevant for our

based on firm's R&D expenditures as a share of total sales.

innovation-centred approach to analyse industrial renewal in Finland. We also present our methodologies, the content of our innovation database, and discuss problems we have encountered as well as some avenues of more in-depth research using our data. The database will be finalised during summer 1999 and the first results of the project are due in autumn 1999. The in-depth projects are scheduled for the third phase of the project, in the year 2000.

Since at this stage we restrict the content of our innovation database to technological product innovations (including indirectly process innovations as well), we will not discuss at any length intangibles such as service sector innovations and organisational innovations, which often are included in the definition of product and process innovations. This is not to deny their importance for industrial renewal. Rather, the methodologies that we adopt now are simply not well suited for including intangibles. Furthermore, owing to the quantitative nature of the present stage of the project, we will restrict our reviews of previous empirical contributions in the field to those which explicitly have collected and harnessed quantitative data on innovation in order to study different aspects of industrial renewal.

The paper is structured as follows. In chapter 2, we review some basic theoretical and conceptual points of departure with regard to the definition of innovation, the relationships between innovations, firm growth and industrial renewal, as well as the origin and sectoral pattern of innovation. In chapter 3, we discuss the main methodological approaches which have been used in previous studies similar to ours. In chapter 4, we present basic definitions, criteria and methodologies which we have used for the identification of innovations and data collection, as well as the content of the database. Chapter 5 sums up and concludes the paper. More details on our data sources, the innovation database and the questionnaire used for data collection can be found in the appendices.

2. Theoretical and conceptual points of departure

2.1. Schumpeter and evolutionary institutional economics

The process of industrial renewal is foremost interesting from an empirical point of view, since the interrelationships between innovation and the evolution of firms and industries in specific local or national settings is at the very heart of the policy discussion. Nonetheless, empirical research in the field also depends on theoretical and conceptual ’focusing devices’ to guide data collection and analysis. It seems fair to say that Schumpeterian economics, and evolutionary economics in particular, has functioned as the dominant source of inspiration in this context, not least within the OECD (OECD 1992, 1997). Of special relevance here is what Grupp (1998) calls the evolutionary institutional tradition, which primarily draws on the work of Nelson & Winter (1982) and researchers from the Science Policy Research Unit (SPRU) at the University of Sussex in Brighton. The evolutionary institutional tradition elaborates on certain core ideas of Joseph Schumpter and blends these with insights from institutional economics. Likewise, the Sfinno-project draws on certain theoretical constructs and concepts which could be classified as belonging to this tradition, at the expense of more formalised neo-classical economic theory.

Although recent developments in the field have approached formalisation and modelling techniques (for an overview see Nelson 1995, and Malerba et al. 1999 for a recent example), most contributions are still heavily influenced by certain basic insights which can be traced back to Schumpeter's work in the early 20th century. While Schumpeter laid the foundations for a 'grand theory' of the relationships between innovation and industrial renewal by dealing with the core issues, it is clear that no such grand theory yet exists. Nonetheless, the basic Schumpeterian insights have given rise to several helpful conceptualisations which are applicable in empirical studies of the sort we are undertaking.

Schumpeter was primarily interested in business cycles and the underlying dynamic processes of the emergence, development and decline of industries. In The Theory of Economic Development (1912), Schumpeter conceptualises the microeconomics of industrial renewal by identifying the *subjects* and *objects* of this process. The objects in Schumpeter's conceptualisation are innovations while the subjects are entrepreneurs who introduce these to the market in order to gain temporary monopoly profit. In his reasoning there existed two types of entrepreneurs: exceptional individuals who are willing to face the hazards and difficulties of innovations as an act of will (innovators), despite all the uncertainties involved, and a much more numerous group who merely follow in the wake of the heroic pioneers of the first group (imitators).

Dosi & Nelson (1994) propose that the theories and models share two general characteristics. First, their purpose is to explain the movement of something over time, or to explain why that something is what it is at a particular moment in terms of how it got there, i.e. the analysis is expressly dynamic and history-friendly. Second, the explanation involves random elements that generate or renew some variation in the variables in question, as well as mechanisms that systematically winnow on this variety through selection. In the social domain this translates into processes of imperfect learning and discovery leading to variety and diversity, on the one hand, and some selection mechanism which selects across this variety, on the other.

The most influential application of the basic evolutionary propositions is the book by Nelson & Winter (1982), where economic development and growth is modelled at the firm level and, competition occurs through selection mechanisms which winnow out successful innovators and imitators. A central feature of the model is the allowance for heterogeneity in the population of firms due to the accumulation of firm-specific competencies. These firm-specific competencies determine the decision rules and 'search space' for R&D and learning along specific *natural trajectories*. Another central feature of the model is the selection environment, which provides a description of the environment within in which firms operate. The selection environment encompasses both market forces as well as non-market forces, such as various institutions, which feed-back on R&D in firms. Examples of such institutions include patent regulations, policies, norms or standards, the science system, as well as various supporting organisations such universities, public R&D labs and collaborators. (Nelson & Winter 1982). This basic evolutionary model of Schumpeterian competition and industrial renewal has subsequently been refined and applied in several direction, in the field of the theory of the firm, industrial dynamics and the modelling of aggregate growth dynamics (see Freeman 1994 and Nelson 1995 for extensive reviews). In the following we will ignore a large part of this literature and merely focus on a selected number of contributions within the evolutionary-institutional tradition which seem especially relevant for the Sfinno-project.

2.2. Definition of innovations

A cornerstone for understanding industrial renewal from the perspective of innovations is a definition of innovations. This is of course especially relevant in our innovation-centred approach because we collect data at the level of specific innovations and have to make certain *ex ante* choices regarding their artefactual conceptualisation. A differentiation of innovations is also important from an analytical perspective, since different types of innovations will have different effects and managerial implications for firms, industries and policymakers.

One might speak of Schumpeterian definitions or taxonomies of innovations, since they all remain surprisingly loyal to Schumpeter's definitions despite the fact that he stated them rather vaguely. One explanation for the vague definitions is that his primary focus was on the relationships between business cycles and industrial renewal on a general level, rather than the emergence and diffusion of specific innovations in specific industries. Nonetheless he made a clear distinction between *inventions*, *innovations*, and *imitations*.

An invention is an idea, a sketch or a model for something. Innovations are those inventions which have been commercialised on the market by entrepreneurs, while imitations are innovations which have been copied by others. In particular, through his clear distinction between invention and innovation Schumpeter assigned commercial criteria for defining innovations as inventiveness alone would not bring an economic advantage to firms. He also made a distinction between innovation and the *diffusion of innovations*. Furthermore, Schumpeter made the basic distinction between *incremental innovations* and *radical innovations* in terms of their socio-economic effects. (Schumpeter 1912, Cantner & Hanusch 1994). Following these basic definitions, it is possible to identify at least three partly overlapping taxonomies of innovations. These are illustrated in Table 1 below.

Table 1. Three taxonomies of innovation

TAXONOMY	CRITERIA FOR DISTINCTION	EMPIRICAL RELEVANCE
Product vs. process innovations. (Schumpeter 1912, Utterback & Abernathy 1975)	Perspective of the use and destination of the innovation, the nature of demand	Diffusion of innovations, competition in price vs. productivity
Incremental vs. radical innovations, change in technological system or techno-economic paradigm. (Schumpeter 1912, 1942, Mensch 1975, Freeman & Perez 1988)	Socio-economic effects of innovations, degree of diffusion in the economic system	Degree of novelty, nature of innovation process, clustering and diffusion of innovations
Competence-enhancing vs. competence-destroying innovations (Abernathy & Clark 1985, Anderson & Tushman 1986, Teece 1988, Henderson & Clark 1990)	Competitive significance of innovations and interrelationships with firms' competencies, degree of architectural complexity	Incorporates firm and market perspectives, relationships between different types of innovations, firm competence and evolution of industries

Product versus process innovations

The first taxonomy makes a straightforward distinction between product innovations and process innovations. In Schumpeter's original words a product innovation is *"the introduction of a new good or a new quality of the good with which consumers on the market are not familiar"*. His emphasis was thus on tangibles as opposed to intangibles, such as new services. Moreover, his emphasis was on characteristics of the goods as perceived by the consumers on the market. Process innovations are typically defined as either technical or organisational. This distinction can also be traced back to Schumpeter's original definition of process innovations as *"the introduction of a new method of production, that is, one not yet tested by experience in the branch of manufacture concerned...*[or] *a new way of handling a commodity commercially"* (Schumpeter 1912, cited in Archibugi et al. 1994).

The distinction between product and process innovations is important for analytical purposes, since process innovations primarily yield productivity gains and affect price competition, while product innovations open new markets, out-compete older products and thus often are assumed to more directly affect firms' competitive position on the market. Nonetheless, on a micro-economic level, a practical application of this basic distinction is not unproblematic and little attention has in fact been paid to the analytical clarity of these definitions (Archibugi et al. 1994).

The primary point of confusion relates to the fact that product and process innovations are typically interrelated. Frequently, process innovations are an integrated part of product innovation e.g. in cases where a new product cannot be manufactured with conventional production methods. Process innovation might also be required for the manufacture of existing products. Hence, the distinction between the two should not be taken too literally. There might be situations where product innovations require no process innovations. They might occur simultaneously if the product innovation dictates the process innovation, or process innovation might be carried out in order to make conventional products more efficiently. Moreover, the intersectoral flow of innovations complicates matters further, since a product innovation in one sector (e.g. an industrial robot) might be a process innovation in another sector (e.g. the car industry) in which case there is the risk of double-counting innovations. (Grupp 1998). Moreover, Utterback & Abernathy (1975) and the subsequent product-life cycle literature suggests that the interrelationships between product and process innovations systematically correspond to the stage of development of the competitive scene in specific industries. Product innovations predominates in the early stages of development, but gradually gives way to a greater number of process innovations as the industries matures and competition shifts from innovativeness to price. (see Nelson 1994 for an overview).

What comes out of the discussion is that a differentiation between product and process innovations is essentially a definitional issue which is particularly sensitive to aggregation. While the distinction is more easily applicable at the firm-level, where questions are asked about the nature of innovative activity in general, special care should be taken to clarify the exact definition and meaning that is applied at the level of individual innovations. This definitional dilemma has recently been discussed by Archibugi et al. (1994), based on empirical observations from the SPRU database of innovations. They conclude that a distinction between product and process innovations is a useful tool for analysis, but stress that, because of empirical problems, any clear-cut definitions are bound to be misleading. Grupp (1998) proposes one way out of this definitional dilemma. This is to regard all innovations as being product innovations and merely to differentiate them according to final demand. Intermediate or capital goods which are used by other firms are regarded as process innovations, while consumer goods used by private households are regarded as product innovations (in this case it is assumed that households are not involved in productive activity).

Incremental versus radical innovations

The second taxonomy defines innovations according to their degree of novelty. Here again, the point of departure has been Schumpeter's basic distinction between incremental and radical innovations (see e.g. Mensch 1975, Abernathy & Clark 1985, Hendersson & Clark 1990). Nonetheless, in innovation studies a shift away from emphasising radical innovations towards emphasising incremental innovation and diffusion is evident, especially in the 1990s. This shift in emphasis is reflected in the increasing acknowledgement of the significance of learning by doing, learning by using and technology diffusion (Mowery & Rosenberg 1979, von Hippel 1988, Lundvall 1992).

Research has produced a fair number of taxonomic exercises with respect to the degree of novelty of innovations. Perhaps the most influential taxonomy is the one proposed by Freeman & Perez (1988), who distinguish between incremental innovations, radical innovations, changes of technology system and changes of techno-economic paradigm. They were primarily concerned with business cycle-theory and the role of different types of innovations in that framework. Therefore the main focus was on the broad set of interrelated and generic innovations, and their diffusion, which contribute to changes in the broader industrial systems or techno-economic paradigms.

At the level of specific technologies or industries Freeman & Perez conceptualise *incremental innovations* as occurring *"...more or less continuously in any industry or service activity although at differing rates in different industries and different countries, depending upon a combination of demand pressures, socio-cultural factors, technological opportunities and trajectories"* (Freeman & Perez 1988, 45). They are often the result of 'unintended' learning processes through learning by doing and learning by using. Incremental innovations are frequently associated with the scaling-up of plant and equipment, and quality improvements to products and processes for a variety of specific applications. Although their combined effect is extremely important in the growth of productivity, no single incremental innovation has dramatic effects, and they may sometimes pass unnoticed.

Radical innovations, by contrast, are *"discontinuous events"* and usually *"the result of a deliberate research and development activity in an enterprise and/or university and in government laboratories"*. They are unevenly distributed over sectors and have the potential to function as the springboard for the growth of new markets and investment. Moreover, radical innovations *"may often involve a combined product, process and organizational innovation"*. (Freeman & Perez 1988, 46). Radical innovations might have greater socio-economic effects than incremental innovations if a whole cluster of radical innovations are linked together by a generic technology, such as biotechnology or IT. Radical innovations also typically involve some change in the organisation of production and markets and thus prompt, or are dependent on, organisational innovation.

Despite the clear distinction incremental and radical innovation on a conceptual level, an empirical application in concrete cases is very difficult especially in industries where product life cycles are short and major discontinuous innovations are rare (the mobile phones industry might be a good example). From a theoretical point of view incremental innovations are sometimes expressed as changes in the level of the coefficients of the input-output matrix of the existing array of technical characteristics of products and processes. Radical innovations demand the inclusions of new arrays of technical characteristics and not merely the qualitative upgrading of the existing arrays. Hence, radical innovations are based on a different set of engineering and scientific principles, or on a different paradigm. (Freeman 1994, Saviotti & Metcalfe 1984).

At the level of industrial systems, Freeman & Perez (1988) identify *changes in technology systems.* These types of innovations correspond to far-reaching changes in technology affecting several branches of the economy and giving rise to entirely new sectors. They are based on a combination or constellations of radical and incremental innovation, together with organisational and managerial innovations affecting more than one or a few firms. Finally, *changes in techno-economic paradigm* are innovations which bring about changes in technology systems that are so far reaching and pervasive in their effects that they have a major influence on the behaviour of the entire economy. A new techno-economic paradigm takes a relatively long period to mature and diffuse throughout the system. This diffusion involves complex interplay between technological, economic and political factors and thus also directly affects the knowledge base of almost every other branch in the economy. A frequently identified example of a techno-economic paradigm is the application of IT. Freeman & Perez also identify the steam engine and the railway system, electronics and mass production automation as examples of techno-economic paradigms which are interrelated to broader economic business cycles.

Competence-enhancing versus competence-destroying innovations

The third taxonomy takes the point of departure in a partial critique of basic Schumpeterian distinctions between incremental innovations and radical innovations. The argument is that an overemphasis on the technical novelty of innovations wrongfully ignores aspects related to the competitive implications of different types of innovations for firms. Authors within this tradition introduce a multi-faceted, more complex view on innovations, which integrates different aspects of firm competencies into a taxonomy of different types of innovations (Abernathy & Clark 1985, Tushman & Anderson 1986, Teece 1988, Henderson & Clark 1990, Tushman et al.1997).

Henderson & Clark (1990) offer a conceptually clear framework for mapping different product innovations according to their complexity, which is particularly useful for our purposes. They accept the distinction between incremental and radical innovations, but suggest that certain incremental changes in technology might have rather disastrous effects for firms also in the longer run. Using examples from the photolithography equipment industry, they introduce the concepts of *architectural innovations* and *modular innovations* as intermediate levels between incremental and radical innovations. This taxonomy makes an important distinction between the product innovation as a system and the product innovation as a set of interrelated core components. This is illustrated in Figure 2, where the horizontal dimension captures an innovation's impact on components constituting the product and the vertical dimension captures its impact on the linkages between components or on the overall product architecture.

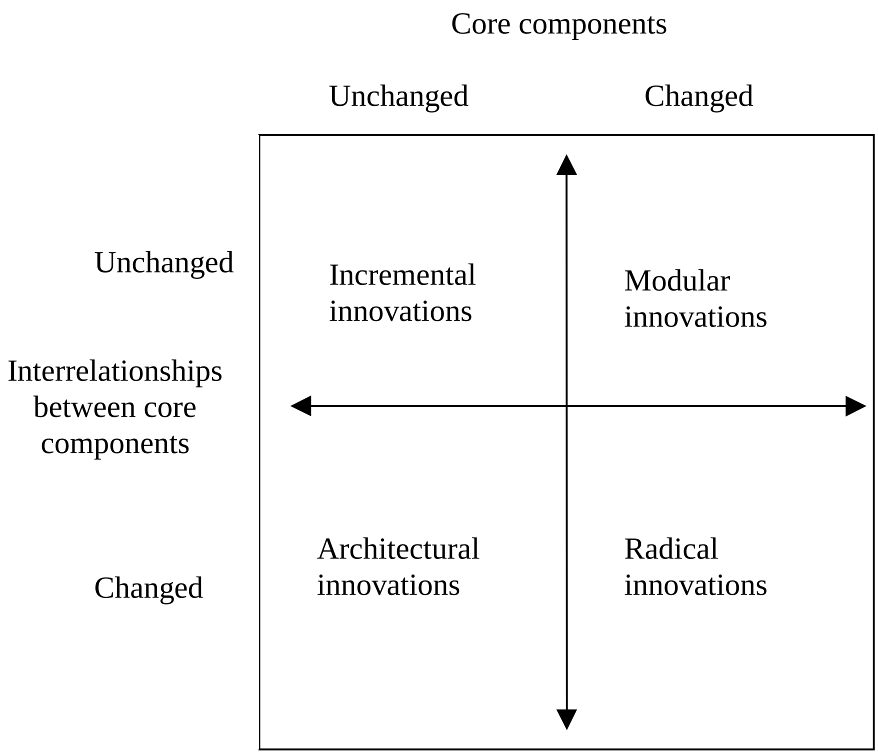

Figure 2. Henderson & Clark's framework for defining product innovations (Henderson & Clark 1990, 12).

Henderson & Clark (1990) define architectural innovations as innovations which link together the existing components of a product in a new way without changing significantly the core components themselves. Modular innovations are new products which only change the core components without changing their interrelationships, or the basic architecture of the product.

The distinction between the product as a system and the product as a set of core components underscores the idea that product development requires two sets of knowledge. First, it requires knowledge about each of the core technologies and the way in which they are implemented in a particular component. Second, it requires knowledge about the ways in which the components are integrated together into a coherent whole (architectural competence). The point made is that architectural innovations might evolve incrementally, but they might still have radical effects on competition in the industry, since they destroy architectural competencies and user networks of firms and establish a new dominant design. The example that Henderson & Clark (1990) use is Xerox, the pioneer of plain-paper copiers during the 1970s. Despite it's dominance on the market as the inventor of the core components, the firm was overtaken by competitors which applied novel features of existing copier components and technologies that enabled miniaturisation. After the establishment of the dominant design, knowledge of components becomes paramount as incremental and modular innovations start to challenge the dominant design and eventually overturn it through the emergence of new architectural or radical innovations.

From the point of view of innovation measurement, the main implication is that it is important to differentiate between the perspectives of the firm and the market in assessing the degree of novelty. An incremental innovation from the user’s perspective might imply a radical innovation from the perspective of the firm (in the cases of architectural or regular/modular innovations), since these might require major changes in the underlying competencies. Furthermore, special attention is needed to acknowledge the complexity of innovations where novelty might be embedded in the overall architecture of the innovation rather than in it’s functional parts or core components.

This basic notion of competence-enhancing versus competence-destroying innovations has been incorporated in more general models of industrial evolution. These attempt to explain how patterns of innovations change competition and structures within industries (for an overview see Tushman et al. 1997). Therefore, a practical application of these taxonomies might also highlight more precisely the competitive significance of innovations in specific industries, not merely their technical novelty.

2.3. Basic issues in industrial renewal

Once we have defined innovations, acknowledged their heterogeneity and complexity in terms of their nature and socio-economic effects, and accepted the basic Schumpeterian caveat that innovations creatively destroy existing industrial structures, there are three basic issues which appear especially relevant in industrial renewal. These relate to the origin and sectoral patterns of innovation. In other words, what accounts for differences in the relationships between the rate and types of innovation, transformation and growth in different industrial sectors? Why are some sectors more conductive to innovation and what accounts for the different patterns of innovation?

Again, the influence of Schumpeter’s work is visible in most theoretical and empirical studies dealing with these basic issues. In particular, reference is often made to his discussion of the relative role that entrepreneurs versus institutionalised and professional R&D in large firms play in industrial renewal. Schumpeter emphasised the role played by new small firms in innovative activity and in the ’creative destruction’ of established industries. This model of industrial renewal is usually referred to as Schumpeter Mark I. In subsequent work, in particular in Capitalism, Socialism and Democracy (1942), there was an shift in emphasis towards highlighting the role of institutionalised and professionalised R&D within the large firms, and the presence of barriers to entry for new innovators. This model is usually referred to as Schumpeter Mark II. (Schumpeter 1912, 1942)

The origin of innovation: science and technology-push versus demand-pull

The Schumpeter Mark I model has been interpreted in support of a linear deterministic model of innovation, which predicts that inventions primarily emerge from goal-oriented R&D and technological opportunity, are transformed into innovations through entrepreneurial activity, and are subsequently diffused in the economy. Later, in the 1960s and 1970s, the role of market demand and users was emphasised as the main source of innovation, likewise in a linear fashion. These sequential, or linear, models of innovation have gradually been replaced by various feedback models and network approaches. These stress the importance of functional interrelationships and complementary assets between firms, as well as the role of other actors and institutions during the innovation process (Rothwell 1994, Lemola 1994). Nonetheless, in innovation studies and the policy discussion in particular, the science and technology-push vs. demand-pull debate continues, in particular with respect to actually quantifying the contribution of science to innovation (see Grupp 1998).

According to Freeman (1994), linear science & technology-push models of innovations have relied on studies of radical innovations in the spirit of Schumpeter, such as the electronic computer, which tended to show that market demand had no significant role to play in the origin of innovations. This led to an interpretation of the innovation process as a smooth unidirectional flow from science and R&D to commercial application. Research leads to inventions, which leads to development, production, marketing and to introduction of innovations to the marketplace. Especially Schmookler (1966) has been credited for suggesting that market demand was the most important determinant of the origin of innovations. He did not entirely deny the role of scientific research, but demonstrated using patent statistics that inventive activity seemed to lag behind the peaks and troughs of investment activity. From this he concluded that the main stimuli to invention and innovation came from the changing pattern of demand as measured by investment in input technology in various industries. In the 1970s, more detailed historical and case-oriented studies yet again shifted the attention of policymakers and researchers. In particular, Mowery & Rosenberg

(1979) showed convincingly that scientific events were caricatured as events free of any commercial component whatsoever. This resulted in an artificial and misleading distinction between basic scientific research and applied industrial research, a theme that Rosenberg has frequently pursued later on as well (Rosenberg 1982, 1992). Instead, the so-called chain-linked model of innovation was introduced some years later, which has been very influential in subsequent innovation studies (see e.g. the OECD Oslo Manual 1992, 1997). The chain-linked model is illustrated in Figure 3.

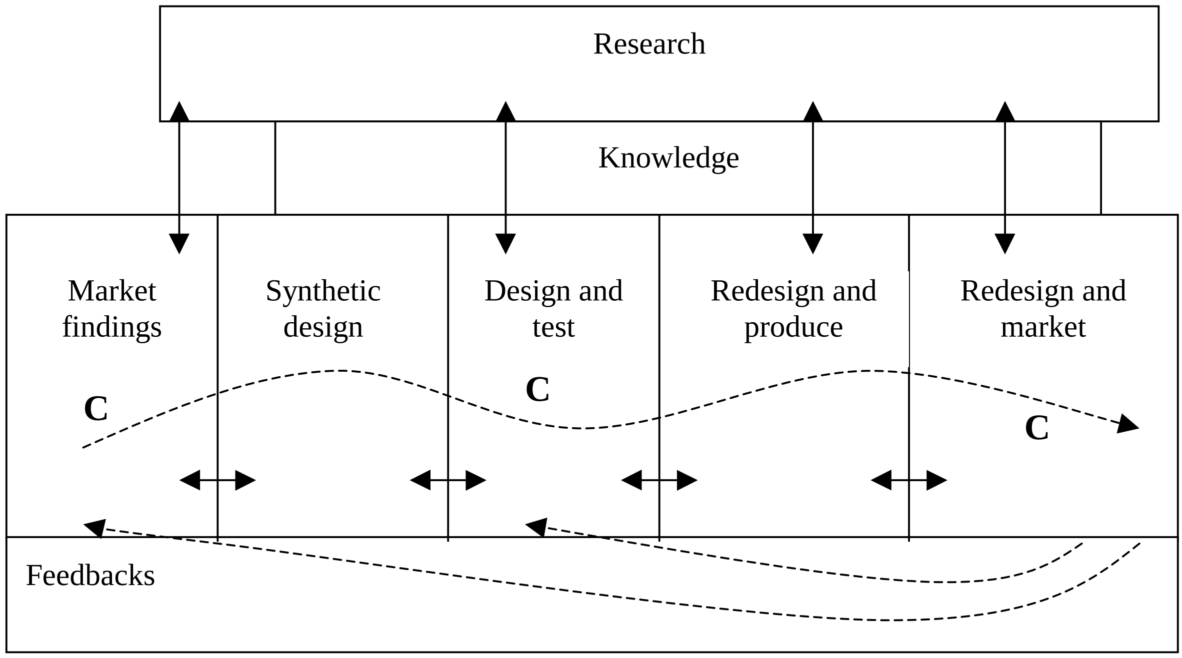

Figure 3. The chain-linked model (adapted from Kline & Rosenberg 1986, 290).

The chain-linked model is also sequential since it divides the innovation process into typical ’stages’, but nonetheless accounts for the origin of innovations as the coupling between science, technology and demand on the marketplace. It emphasises the importance of multiple kinds of input, interactions and feedback loops during the process of innovation. Central to this model are the multidirectional linkages between parallel processes of research, often undertaken at universities or in public research organisations, knowledge generation in society in general, and the development and design of innovations along the "central chain of innovation" (C in the figure), as well as the feedback linkages from the market or between various functional departments of the firm (learning by doing and using) to design, testing, production and marketing. The main point of the model is that the vast majority of innovations involve some imaginative combination of scientific or technological opportunities and market possibilities.

Kline & Rosenberg (1986) also stress that the linkage from research, or science, to innovation is not predominantly at the beginning of typical innovations, but rather extends all through the innovation process, as a part of normal problem-solving activity in industry. Recently, there has been particular interest in studying the user-producer interface in innovation, especially in the case of complex high-tech product innovations and incremental innovation where the competence of users is paramount (von Hippel 1988, Lundvall 1992).

The chain-linked model is implicitly or explicitly present in most subsequent models of innovation, even though technology policy in practice continues to be strongly influenced by a linear science and technology-push view (Freeman 1994, Mowery 1995). One reason might be the strong reliance on the neo-classical market-failure theory, which suggests quite consistently that R&D subsidies are the proper cure for correcting markets which do not produce the optimal level of R&D and innovations (Arrows 1962, Metcalfe 1995). The question of the origin of innovations viewed from the perspective of technology policy is interesting especially in Finland, where the commitment to continue the quantitative upgrading of the R&D system is high on the agenda.

Firm size, market structure and innovation

Another classic question is whether small or large firms contribute more to innovation output and industrial renewal. This question is particularly relevant in innovation-centred approaches, such as ours, since it requires innovation-output data rather than indirect proxies for innovation, such as R&D expenditures and patents. The relationship between firm size and innovation is also especially topical in Finland, where relatively large scale-intensive firms within the pulp & paper and metal products industries have played a dominant role in the 1970s and 1980s. On the other hand, the 1990s have witnesses the emergence of new firms, especially in the fields of electronics, software and biotechnology.

The relationships between firm size and innovation is highlighted by the apparent contradiction between the Schmpeterian Mark I and Mark II models of innovation. The interpretation of Schumpeter is that he was primarily impressed by the qualitative difference between the innovative activities of small entrepreneurial firms and large modern corporations with formal R&D laboratories. Furthermore, he argued that the resources required to develop new products and processes could only come from the supernormal profits possible in a concentrated market. The logical conclusion of this was that innovative activity increases more than proportionately with firm size, in which case monopolistic or oligopolistic markets with imperfect competition should yield more innovations. (see Coombs et al 1987 and the references therein). Reference is also frequently made to Galbraith (1956, 1967), who argued that large firms confer an advantage to innovation, because, among other things, they are more capable of financing risky R&D projects. Others have provided counter-arguments, suggesting that as firms grow large they also become incumbent, as efficiency in R&D and learning is undermined by managerial inertia, path dependency and loss of control. (see Anderson et al. 1997 and the references therein).

In the theoretical and empirical discussion the attention shifted from dynamic interpretations of the relationship between market structure and innovation to mostly static analyses within the neo-classical industrial organisations and game-theoretic tradition (see e.g. Mason 1957, Arrow 1962, Scherer 1967, Kamien & Schwartz 1982, Dasgupta & Stiglitz 1980). The empirical tests typically took the form of a statistical correlation between some measure of research intensity - usually R&D and patents - and some measure of either market concentration or firm size, where research intensity was related more or less linearly to output in terms of innovation. Despite significant methodological problems and ambiguities in measuring research intensity and market concentration in particular, the studies generated a consensus that R&D does not rise proportionally with firm size. This has been interpreted as indicating that large size does not offer an advantage in the conduct of R&D, and hence that Mark II is not necessarily a correct model in this respect. (see Cohen 1995 for a review).

Nonetheless, the more robust findings of these studies are that different and persistent size-distributions of firms across industries might reflect differences in the rate, type and direction of innovation rather than the other way around. This viewpoint received confirmation in numerous detailed case studies of specific industries undertaken during the 1970s and 1980s, as well as better access to longitudinal databases of firms' innovative activities. These studies have demonstrated that inter-industry differences in technological variables such as research intensity, patenting or innovation counts used as proxies for innovation output are actually more significant than inter-firm differences in the same industry. Hence, they suggest that various aspects of the dynamics of specific industries in the rate, type and direction of innovation, rather than market concentration and firm size, are more significant explanatory factors for differences in innovativeness and patterns of innovation over industries. (Coombs et al. 1987, Malerba & Orsenigo 1996).

Sectoral patterns of innovation

Another related issue further elaborates on the discussion on Mark I and Mark II, and on the relationships between firm size, market structure and innovation. This literature, sometimes referred to as the industrial-dynamics literature, takes the point of departure in the above mentioned observations that firm size, market structure and innovation might be endogenously determined by a range of other invariant technology- or sector-specific features. Moreover, the analysis is expressively dynamic and evolutionary, since the relationships between changes in various structural variables and innovation are traced over time (for a review see Nelson 1994, Malerba & Orsenigo 1997).

Explanations for differences in sectoral patterns of innovation are primarily captured in the concept of technological regime or technological paradigm, which have been developed by, among others, Nelson & Winter (1977), Dosi (1982, 1988) and more recently by Malerba & Orsenigo (1993, 1997). Nelson & Winter (1977, 57) applied the concept to refer to *"a frontier of achievable capabilities, defined in the relevant economic dimensions, limited by physical, biological, and other constraints, given a broadly defined way of doing things"*. Later, Dosi (1982, 1988) redefined technological regimes within his own framework to explain sectoral patterns of innovation, based on his studies of the microelectronic industry a numerous other case studies of specific industries. According to Dosi, certain stylised facts of innovation - such as a fundamental element of uncertainty, the complexity of the required knowledge and increasing reliance on major new technological opportunities and science, the importance of learning by doing and using, as well as the cumulativeness of technological change - point towards invariant features of specific technologies and industrial sectors. Dosi proposes that these invariant features of technologies are captured in the concepts of *technological paradigms* and *technological trajectories* which shape technological change in specific industries (compare with Kuhn's 1962 scientific paradigms)[2].

A technological paradigm defines the technological opportunities for further innovations and some basic procedures on how to exploit them, i.e. the cognitive aspects and structures of what technologists understand that they can achieve with R&D and what entrepreneurs believe that customers on markets will buy. Dosi places particular emphasises on the sectoral differences in technological opportunities, or the easiness of innovation (for example, the degree to which sectors directly benefit from scientific progress and/or technological breakthroughs), the degree to which firms can obtain economic returns from innovation (appropriability e.g. through patenting), and the patterns of demand that firms face, which in turn gives rise to different modes and organisation of innovation.

Technological trajectories defines the direction of innovation and technological change along the economic and technological trade-offs defined by the prevailing paradigm (compare with Rosenberg's 1976 *focusing devices*, or Sahal's 1981 *technological guide-posts*). The main point is that innovative activity is cumulative. Existing technology and innovations build on previous technologies and innovations and thus follows specific paths over time in specific industries. Hence, how a firm will innovate in the future is tightly constrained by what it has been capable of doing in the past. In Dosi's framework, new trajectories emerge in the wake of radical innovation or change of technological paradigm, whereby the firm faces a new set of technological and commercial opportunities for innovation.

These slightly differing concepts have proven conceptually useful in case studies of specific industries and innovations. Nonetheless, they also introduce variables which are difficult to operationalise and measure in statistical analyses covering a large number of sectors and innovations. A particularly practical contribution in this respect is Pavitt's (1984) taxonomy of sectoral patterns of innovation, based on the SPRU innovation database. He used sectoral classifications of innovations and firms combined with data on the main knowledge input to innovation, the size of firms and the type of innovation to distinguish invariant features of broadly defined sectors as a first approximation.

More recently, Malerba & Orsenigo (1993, 1997) operationalised technological regimes using rough proxies for technological opportunity, appropriability conditions, cumulativeness and the nature of the knowledge base of the technology, which they related to patent data as indirect proxies describing the entry, exit and survival of firms to specific technological classes. Based on these proxies they conclude that systematic differences in the patterns of innovation can be found in the three main technological families: chemicals, electronics and mechanical industries, and that these differences persist over countries. Chemicals and electronics resemble Schumpeter Mark II, where large firms dominate, whereas mechanical industries (agriculture, furniture, clothing, engineering industries, consumer goods) meet the criteria of Schumpeter Mark I, with the pervasiveness of the entry of new small firms. Based on their own work and a review of others' work, Malerba & Orsenigo (1997) provide a more exact definition of technological regime as the combination of some fundamental properties of

[2] Technological paradigm refer to specific technologies and industries while Freemsn & Perez's (1988) techno-economic paradigms refer to the clustering of innovations at higher levels of aggregation.

specific technologies in terms of the (i) technological opportunity they embody (the easiness of innovation for any given amount of resources), their (ii) appropriability conditions (the possibilities of protecting innovations), (iii) cumulativeness (the relationships between current innovative activities and new innovations), and the (iv) nature of the knowledge base of the technology. Conceptually, technological regimes therefore closely resemble technological paradigms, as discussed by Dosi (1988). Several other contributions come up with slightly different variables that explain sectoral patterns of innovation (see e.g. Industrial and Corporate Change, Vol. 6, No.1, 1997 for a range of alternative approaches).

3. Methodological points of departure

3.1. The subject-approach

If we disregard the enormous number of case studies undertaken especially in the 1980s and 1990s (for a good overview, see Freeman 1994), it is possible to distinguish between two basic methodological approaches in quantitative innovation studies: the subject approach and the object approach. In addition to these, a third and less well know methodology is technometrics. Technometrics focuses on the performance characteristics of narrowly defined technologies underlying innovations, and has primarily been developed by the Fraunhofer Institute in Karlsruhe (Grupp 1998).

Of the two former methodologies which are particularly relevant here, the subject approach has perhaps been the more influential because of it's comprehensive application in the EU member countries, although the object approach has attracted increasing interest in the 1990s. The subject approach takes Schumpeterian subjects of industrial renewal as its point of departure, and thus collects data on the innovator. The subject approach identifies innovating firms and uses surveys to collect data on various aspects of innovation and diffusion at the firm level. Typically, the surveys use indirect proxies for the measurement of innovation, such as R&D expenditure and patents, but sometimes also include questions on innovation output, albeit in a very aggregate and arbitrary way. The impetus of the subject approach is primarily related to standardisation exercises within the OECD, which has resulted in two versions of proposed guidelines for collecting and interpreting technological innovation data, the so-called Oslo Manual.

The Oslo Manual

Within the OECD, comparative firm-level data on innovation has been systematically collected since the late 1960s. These consist mainly of R&D expenditures and patenting, although it was admitted early on that a more comprehensive data on the innovation process of the enterprises was needed. One of the early examples is the IFO innovation survey in Germany, which collected annual innovation data in their panel survey of German firms from 1979 onwards (Scholtz 1992). The basic components of the innovation process, such as innovation expenditure, objectives and output, were already included in the IFO survey. Also, sporadic surveys were conducted, e.g. in Italy in the late 1980s and in France, the Netherlands and the Nordic countries (OECD 1989, Smith 1997).

In the late 1980s comprehensive standardisation work on the conducting of internationally comparable innovation surveys began to cater to the increasing need in policy discussions for internationally compatible innovation surveys. The background work was done within the OECD by the Group of National Experts on Science and Technology Indicators (NESTI) and consultants. A particularly important input for the standardisation work was the Nordic Science and Technology Indicators project funded by The Nordic Fund for Industrial Development. Within this project an innovation survey using a standardised methodology was conducted in each Nordic country (including Finland). This led to the publication of the first Oslo Manual in 1992. The manual was subsequently revised and the second version was published in 1997 (OECD 1997).

The aim of the Oslo Manual is to outline the guidelines for internationally comparable innovation surveys. The theoretical orientation of the manual can be derived from Schumpeterian definitions of innovation and the emphasis of evolutionary-institutional economics on variety, interactive models of innovation (especially the chain-linked model) and learning within national systems of innovation. The basic concept introduced is technological product and process innovation (TPP). In the definitions of 'technologically new', reference is made to the technological characteristics and uses of TPP. Respondents are guided with the help of general guidelines and illustrative examples. The minimum requirement for TPP is that it is new to the firm. Thus, a firm can be an innovator if it only implements TTP's developed elsewhere. Among innovators the degree of novelty is further evaluated by distinguishing product innovation that is new to the market. The concept of TPP enlarges the scope of innovation surveys because it also comprises the ongoing or aborted activities aimed at the implementation of TPP innovation. Service sector innovations are also included in the definition of TPP according to the same principles.

The costs of TPP are measured by inputs to innovation activities. Besides the traditional R&D expenditures, these include innovation-related acquisition of embodied and disembodied technology, production preparation, design, training, software and marketing. The characteristics of the innovation process are measured by asking questions about the objectives, the sources of ideas, co-operation, and the obstacles to innovations. The most important output indicator for TPP is the proportion of sales due to technologically new or improved products. The frequency of data collection is a compromise between costs, response burden of the firms and data accuracy.

The practical problems of measurement and operationalisation of the definitions are readily stated in the manual. However, the manual does not directly differentiate between innovation as adaptation from innovation as creative effort (see also Arundel et al. 1998). A firm which imports a new good and introduces it to the domestic market can therefore in practice be counted as an innovator even though the innovation effort could be non-existent. Moreover, new firms are analytically difficult because all new firms established during the period studied are innovators if the definition of TPP is taken literally.

Although the population of firms in a country is known, an applicable statistical unit is problematical in surveys of the kind proposed by the Oslo Manual. This is due to the disparity between the formal organisation of the firm and the way in which innovative activity is actually realised in the organisation. The decision-making process does not always match the formal classification of firms or local units in business registers. Hence, the impact of innovation might be misleading since the link between innovation input and output is distorted. Furthermore, in multinational firms the problem is exacerbated because their innovative activities cannot be delimited to one country only. Workable general solutions to this problem are difficult to find. The problems of sampling the large firms are considered, for example, in Arundel et al. (1998). In practice, however, most of the firms, at least SMEs, are still concise units and thus the legal unit can be defended as the basis of the surveys.

Besides the sampling problems, there is always a potentially considerable measurement error involved since innovation is an unstandardised concept in the firm accounts or in the common understanding within firms. The definitions of innovation and related activities are left to the subjective judgement of the firms. Instructions provided in the survey should be general enough so that they can be applied to several different industries. At the same time they have to be detailed enough to demarcate meaningfully between innovators and non-innovators in each industry.

The First Community Innovation Survey

The recommendations of the first version of the Oslo Manual were applied by the EU's statistical office Eurostat in the early 1990's. The project was called Community Innovation Survey (CIS). For the survey a harmonised questionnaire was designed according to the common guidelines. As a filtering question, the responding firms were asked whether they had introduced TPP's during the past three years or had projects aiming at them. If the firm reported 'no' to each of the questions it was defined as non-innovating and it could skip the detailed questions on the innovation process. The aim of the first CIS was to cover manufacturing but some countries extended the survey to service sectors as well. The questionnaire covered all stages of the innovation process. It included questions on the sources of innovation ideas, expenditures, collaboration, output and obstacles to innovation. As could be expected, the most problematic question turned out to be those on innovation expenditures. Respondents were asked to give expenditures on items such as R&D, innovation-related investments, acquisition of technology, training and marketing. The non-response rate was particularly high for those questions, so the reliability of the data collected is questionable.

The success of the first CIS varied significantly between the participating countries. Practically all the countries had problems with low response rates. In fact, the quality of data in some countries was so low that the results could not be published at all. In addition to the country-specific problems, the harmonisation and standardisation of implementation across the countries could not be achieved satisfactorily. International comparability requires common procedures in sampling and data collection. In some countries firms were selected according to the principles of random sampling, in other countries the census was used while a few countries defined a sample of likely innovators. The timing of surveys, protocols used in the data collection, and the handling of non-responsiveness also varied, which all led to the above-mentioned loss of international comparability and to the inability to calculate total figures for the EU level. (Archibugi et al. 1994a). As a pioneering exercise it is not surprising that the first CIS had considerable teething problems and failed to achieve comparability across the member countries. However, the data have proven to be useful in various studies where the interest is on the specific topics of the questionnaire, rather than on the macro-level statistics. The experiences from the process have been utilised in the second round of CIS, which was implemented in 1997.

The CIS is important because it is likely to become the guiding model for future comparative innovations surveys, especially if it becomes mandatory in the EU member countries. Eurostat together with OECD has made an major effort to provide an established methodology and to harmonise the second CIS round. Furthermore, in the context of the OECD, the methodology is spreading to non-EU countries as well. In addition to mere instructions, the EU funding of the data collection in the member countries is dependent on the quality of the results.

Other firm-level surveys

Besides the CIS, there has been a number of other firm-level surveys on innovation. They differ somewhat in their definitions or contents, but from the methodological point of view they are more or less similar to CIS. One example is the survey on policies, appropriability and firm-level competetiveness for innovation (PACE) (Arundel et al. 1995). The study was funded by the European Commission and it was conducted by the Dutch research institute MERIT, Aalborg University and the French statistical office INSEE. In PACE the definition of the survey population and the unit of analysis offers an alternative to the sampling of firms. The first step was to select eligible firms on the basis of a publicly available list on 800 large firms in Europe. The criteria for inclusion of the firms was separate legal status, manufacturing or industrial activity, the undertaking of R&D and annual sales exceeding ECU 1 billion. Besides this, some firms were included on the basis that they were top R&D performers in their country. In all the population consisted of 528 firms.

Because PACE concentrated on the largest firms in the EU, the problems of handling complex organisational structures were accentuated. The solution was to focus on the area of responsibility of the R&D manager who received the questionnaire. In firms which received more than one questionnaire, the separateness of responsibility areas was defined either on an organisational, geographical or functional basis. After defining the default for the maximum practicable number of R&D managers per firm, the number of R&D managers to be allotted to each firm was determined by each firm’s share of total sales in a given country. The response rate by questionnaire or R&D manager was 56% and by firm 78%. Non-response analysis did not show any noteworthy bias that could distort the results.

Beside the efforts made by the EU, there have been several other firm-level surveys, which more or less share the common methodology of the Oslo Manual. Examples include the Mannheim innovation panel by the ZEW-institute (Licht et al. 1996), the Swiss innovation survey (Arvantis & Hollenstein 1995), innovation surveys by Statistics Canada (Baldwin 1996), and the Australian innovation surveys (Australian Bureau of Statistics 1998). In Finland, Statistics Finland has conducted three innovation surveys in line with the CIS methodology. The innovation data have been linked to several other variables like firm accounts, investments and educational background of employees. Research has focused on the role of competencies and impact of R&D and innovation on firm performance (Husso et al. 1996, Leiponen 1996a, 1996b & 1999, Lehtoranta 1998).

3.2. The object-approach

The object approach differs from the subject approach in that data is collected directly at the level of individual innovations, the Schumpeterian objects of industrial renewal. The object approach thus deals directly with the output of innovation and produces a richer analysis of the nature of different types of innovations and the underlying knowledge base, their origin, development over time and diffusion.

There are two primary methodologies identifiable within the object approach. The first methodology identifies innovations using expert opinion and then collects additional data on the innovations through surveys directed at the commercialising firm or from publicly available sources. The second methodology identifies innovations through systematic reviews of technical and trade journals and collects data on innovations from these without contacting the commercialising firm (the literature-based methodology, or LBIO).

The object approach is characterised by the fact that there is as yet no standardised procedure comparable with the Oslo Manual, and therefore the different studies are not comparable in a strictly statistical sense. On the other hand, the object approach provides more possibilities for experimentation since a combination of innovation-centred data sources can be used in triangulation. Moreover, since individual innovations can be traced from historical sources and linked to specific firms in time, the object approach enables a more exact analysis of the relationships between different types of innovation, the birth, growth or death of different firms and industries over time in a truly Schumpeterian and evolutionary-institutional sense.

Innovations identified by expert opinion

Perhaps the best known pioneering application of the object approach is the SPRU database of significant UK innovations compiled by the Science Policy Research Unit (SPRU) at the University of Sussex. The database was motivated by a desire to develop indicators to provide more systematic statistical information on the sources, nature and impact of significant innovations in the UK. The identification of innovations relied on the opinion of nearly 400 experts drawn from research and trade associations, government departments, academic institutions, trade and technical journals, firms and consultants representing different sectors of the economy. Thereafter the innovations were traced to the respective firms and basic data on the firm and the innovation were collected using a short survey. The first version of the database was compiled for the Bolton Committee of Inquiry on Small Firms in an effort to assess the relative role of small firms in innovation. (Townsend et al. 1981). The database was updated on several occasions during the 1970s and early 1980s. Presently, it consists of some 4 400 significant industrial innovations introduced in the United Kingdom between 1945 and 1983 (Freeman & Soete 1997).

The first criterion for an innovation to be included in the database was that it had been a successful commercial introduction of a new product or process. It was not required that a British-owned firm originally developed the innovation. The innovating firm could be a British subsidiary of a multinational firm operating in the UK. The distinction between product and process innovation was defined according to the so-called sectoral approach, which classifies an innovation as a process if the sector of production coincided with the sector of use of the innovation, and as a product if the sector of production did not coincide with the sector of use. Besides the commercial success, it was also required that an innovation should feature a significant technical advance in some respect, in which case innovations of a more incremental nature were excluded. Special care was taken to ensure sectoral coverage and the inclusion of small firms. In order to find innovations that would fulfil the above criteria, most innovations were confirmed by more than just one expert, and people with expertise working outside the sector in question were also used to make the selection procedure more consistent. (Townsend et al. 1981).

The SPRU database of innovations has proved a valuable source for a very wide range of different empirical studies. Evidently the good quality of the data as well as the comprehensive sectoral coverage and the long time series available have been particularly important features of the database. Special care was also taken to include larger firms. Some of the more significant studies based on the database are presented in Table 2 .

Table 2. Selected empirical studies based on the SPRU innovation database.

AUTHORS	FOCUS OF STUDIES
Freeman (1971), Pavitt et al. (1987), Tether et al. (1997), Tether (1998)	The relative role of small firms vs. large firms in innovation
Geroski & Pompoy (1990), Geroski (1991 & 1994)	Relationships between market structure and innovation
Pavitt (1984), Robson et al. (1989)	Sectoral patterns of innovation
Geroski & Walters (1995), Geroski et al. (1996)	The origin and determinants of innovations, persistency of innovators

In concordance with the original aim of the database, there is a large body of literature which uses the database for inquires into the relative role of small vs. large firms in innovation (see Freeman 1971, Pavitt et al. 1987). These studies have classified innovating firms into different size cohorts, compared both their entry into new industries and the propensity to innovate with R&D expenditure and employment over the size cohorts and sectors, and derived general conclusions about the relative role of small firms vs. large firms in industrial renewal. In this connection, Geroski & Pomroy (1990), Geroski (1991 & 1994) have examined the relationship between markets structure and innovation. Overall, the conclusions have tended to refute the Schumpeterian hypothesis of a positive correlation between firm size, market concentration and the propensity to innovate. However, subsequent studies which harnessed more detailed inquires and classifications of firms point to particular biases in the database which favoured large firms (for more recent studies based on the same database, see Tether et al. 1997, Tether 1998). The methodological lessons of these exercises appear to be that special care has to be taken when linking innovations to commercialising firms, since the ownership status of large as well as small firms are complex and might produce classification discrepancies and biases. Such biases can also be related to the use of experts, who might disproportionally favour significant innovations of large firms.

Another major study using the database is Pavitt's (1984) much-referred-to taxonomy of sectoral patterns of innovation which was discussed in chapter 2.3. (see also Robson et al. 1989, who elaborated further on certain aspects of Pavitt's study). Other examples are Geroski & Walters (1995) and Geroski et al. (1996). Geroski & Walters (1995) examined the relationships between business cycles and patterns of innovative activity during the period covered by the SPRU database, using data on innovations, patents and industrial production indexes at the sectoral level. They came to the conclusion that a positive relationship exists, although the data provided no clear support for the Schumpeterian ’supply-push’ assertion that clusters of innovation cause cyclic variation in economic activity. Geroski et al. (1996) examined the persistency of innovators over time, using a combination of patents and innovation data, in order to test whether increasing returns to scale in innovation could be identifiable at the firm level. Their conclusion was that very few firms in either data set produced long innovation spells and could not therefore be considered persistently innovative. Rather the distribution of patents and significant innovations was dispersed over many firms, and turbulence in the introduction of innovations to the market was high. The SPRU database produced an average of 2,66 innovations per business unit contained in the data set.

To our knowledge, there are two other examples of harnessing expert-opinion for collecting data on innovations. The first one is the database compiled by the Gellman Research Association in the US during the 1970s. The second is a database of 100 significant innovations commercialised in Sweden between 1945 and 1980, which was constructed by researchers at Chalmers University of Technology in collaboration with the Board of Technical Development. While interesting in their own right, these two databases have apparently not generated as much research as the SPRU database, perhaps owing to their more limited scope and coverage as well as the fact that no additional survey data have been collected.

In the U.S. the Gellman Research Association identified 500 major innovations that were introduced to the market between 1953 and 1973 in the US, the United Kingdom, Japan, West Germany, France and Canada. The initiative for this work came from the National Science Foundation with the aim of developing science and technology indicators. The innovations were selected by an international panel of experts representing the most significant new industrial products and processes, in terms of their ’economic and social impact’. The study resulted in a couple of publications by the US National Science Board and the National Science Foundation during the late 1970s (Acs & Audretsch 1990).

The Swedish study was designed to produce generalisable results on innovations of particularly important economic impact on the economy. The basic list of 176 innovations was obtained form The Royal Swedish Academy of Engineering Sciences which published annually a list of significant innovative achievement to the president of the Academy through peer review by experts from different fields. The list was subsequently modified by various criteria such as novelty of related patents, technical content and economic impact of the innovations. The requirement for inclusion in the database was a 'meaningful patent' and the economic impact of innovations was approximated in relation to the share of turnover of the commercialising firm, whereafter minimum monetary thresholds were assigned. The number of innovations was deliberately set at 100 in order to incorporate meaningful statistical analyses. These analyses have been reported in Wallmark & McQueen (1983 & 1991) and cover the frequency of innovations over time, the time taken between conceiving the idea to the commercial introduction, the rate of increase of annual turnover, patenting, characteristics and backgrounds of the innovations, and the relative role of small firms vs. large firms.

Literature-based methodology

Innovation, especially a new product or service, is by definition made public when introduced to the marketplace. It is reasonable to assume that the editors of professional trade and technological journals will draw attention to the most interesting ones and publish stories on them. Following this logic, professional trade and technological journals might also be considered as relevant sources for the identification of innovations.

The first extensive application of the literature-based methodology also involved the Gellman Research Association. In this study, the aim was to study the role of small firms in innovation. Some additional 600 innovations were selected through systematic review of fourteen industry and trade journals during the period 1970-79, including lists of award winning innovations. The Gellman Research Association also included a number of innovations from their previous identification round, which was done using expert opinion.

The third and most comprehensive data set of innovations compiled in the US using the literature-based methodology was done by the Futures Group in the early 1980s. The Futures Group collected data on 8 074 innovations mentioned in more than one hundred technology, engineering and trade journals in the United States in 1982. From the sections in each trade journal listing innovations and new products, a database consisting of the innovations by four-digit standard industrial classification (SIC) industries was formed. The data was then traced to firms and the firms were classified into different size cohorts. An innovation was defined as *"a process that begins with innovation, proceeds with the development of the invention and results in introduction of a new product, process or service to the marketplace"* (quoted in Acs & Audretsch 1990). The database thus contained significant innovations as well as incremental innovations. Nonetheless, it was found that journals were more likely to report on product innovations of large firm rather than small firms. (Acs & Audretsch 1990).

Following these first applications of the literature-based methodology, there has been increasing interest in this kind of approach in Europe in the 1990s. The first European study was conducted in the late 1980s in Holland, and a similar methodology was later used in Austria, Ireland and the UK. The results of these studies are reported in Kleinknecht & Bains (1993). Later, Santarelli & Piergiovanni (1996) and Coombs et al. (1996) conducted similar studies in Italy and the UK, respectively.

While all these above-mentioned studies diverge in specific aspects, and hence are not strictly comparable in a statistical sense, they all share the basic logic of the literature-based methodology. The first step has been the selection of relevant journals. One criterion that has been applied is that a journal should have some kind of edited ’new products’ column. Furthermore, the journal should supply enough information on the innovation, on it’s characteristics, and on the firm responsible for the development of the innovation. Special care has also been taken to include a sufficient number of journals, ensuring proper sectoral coverage, even though it is not possible to evaluate precisely to which degree the selection of journals covers the theoretical total population of innovations. Different industries and technologies are covered by different journals with varying publishing policies. Also, firms of different sizes may have dissimilar incentives to have their innovation published.

Even though the selected journals do not cover all the possible innovations and industries, and the selection might therefore be systematically biased in one way or the other, the literature-based methodology has in a statistical sense also some favourable aspects which are important from the viewpoint of generalisability: the relevant journals constitute a clearly defined population, the journals are edited, and mention of an innovation in the journal implies some kind of judgement of people knowledgeable in the field. In principle, different types of firms have the same probability of having their innovations included. Nonetheless, most databases compiled using this methodology, especially in Europe, tend to consist of a significantly larger share of smaller new firms whose products more frequently get noticed by the press.

The literature-based methodology typically collects data directly from the reviewed journals in order to diminish the response burden of the firm. Hence, apart from selecting the relevant journals, it is necessary to develop a classification scheme (corresponding questionnaire design in surveys). Here there is the usual problems of defining technical complexity, and in particular the significance or novelty of the innovations. Most literature-based studies have developed detailed classification schemes for this purpose. The production sector of innovations, and the sectors of the potential user are also essential data. An important distinction in the various studies mentioned above has been between innovations of domestic and foreign original, though measurement error is still present.

All-in-all, the literature-based methodology produces a large number of innovations from historical sources dating, in principle, as far back in time as the journals are available. Data collection is of course always subject to a trade-off between resources and time. Time-wise, the literature-based studies have typically collected data from a large number of journals in a specific year, in which case the data has been less useful for longitudinal studies involving time-series. Thusfar, the studies based on the literature-based methodology have primarily focused on cross-sectional analysis of the relative contribution of small firms vs. large firms, different types of innovations (in terms of their complexity), the sectoral distribution of innovations, and intersectoral innovation flows. The studies are summarised in Table 3.

Table 3. Studies based on literature-based methodology.

AUTHORS	FOCUS OF STUDY
Acs & Audretsch (1990, 1993)	The relative role of small firms vs. large firms in innovation, relationship between innovation and firm demography (size, age, growth and survival rates)
Kleinknecht et al. (1993), Cogan (1993), Coombs et al. (1996), Fleissner et al. (1993), Santarelli & Piergiovanni (1996)	Small firms vs. large firms, differentiation between different types of innovation, domestic content of innovations, sectoral distribution
Steward (1993)	Technology monitoring of ’significant innovations’

It is not meaningful to review all the studies mentioned in Table 3 here, although the coverage and results of the studies differ somewhat. A particularly extensive study is Acs & Audretsch (1990), which is based on the 8 074 innovations collected by the Futures Group in 1982. The overall conclusion that Acs & Audretsch arrive at is that small firms play a key role in the process of technological change, especially in R&D-intensive high-technology industries. This is because they generate much of the turbulence in terms of entry, growth and exits, which is crucial for employment growth, competition and industrial renewal.

Drawbacks to the object-approach

As has been noted above, the object approach has some apparent advantages over the subject approach due to the fact that the output of firms’ innovative activity is measured directly. However, there are also drawbacks to the object-based approach which have to be kept in mind when analysing data collected in this way (see also Coombs et al. 1996, Santarelli & Piergiovanni 1996).

The degree of coverage of innovation-count studies is generally difficult to evaluate statistically. No matter how the data are gathered it is practically impossible to obtain all the relevant innovations of particular firms, sectors or periods, i.e. the theoretical population of innovations is practically unobservable. Therefore the calculation of standard sample weights is not applicable and the total number of innovations in a specific industry or country cannot be estimated. Furthermore, as was discussed above, databases compiled in this way might carry certain systematic biases. There are problems of judgement involved in the selection of relevant journals. In principle, it is probable that the number of innovations identified will be positively correlated with the number of journals selected. On the other hand, different journals can be cross-checked against each other, in which case duplicate entries of innovations are avoided and a point of saturation might be reached. The different methodologies might also produce biases in the size distribution of the innovating firms, e.g. if experts tend to select mainly significant innovations of large firms, while the literature-based methodology produces relatively more innovations commercialised by small firms. All-in-all this means that care has to be taken when the innovations are related to other data, for example to sectoral production or R&D expenditure data.

Fundamental aspects of the object-based method are the definition of innovations and the establishment of selection criteria for assessing their degree of novelty. Experts or journal editors may apply varying 'threshold criteria' when selecting the innovations, and they might be subject to different biases. Also, the literature-based methodology is in practice mainly applicable for identifying product innovations available on the market, since firms evidently have less incentives to report on in-house process innovations which might be vital to their competitive advantage. Moreover, there is the problem of establishing the analytical unit of 'one' innovation. A particular mobile phone might be regarded as a significant innovation in the telecommunications industry. But how does one account for the various constituent innovations in technologies comprising the system (signalling software, batteries, speech quality, RF and so on)? This problem is partly a definitional one and depends on how precisely and from what perspective one defines innovation. A more general problem is the fact that both expert opinion and literature-based methodology will always contain nation-specific characteristics, which hampers international comparability.

4. The Sfinno-approach

4.1. The main elements of the approach

The purpose of this chapter is to present the definitional and methodological approach that we use in the Sfinno-project with reference to the broader theoretical and conceptual framework reviewed in chapter 2, as well as the methodological review discussed in chapter 3. Overall, the Sfinno approach is holistic, since we combine different methodologies. The basic structure of our approach is illustrated in Figure 4.

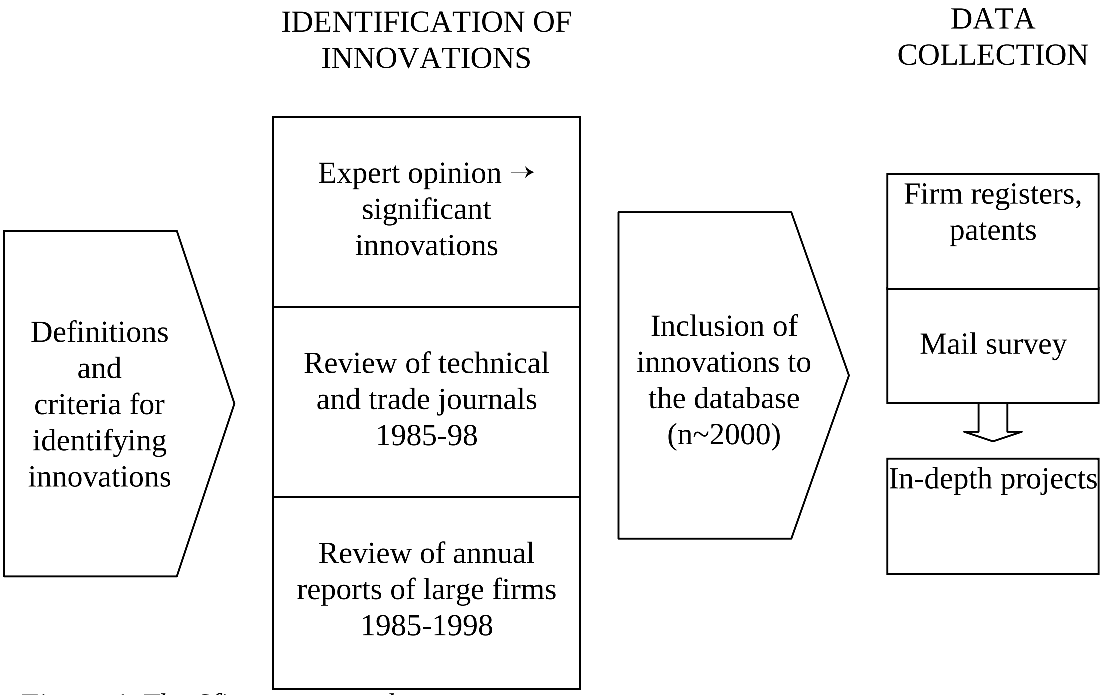

Figure 4. The Sfinno-approach.

As has become clear already, we employ the object approach for the identification of innovations and data collection. Adhering to certain definitions and criteria, we have taken individual innovations as the starting point without prior contacts with the firms that have introduced the innovations to the markets. However, the Sfinno approach is novel and unique since we have relied on both expert opinion and literature-based reviews for the identification of innovations. In addition, we have dealt with large firms and concerns on a case-by-case basis by identifying innovations, based on their annual reports. Furthermore, we extend the scope of the project to cover innovations commercialised during the period from the early 1980s to 1998, although some innovations date back even further. This contrasts with previous literature-based studies, which have focused on one particular year and collected cross-sectional data from journals from that particular year. The identified and selected innovations have been registered in the database, which will consist of approximately 2000 innovations altogether.

Compared with previous studies that we have encountered, we have also used a slightly modified methodology for data collection. We have collected certain basic data on all innovations and firms included in the database directly from the reviewed journals, using the experts, firm registers and patent databases and the World Wide Web. However, we have also approached most of the firms with a questionnaire asking for additional data on the innovations. In addition to this, the Sfinno project is envisioned to generate a range of different so-called in-depth projects, which will basically elaborate on the data collected by adding complementary data for analysis of specific aspects of industrial renewal processes in Finland.

4.2. Basic definitions and criteria for identifying innovations

Owing to the fact that the object approach is more conducive to studying product innovations, we have, in practice, excluded ’pure’ process innovations developed for the firm’s own use. In line with Schumpeterian definitions, we define a product innovation as an invention which has been commercialised on the market by a business firm or equivalent. As a minimum requirement, an innovation has had to pass successfully the development and prototype phase of innovation, involving at least one major market transaction.

The commercial success of the innovation has not been our prime consideration at this stage of the project, although the mail survey asks for rough proxies on this from the perspective of the turnover and exports of the commercialising firm. Obviously our neglect of the commercial success of the innovations is a shortcoming in analysis of the relationship between innovations and industrial renewal, since the ’significance’ (e.g. measured in terms of it’s commercial importance for a firm or industry) of each innovation should be a crucial parameter. Nonetheless, our present methodology (and the object-approch in general) simple does not yet allow for any clear-cut judgement of commercial significance and this issue will need more elaborate consideration later e.g. through the gathering of complementary data and further expert opinion. Thus, the database comprises of innovations which have established extensive economic activity, innovations characterised by shorter life cycles, and innovations which have disappeared from the market shortly after their introduction. These latter cases are also interesting from a historical point of view, since they might involve firms which have entered an industry successfully but subsequently exited or disappeared altogether.

We have tried to define innovations as concise objects, which can be named and separated or disaggregated from the other products of the firm. While this has been deemed especially important from the point of view of the questionnaire, it is no easy task in practice. For example, a generic technology or new production method may generate a bunch of new products, in which case the identification of only one concrete innovation is difficult. Moreover, the above mentioned problem of the object-approach of establishing the analytical unit of ’one’ innovation has been dealt with on a case-by-case basis to the best of our knowledge. There is also the problem of different generations of incrementally developed products, e.g. in the case of mobile phones. In such cases we have sought to identify the most discontinuous one. Also, products, processes and services are sometimes intervened and the innovation is actually a system, an integrated and complex package of product and process innovations which is customised to each client. In these cases we have been fuzzier in our definitions of a product innovation and included the innovations as long as market introduction has been realised.

Assessing the degree of novelty

Our basic assessments of the degree of novelty of innovations rely loosely on the Oslo Manual (1997). Our benchmark has been the technological novelty of the innovation. Hence, we define an innovation as a technologically new or significantly enhanced product. A technologically new or significantly enhanced product involves some of the following elements (compare to the Oslo Manual 1997, 109):

- use of new materials
- use of new intermediate products
- new functional parts
- use of radically new technology
- fundamentally new functions

In addition to technological novelty, we apply the perspective of the firm. This means that an innovation is considered novel if it is new to the firm, and therefore has required some reconfiguration or accumulation of firm’s knowledge base. This is compatible with evolutionary theories of the firm, which stress the complex set of interactions between innovation and the competencies of the firm (compare e.g. to Nelson & Winter 1982, Henderson & Clark 1990, Teece et al. 1994). The alternative would be to also apply a new-to-the-market criterion, which is stricter but also significantly more difficult to monitor in practice.

One general aspect of our assessment of the degree of novelty is that the innovation is the first appearance of the product in question. We have checked for duplicates at the firm-level in cases where the same innovation has entered the database from different sources. Another potential problem is the fact that the same innovation might travel through several firms and enter the market several times in slightly modified forms. One example is an innovation that has subsequently been acquired by another firm that redevelops the same innovation for a new market or usage. Here again, we can refer to the new-to-the-firm-criterion, which, of course, might be difficult to apply in borderline cases. Thus, despite our precautions, some of the innovations in the database might be at least partly imitations of existing innovations. This is a common problem when using the object-approach.

The question of whether innovations are incremental, radical or merely product differentiation is also a difficult one, regardless of whether the viewpoint of the firm or the market is taken. For those innovations in our database on which we have data from the questionnaire, the solution is straightforward since the respondents themselves have reported the degree of novelty (from the firm's perspective). But in all, our methodology aims at the exclusion of product differentiation, and the bottom-line eligibility of an innovation for inclusion in the database can be established as 'incremental technological product innovation new to the firm'.

As was discussed in chapter 3, assessing the degree of novelty is particularly tricky in the case of new firms, when the viewpoint of the firm is taken, as by definition these are always innovators despite the fact that their products might be differentiation, pure imitations or adaptations of existing innovations. We have partly circumvented this problem since new firms are not included on the basis of their own evaluation, but because of some external criterion based on the characteristics of their products that is inherent in both the expert opinion and the literature-based methodology. In the case of large firms this is obviously not a problem, since large firms are typically incumbents. It should also be noted that the different methodologies and sources used to identify innovations will obviously produce different assessments of the degree of novelty, even though we have strived to stick to these basic definitions and criteria throughout. We deal with these source-specific differences more thoroughly in chapter 4.3.

Domestic content of innovations

Our focus on Finnish innovations implies that we are interested in innovations of domestic origin, i.e., innovations developed in the context of the Finnish economy. Given that innovations are frequently developed in close collaboration with foreign universities and firms, it is obviously difficult to establish the domestic content of innovations. Moreover, due to the diffusion of innovations and technology transfer, an innovation which is new to the firm is quite often to a significant extent based on imitation and adaptation to the local or national market. In the case of new firms, it might sometimes be difficult to judge whether an innovation originates from abroad, e.g. through importation or in-licensing. In the case of large firms and concerns, R&D and production are typically internationalised to a significant degree, in which case the contributions of foreign units or subsidiaries are almost impossible to distinguish. Likewise, the units and subsidiaries of foreign firms' might conduct R&D in Finland, resulting in innovations commercialised on the Finnish or international market.

In Sfinno we define an innovation as having originated in Finland if the commercialising firm is registered as a domestic firm in the firm registers. Implicit in this definition is the assumption that the commercialising firm is the same firm that has developed the innovation. Although this definition is clear-cut and practical, the above-mentioned problems are still relevant in certain cases. Specifically, this definition includes foreign firms' subsidiaries which are registered in Finland, even though they might conduct a large share of R&D and product development at their home base abroad. On the other hand the definition excludes innovations which have been commercialised by foreign subsidiaries to domestic firms, even in such cases where these might have been developed primarily domestically. In this sense we might overestimate or underestimate the results of 'national innovative activities' and the problem is impossible to mitigate completely. Again, however, we have also been flexible and resorted to case-by-case judgement in cases of doubt by using additional data sources. We exclude all merchant houses and retailers which presumably sell mainly imported products on Finnish markets. Furthermore, the questionnaire enables some judgement as to the domestic content of innovations, for those responding to the mail survey.

Distinction between product innovation and process innovation

The exclusion of process innovations during the identification of innovations does not mean that process innovations are ignored altogether from an analytical point of view. As was discussed in chapter 2.2., this is because product and process innovations are typically interrelated, and many products might be implemented as process innovations in firms which are customers of the product innovation. Hence, the distinction between product and process innovations is first and foremost a definitional issue. We harness two definitional approaches for distinguishing between product and process innovations. First, we treat all innovations which have been commercialised on the market as product innovations without differentiating between their destination and use. Second, we are in principle able to sample between innovations based on the final demand-approach, in cases that are covered by the mail survey.

The fact that we treat all innovations which have been commercialised on the market as product innovations is consistent with our exclusion of process innovations developed for the firm's own use. Once introduced to the market, however, the innovations can be classified somewhere along a continuum between process innovations and product innovations, depending on the nature of final demand and the use of the innovation. At one end of the continuum, there is a group of 'business-to-business innovations' which are used as process innovations by other firms. These innovations might be capital goods used in the production processes of other firms, or they might be intermediate goods embedded as components in other products commercialised by the user firm. This group is thus specially interesting from the point of view of the diffusion of innovations. At the other end of the continuum, there is a group of innovations which might be defined as pure product innovations with direct benefits to the end-consumer. Examples might include foodstuffs, sports equipment or mobile phones.

From an analytical point of view, the problematic cases are those where the innovation is a consumer good that is in professional use, for instance, by firms according to final demand, and therefore could also be classified as a process innovation. An obvious example is a new software program or mobile phones which are used professionally. Hence, the final demand approach to distinguishing between product and process innovations produces a 'grey zone' of innovations, which are difficult to classify as either products or processes. Furthermore, we acknowledge that it is sometimes difficult to judge whether it is the technological qualities of the product itself, the underlying process technology, or the related organisational innovations and accompanying services which are actually most crucial from the commercial point of view.

4.3. Identification of innovations

Our holistic approach demands closer consideration since it is clear that there will be some divergence in the application of our basic definitions and criteria, depending on the methodology used for identifying innovations. The different methodologies might also produce certain biases during data collection, which have to be taken into consideration in a strict statistical analysis. These biases might, for example, arise since the expert opinion methodology tends to focus on significant innovations, whereas the literature-based methodology identifies relatively more small firms and innovations of the incremental kind.

Moreover, the annual reports of large firms are a more subjective source compared with the first two, since the firms themselves decide which innovations are covered in their annual reports.

We harness a holistic approach in order to assure the inclusion of a multitude of different innovations and firms in our database over the whole period covered. We have also striven to triangulate different methodologies and sources in order to secure the coverage and reliability of our data. Owing to the discrepancies in our methodologies, and the problems connected with this, we have taken special care to enable a separation of different subsets of innovations, depending on the source through which they have entered the database. Since the sources sometimes overlap, some of the innovations enter the database through more than one of the sources. The results of different methodologies are saved by updating the source of identification and allowing for more than just one source. Thus, Sfinno enables studies based on expert opinion or the literature-based data, either separately or combined. It also allows for a separate analysis of the large firms and concerns.

Innovations selected by expert opinion

The use of experts in the accumulation of innovations started at VTT Group for Technology Studies already in 1992. In the beginning, a group of a dozen senior researchers of VTT were asked to list the most significant Finnish innovations of their fields that had been commercialised since the beginning of 1980s. This list was supplemented by some experts of the Helsinki University of Technology and from industry, and the data and results of other studies of the Group were exploited. The experts were asked to give the name of the innovation, the innovator or innovators, a brief description of the innovation, and the name of a suitable contact person. The main criterion for inclusion was that it had been commercialised on the market. The criteria and definitions were stricter than those discussed in chapter 4.2, in particular with regard to the commercial significance of the innovations. This introductory collection resulted in 130 innovations. Afterwards, written material was gathered on the innovations from different sources, but the list itself was not modified.

The next step was taken in summer 1997. The old list of 130 innovations was sent to a new group of experts, which consisted of 150 people representing firms, research institutes and universities from different fields of technology. Originally the group of experts had been formed by the Technology Development Centre of Finland (Tekes) to prepare technology visions for the Ministry of Trade and Industry. Similar basic definitions and requests were used as in the previous phase. As a result, the number of innovations grew to around 230. This list was supplemented by other data of the VTT Group for Technology Studies, and the final list incorporated close to 300 innovations.

Review of technical and trade journals

Most of the innovations in the database, approximately 1400, were identified using the literature-based methodology. From a population of some 60 eligible trade and technical journals we selected 18, which were systematically reviewed over the period 1985-98 (the list of the selected journals is in Appendix 1). We took great care to select journals which seemed particularly conductive to the identification of innovations for our purposes. Our objective was also to cover the most important industrial sectors in Finland as extensively as possible.

Since we restricted the study to Finnish journals, the selection of the relevant one's was quite straight-forward, because of their limited number. While this is a practical advantage, one problem is that some sectors might be poorly represented because of the variable quality or limited availability of journals. Furthermore, the journals varied quite significantly in terms of their editorial style. Some journals are more generic in scope and focus more on the underlying technology of the innovations in the context of the industry in question. Others deal with particular product launches in a firm context, in which case the broader nature of the innovations is more difficult to comprehend, and hence the novelty of the innovation is also more difficult to assess.

The journals were reviewed by four students. We provided the students with our basic definitions and criteria for identifying innovations and discussed encountered problems and borderline cases during frequent meetings and e-mail correspondence. A particularly important aspect was that the whole content of the journals was reviewed systematically for the whole period, and we explicitly instructed the students to avoid simple 'new products' listings, which have been the prime focus of the previous literature-based studies that we have encountered. This was because we wanted to avoid design modifications, product differentiation and imitations, which frequently seem to figure in previous studies. On the contrary, we told the students to concentrate on longer stories describing the innovations and containing some mention of their novelty. We thus applied a rather time-consuming approach, which apparently produced relatively fewer innovations than in previous studies undertaken in similarly small countries (see e.g. Cogan 1993 on Ireland, and Fleissner et al. 1993 on Austria), but applied stricter selection criteria.

Another important aspect was the requirement that the name of the firm responsible for the market introduction of the innovation was stated clearly in the journal. The students were also asked to provide a description of the innovations and, if possible, to record potential contact persons in the firm for the purpose of the mail survey. They were also asked to consider carefully the domestic content of the innovations and to exclude all such cases which had not been predominantly developed by domestic firms in Finland. This was later double-checked from the firm registers. In contrast with studies such as those by Kleinknecht et al. (1993), Cogan (1993) and Coombs et al. (1996) (see chapter 3.2.) we did not consider it worthwhile to classify the innovations in terms of their complexity at this stage, since we wanted to simplify the tasks of the students as much as possible. Instead, we can rely on the descriptions of each innovations that the students have produced for various *ex post* classifications and taxonomies of different types of innovations.

Although the literature-based methodology seems feasible in a small country like Finland, due to the limited number of relevant journals the particular national context might warrant some reservations. The bias in journals against reporting on process innovations, which are typically kept secret, might be particularly problematic in Finland due to the fact that traditionally important process-intensive sectors such as pulp & paper, metal products and chemicals might be underrepresented. As a preliminary observation, it seems that there are plenty of product announcements from the machinery and electronics industries, many of which are related to the pulp & paper industry. There are, however, relatively few product innovations which originate directly from these process-intensive industries. This should not be interpreted as suggesting that these process-intensive sectors are not product innovative, but rather that the logic of innovative activity is different and produces technologically less visible innovations, albeit with a higher degree of embodied process technology. Also, journals reporting on traditional industries like pulp & paper, metals, construction, textiles and foodstuffs tend to focus on generic technologies, techniques and concepts in those sectors, while the identification of product innovations is less frequent. The application of criteria for defining technological innovations is also more difficult in these sectors, where technology intensity in the traditional meaning of the word is lower.

Review of annual reports of large firms and concerns

The inclusion of large firms and concerns was considered important right from the start owing to their central role in the Finnish economy. This is due to the dominant position that large firms have played in the forest-based, metal products and engineering industries, which have been the cornerstones of post-war industrialisation. The recent growth of the electronics industry and especially of the telecommunications industry has also largely relied on one firm, Nokia.

Although some innovations of these large firms and their subsidiaries entered the database through expert opinion and sporadically also through the literature-based review, we decided to approach them on a case-by-case basis as well in order to ensure their inclusion. The selection of the firms was made on the basis on their R&D intensity and patenting (the list of the selected large firms and concerns is in Appendix 2). We therefore assume that large R&D spenders, with a large number of patents granted in both Finland and the US, could also be considered innovative and hence warranted special coverage during the identification of innovation.

Again, the selection was limited to firms and concerns which had their headquarters in Finland and could thus be classified as domestic. Thereafter two students helped us to review systematically the annual reports of these firms over the period 1985-97. They were instructed to produce lists of product launches of the firms belonging to the concern, a brief description of each product, the year of commercialisation, and the name of the unit or firm involved in the commercialisation. We should stress that we did not apply the same basic criteria and definitions of innovations that we used for expert opinion and the literature-based reviews. Instead, we approached each unit and firm separately, asking the R&D managers or other key persons to check the list of product launches and to delineate from the list the most significant innovations from the perspective of the firm, applying the same criteria that we used to assess the degree of novelty, the domestic content of the innovations and the distinction between product and process innovations. The end-result of this exercise was a list of some 200 significant innovations of the large firms. This list was subsequently included in the database, and data collection proceeded in the normal fashion.

Obviously, the fact that we have included the large firms on a case-by-case basis does not completely resolve the various biases of the database that we wanted to avoid in the first place. One problem is the fact that certain sectors included in the database might now be dominated by the innovations of one large firm, especially in process-intensive industries where product innovations are less visible in trade and technical journals. A more fundamental problem, however, is the fact that the innovations of the large firms have entered the database through he subjective judgement of the firms themselves, notwithstanding that we selected the firms based on their R&D expenditure and patenting. This methodology is therefore problematic from the viewpoint of statistical sampling theory and makes certain kinds of analysis of the joint contribution of small firms and large firm to innovation difficult, if we harness the complete dataset of innovations in the database. The problem is of course less relevant in case-studies and descriptive analyses.

In addition to these analytical problems, the identification of innovations caused some practical problems. Obviously, the editorial styles of the different firms' annual reports also varied significantly. In some cases the annual reports proved to be good sources and produced long and concise lists of all product launches. In other cases, it was difficult to separate single products from the overall activities of the firms and units. Separating product differentiation tailored for specific markets from new product launches proved to be a particularly difficult task. We also faced the above-mentioned problem of treating the commercialisation of generic technologies and differentiating between generations of incrementally developed products. Sometimes the firms commented on these problems and helped us out. In the last resort, we again had to rely on our own subjective judgement.

Accounting for organisational changes within the firm, including acquisitions and mergers which have been particularly frequent in the early 1990s in Finland, was also problematic. This problem was at least partly remedied because we focused on individual innovations, which at the time of commercialisation could, in most cases, be linked to a specific firm or unit within the concern. With regard to the letter which was sent to the firms as well as the subsequent mail survey, the innovations had to be traced over time and related to the most recent structure of the concern. The problem caused by the frequent acquisitions and mergers was also partly remedied by the fact that units and firms often move from one large firm to another, in which case the same innovation would sometimes appear in a different year in another firm included in our study. These innovations were cross-checked at the firm level, and related to the most recent firm.

4.4. Data collection and the content of the database

Data on the innovations and the firms that have been identified and included in the Sfinno-database has been collected using three main sources: firm registers, patent databases and a mail survey. The World Wide Web has also been used as a complementary source. The guiding principle has been to extend the survey to cover as many innovations as possible. In practice, however, the time period covered in the project, the related problems of tracing the innovation to present firms and respondents, as well as non-responses, set certain practical limits on data collection using the survey. Hence, apart from identifying innovations and including them in the database, we have also relied on firm registers and patent databases in order to ensure that we have at least certain basic data on all innovations that are included in the database - this is the core of the database. In addition, we will have more detailed data on those innovations which have been successfully included in the survey. A technical description of the database is in Appendix 3.

The core of the database: basic data on the innovations

The name and description of the innovations, as well as the name of the commercialising firm, make it possible to classify the innovations into specific disaggregated industrial fields and technological classes. The classification of innovations into specific industrial fields is interesting since it becomes possible to distinguish between the industrial field to which the commercialising firm belongs and the industrial field to which the respective innovation belongs. Furthermore, it become possible to trace patterns of diffusion of individual innovations, based on their industry of destination. The technological class of innovations, in turn, is based on the International Patent Classification (IPC) system and reveals the underlying technology that is embodied in the innovation. This classification goes some way towards identifying technological trajectories, or patterns of technological development, depending on the level of disaggregation that is achieved.

We have classified the innovations into specific industrial fields by systematically identifying the TOL-95/NACE classification code that most closely corresponds to the name and description of the innovation.[3] A classification of innovations by technology class is complicated by the fact that the name and description of the innovations typically do not provide information on the underlying technology. One way to circumvent this problem would be to identify patents for specific innovations, in cases where the innovation has been protected by patent, and deduce the technology class of the innovation based on the IPC of the related patents. Recently, the Fraunhofer ISI-institute in Karlsruhe has been developing specific technology classification systems, which are helpful for such exercises (Grupp 1998). In Sfinno the database is complemented with patent data at the level of the firm, harnessing available keys, which establish a concordance between the name of the firm and the patent number of individual patents. At the time of writing, however, it is unclear whether we will also be able to link specific innovations to specific patents, and thereby classify innovations by technology class.

In addition to classifying innovations into disaggregated industrial fields and linking patents to the firm-level, we have used the firm registers to gather basic data on the commercialising firm. These basic data include the year of entry (and possible exit) of the firm to (and from) the register, the principle industrial field of activity, and the size of the firm in terms of employees and turnover. In cases where the innovation has travelled from one firm to another, e.g. through firm take-overs or licensing, we have included the names of both the original commercialising firm and the present firm. Hence, it is possible to link time series of these data to specific firms, that have been involved in the development and commercialisation of a specific innovation. This possibility of linking data is obviously especially relevant from the perspective of industrial renewal, since it becomes possible to trace the demography of innovating firms over time from the perspective of the commercialisation of individual innovations, in terms of entry and exit, firm size and growth.

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[3] The Finnish TOL-95 classification nomeclature is compatible with the NACE nomenclature used within the EU.

Table 4 summarises the basic data that we have on the vast majority of innovations.

Table 4. Basic data on the innovations in the database.

TABLE IN THE DATABASE	SECTIONS IN THE TABLE
1. Data on the innovation	- Name in Finnish - A brief description - Year of commercialisation - TOL 95/NACE industrial field - Technological class (ICP) ??
2. Data on the firm	- Firm identification code - Name and address - TOL 95/NACE industrial field - Number of employee's - Turnover - Patents

The questionnaire: additional data on the innovations

The aim of the questionnaire is to gather additional data on individual innovations that only the innovators can provide. Our idea has been to include questions which makes it possible to sample between different types of innovations and firms, industrial fields and technological fields. Furthermore, we have included questions on the degree of novelty and the commercial significance of innovations, as subjective judgement by the respondent. We have also included questions on the origin and diffusion of the innovation, the time dimension of innovation processes, the role of public promotion and R&D collaboration. We can then use this data to make some first rough analysis of industrial renewal processes in Finland from the perspective of innovations. This data will also enable a range of more detailed in-depth projects of both a quantitative and a qualitative nature. The Sfinno-database is thus designed to provide some aggregate hands-on analysis on the origin and sectoral pattern of innovation discussed in chapter 2, as well as a range of more specific analyses of particular aspects of industrial renewal which can be undertaken when the Sfinno-database is linked to other firm-level database and more qualitative research. Implicit in our approach is also the idea that this first mail survey will set a standard for recurrent updating of the Sfinno-database in the future. In Table 5 we present the main sections of the questionnaire. An English-language version of the questionnaire is attached in Appendix 4.

Table 5. Main sections of the Sfinno-questionnaire.

INNOVATIONS TABLE IN THE DATABASE	SECTIONS IN THE QUESTIONNAIRE / TABLE
1. Background data on the innovation	- The Finnish and English name of the innovation - A brief description of the innovation
2. The commercialising firm	- The name of the firm - The legal status of the firm - Firms previously involved in developing and commercialising the innovation
3. Characteristics of the innovation	- Degree of novelty from the firm and market perspective - The nature of the required knowledge for the development of the innovation - Diffusion of the innovation
4. Patenting	- The name of patent assignees and patent authorities where patents are granted
5. The origin of innovation and the time dimension	- Time taken from basic idea to prototype, commercialisation and profits - Impulses for developing the innovation
6. Formal R&D	- Yes/no
7. Public promotion	- The significance of public R&D funding
8. R&D collaboration	- The role of different types of partners during R&D collaboration - The role of public promotion for R&D collaboration
9. The commercial significance of the innovation	- The innovation's share of turnover and exports of the commercialising firm, developments 1996-98 and forecasted 1999-2000
Other comments, e.g. related to obstacles to innovation	

We put significant effort into the design and layout of the questionnaire in order to maximise the response rate and minimise the burden imposed on the respondent. As noted already, we also took care in defining the innovation as concisely as possible to clarify the object of the questionnaire. The name of the innovation as well as the firm presently commercialising it were filled in beforehand. The questionnaire was tested on the field several times before finalisation, and we decided to drop several trickier and sensitive questions as a result of that process.

Owing to the various problems related to the extensive time period covered, e.g. organisational change within large firms and concerns, there was a significant amount of preparatory work that had to be done before the questionnaires was sent out. First, we had to check whether the firm in question was active according to the firm registers. In cases where the firm had disappeared from the register, we left the innovation in the database as a historical notation but did not attempt to track the innovation to another firm which might have acquired the innovation for one reason or the other. Once an active firm had been identified, we relied on information from a journal as the primary source. The World Wide Web or telephone directories enabled us to identify a respondent who was particularly familiar with the origin and present status of the innovation. In the case of smaller firms, this was not such a big effort. In the case of larger firms the mail survey often required telephone contacts with the firm and we could also cross-check our information using the separate reviews that we have undertaken of the annual reports of the large firms. Sometimes we contacted the person in charge of the innovation directly in order to ensure that the mail survey could be directed to the correct person. We also sought to avoid having the same respondent answer two or more questionnaires, even though this was sometimes impossible. The respondents have typically been R&D managers, researchers, or in the case of smaller firms, company managers. The mail survey was undertaken in three successive rounds during 1998 and spring 1999.

5. Summing up

Apart from providing a new approach for understanding the micro-level mechanisms of recent industrial renewal in Finland, we have presented in many respects a novel application of previous object-based approaches to innovation-centred data collection, which combines expert opinion and literature-based methodologies. In addition, we have included large firms on a case-by-case basis. We have also extended the scope of the project to cover a relatively long time period, and collected additional detailed data using a mail survey. This approach is probably particularly conducive to a small country like Finland, where the identification of innovations is relatively easy and the population of firms is fairly transparent.

To our mind, the object-approach, and our approach in particular, is especially suitable for studies on industrial renewal, since we can take the central evolutionary concept of variety seriously and focus on the nature of different types of innovations and their interrelationship with different types of firms. We also apply a bottom-up perspective, where industrial sectors and clusters, however defined, are identified through microeconomic data - such as the description of individual innovations and patents - rather than the other way round. Moreover, our data allows for linkages with various time series data at the firm level (such as the industrial field of activity, entry, exit, and growth), in which case the essence of industrial renewal can be studied in a truly Schumpetrian framework.

Appendix 1: list of technical and trade journals reviewed 1985-1997*

NAME OF JOURNAL	ISSUES PER YEAR / YEARS COVERED	SECTORAL COVERAGE / FOCUS
Aromi	9-10 / 1985-98	Foodstuffs
Energia	10 / 1985-98	Energy technology
Forum för teknik och ekonomi	10-11 / 1998	Broad coverage of Finnish industry
Hyvä Suomi	6 / 1994-98	For the promotion of Finnish products
Insinööriuutiset & Tekniikka ja talous	150-160 & 52-53 / 1985-98	Broad coverage of Finnish industry, biased towards the engineering industries
Jäte ja ympäristö	5-6 / 1985-98	Waste disposal and environmental technology
Kehittyvä elintarvike	6 / 1985-98	Foodstuffs
Kemia-Kemi	10 / 1985-98	Chemicals
Konepaja & Metallitekniikka	12 / 1985-98	Metals, engineering
Logistiikka	10 / 1994-98	Logistics
Pakkaus	12 / 1985-98	Packaging industry, including machinery
Paperi ja puu	10-11 / 1994-98	Pulp & paper
Puumies	10 / 1985-98	Mechanical wood products
Sähkö ja Tele	10-11 / 1985-97	Telecommunications
Tekniikan näköalat	5 / 1985-98	For the promotion of Finnish technology
Tekstiilit	10 / 1994-98	Textiles
Tietotekniikan tuoteuutuudet	6 / 1985-97	IT
Tietoviikko	45 / 1985-98	Software

* We kindly acknowledge the help of our student assistants: Adam Tulos, Miikka Virtaharju, Petri Rytkölä and Ville Walden.

Appendix 2: list of large firms and concerns covered separately*

NAME OF FIRM / CONCERN	PRINCIPLE FIELDS OF ACTIVITY
Ahlström	Pulp & paper and related machinery
Cultor	Foodstuffs, enzymes
Farmos / Orion	Pharmaceuticals, diagnostics
Fiskars	Houseware goods and machinery
Instrumentarium	Medical equipment
Kemira	Chemicals
Kone / Kone Elevator	Elevator systems
Labsystems	Medical equipment
Leiras	Pharmaceuticals
Lännen Tehtaat	Foodstuffs
Metra	Engineering and machinery
Neste / Fortum	Chemicals, energy
Nokia	Telecommunications
Outokumpu	Metal products
Partek	Construction equipment
Raisio	Foodstuffs, fertilisers
Rauma-Repola	Pulp & paper machinery, engineering
Sonera	Telecommunications
Tampella/Tamrock/Kvaerner Pulping	Engineering, pulp & paper machinery
UPM-Kymmene	Pulp & paper
Valmet	Pulp & paper machinery and automation
Wärtsilä/Kvaerner Masa Yards/ Wärtsilä Diesel	Machinery, engineering
Metsäliitto, Rautaruukki, Stora Enso**	

* We kindly acknowledge the help of our student assistants Jyrki Kiviniemi, Jukka Hyvönen and Petri Rytkölä.
** At the time of writing the annual reports of these firms have not yet been reviewed.

Appendix 3: technical description of the Sfinno-database

The Sfinno-database is a relational database, which consists of the following five tables:

1. Innovations
2. Firms
3. Contact persons
4. Data on firms (provided by Statistics Finland)
5. Patent data (provided by the National Board of Patents and Registration of Finland)

Relations between the tables are defined by unique key variables, or so-called primary keys. The primary keys are "InnoID" and "LY". The modular structure of the database easily enables the linking of additional tables for various future research needs. The field names, content and variables have been fixed per 22.6. 1999, but might of course change somewhat in the future. The tables below provide information on the field name in each of the five tables, the content of the fields as well as the type of variables used for each field. The variables are explained in an auxiliary table

1. Innovations

Field name	Content	Variable
InnoID	ID number for the innovation	Number
LY	ID number obtained from the firm register of the firm currently commercialising the innovation	Number
Inno	Name of the innovation in Finnish	Text
InnoE	Name of the innovation in English	Text
InnoDe	Description of the innovation	Text
Type	Type/status of the innovation	VarType
Prod	Standard industrial classification (NACE) of the innovation	VarProd
Tech	Technological class of the innovation (IPC)	VarTech
K024a1	Name of the firm previously responsible for the commercialisation or development of the innovation	Text
K024a2	From year	Number
K024a3	To year	Number
K024b1	Name of the firm previously responsible for the commercialisation or development of the innovation	Text
K024b2	From year	Number
K024b3	To year	Number
K024c1	Name of the firm previously responsible for the commercialisation or development of the innovation	Text
K024c2	From year	Number
K024c3	To year	Number
K024d1	Name of the firm previously responsible for the commercialisation or development of the innovation	Text
K024d2	From year	Number
K024d3	To year	Number
K031	Degree of novelty of the innovation from the firm perspective	Variable
K032	Degree of novelty of the innovation from the perspective of the Finnish markets / global market	VarK032
K033	Technological know-how involved in the development of the innovation	VarK033

K033m	If something else, what?	Text
K034a	Do other firms exploit the innovation?	Yes/No
K034b1	Agriculture, forestry and fisheries	Yes/No
K034b2	Mining of minerals	Yes/No
K034b3	Food, beverages and tobacco	Yes/No
K034b4	Textiles, apparel, leather, footwear	Yes/No
K034b5	Wood and wood products	Yes/No
K034b6	Pulp and paper	Yes/No
K034b7	Publishing and printing	Yes/No
K034b8	Chemicals, rubber, plastics, oil	Yes/No
K034b9	Glass, ceramic products, concrete	Yes/No
K034b10	Basic metals, metal products	Yes/No
K034b11	Machinery and equipment	Yes/No
K034b12	Electrotechnical products	Yes/No
K034b13	Transport equipment	Yes/No
K034b14	Other industry, recycling	Yes/No
K034b15	Electricity, gas and water supply	Yes/No
K034b16	Construction	Yes/No
K034b17	Trade, hotels, restaurants, etc.	Yes/No
K034b18	Transport	Yes/No
K034b19	Telecommunications	Yes/No
K034b20	Financial and insurance services	Yes/No
K034b21	Data processing services	Yes/No
K034b22	Technical services	Yes/No
K034b23	Other services	
K041a	Is there a patent application for the above-mentioned innovation?	Yes/No
K041b1	If a patent has been granted, the name of assignee of the patent if a firm	Text
K041b2	If a patent has been granted, the name of assignee of the patent if a firm	Text
K041b3	If a patent is granted, the name of assignee of the patent if firm	Text
HakHenk	Has a person applied for a patent for the innovation mentioned above?	Yes/No

Ko41c1	Patent granted in Finland	Yes/No
Ko41c2	Patent granted at EPO	Yes/No
Ko41c3	Patent granted at USA	Yes/No
Ko41c4	Patent granted in Japan	Yes/No
K041c5	Patent granted somewhere else	Yes/No
K041m	If a patent has been granted somewhere else, where?	Text
K051a1	The basic idea of the innovation was presented in year	Number
K051a2	The development of the innovation started in year	Number
K051a3	First prototype was introduced in year	Number
K051a4	Commercialisation of the innovation began in year	Number
K051b4	Commercialisation of the innovation has not yet begun	Yes/No
K051a5	Export of the innovation began in year	Number
K051b5	Export of the innovation has not yet begun	Yes/No
K051a6	Year of the break-even point of the innovation	Number
K051b6	The break-even point of the innovation not yet been reached	Yes/No
K052a1	How significant was the intensification of price competition for the commencement of the development of the innovation?	K052
K052a2	How significant was the threat posed by rival innovation for the commencement of the development of the innovation?	K052
K052a3	How significant was the realisation of a market niche for the commencement of the development of the innovation?	K052
K052a4	How significant was the role of the customers for the commencement of the development of the innovation?	K052
K052a5	How significant was public procurement for the commencement of the development of the innovation?	K052
K052a6	How significant was a new scientific breakthrough for the commencement of the development of the innovation?	K052
K052a6m	If K052a6 is yes, then which?	Text
K052a7	How significant were new technologies for the commencement of the development of the innovation?	K052

K052a7m	If K052a7 is yes, then which?	Text
K052a8	How significant was public research or a technology programme for the commencement of the development of the innovation?	K052
K052a9	How significant were environmental factors for the commencement of the development of the innovation	K052
K052a10	How significant were official regulations, legislation, standards for the commencement of the development of the innovation?	K052
K052a11	How significant was the availability of a licence for the commencement of the development of the innovation?	K052
K052a12	Which other factor was significant for the commencement of the development of the innovation, how significant?	K052
K052a12m	If K052a12 is yes, then what?	Text
K06	Has intramural R&D-activity been involved in the development of the innovation?	Yes/No
K071	Have you received a public subsidy for the development of the innovation?	Yes/No
K071b1	From the Technology Development Centre (Tekes)?	Yes/No
K071b2	From the Ministry of Trade and Industry, other than Tekes?	Yes/No
K071b3	From the Finnish National Fund (Sitra)?	Yes/No
K071b4	From the Regional Development Fund (Kera)?	Yes/No
K071b5	From Nordiska Industrifonden?	Yes/No
K071b6	From the European Union?	Yes/No
K071b7	From some other public organisation?	Yes/No
K071bm	If K071b7 yes, then from which organisation?	Text
K08A	Has the development of the innovation included collaboration with others? If yes, please answer in fields K08b1-K08b15m	Yes/No
K08b1	Collaboration with other firms belonging to the same concern as the firm currently commercialising the innovation	K08
K08b2	Domestic customers	K08

K08b3	Foreign customers	K08
K08b4	Domestic consults	K08
K08b5	Foreign consults	K08
K08b6	Domestic subcontractors	K08
K08b7	Foreign subcontractors	K08
K08b8	Domestic universities	K08
K08b9	Foreign universities	K08
K08b10	The Technical Research Centre of Finland (VTT)	K08
K08b11	Other domestic research institutes	K08
K08b12	Foreign research institutes	K08
K08b13	Domestic competing company	K08
K08b14	Foreign competing company	K08
K08b15	Other than mentioned above	K08
K08b15m	If other, then what?	Text
K08c1	Has a Tekes technology programme been important to the collaboration involved in developing the innovation?	Yes/No
K08c1m	If K08c1 is yes, then what which Tekes-programme?	Text
K08c2	Has a another public technology programme had relevance to the collaboration involved in developing the innovation?	Yes/No
K08c2m	If K08c2 is yes, then which programme?	Text
K091a	The innovation's share of the turnover of the commercialising firm in the year 1998	VarK091a
K091b	The innovation's share of the exports of the commercialising firm in the year 1998	Vark091a
K092a	Development of the turnover generated by the innovation in 1996-1998	VarK092a
K092b	Development of the exports of the innovation in 1996-1998	VarK092a
K093a	Expectations of the development of turnover generated by the innovation in 1999-2001	VarKo93a
K093b	Expectations of the development of exports of the innovation 1999-2001	VarKo93a
Other	Other possible notes or addtional comments	Text

Explanation of variables

Variable	Explanation	Fields where used
VarType	1=Available on the markets 2=Not available on the markets 3=Process innovation 4=Development not yet finished 5=Innovation is introduced before 1980	Type
VarProd	According to the standard industrial classification (NACE)	Prod
VarTech	Technological class of innovation based on the International Patent Classification (IPC)	Tech
VarK031	1=Totally new 2=Major improvement 3=Incremental improvement	K031
VarK032	1=New to the Finnish markets 2=New to the global markets	K032
VarK033	1=Commercialisation of the core technology of the firm 2=Development and integration of components and modules 3=Development of production methods 4= Commercialisation of service concepts 5=Other	K033
K052	0=No significance 1=Minor significance 2=Significant 3=Great significance	K052a1-K052a12
K08	0=Not important 1=Minor importance 2=Important 3=Great importance	K08b1-K08b15

VarK091a	0=0% 1=1-5% 2=5-25% 3=25-50% 4=Over 50%	K091a K091b
VarK092a	1=Has increased 2=Has been stable 3=Has decreased	K092a K092b
VarKo93a	1=Will increase 2=Will be stable 3=Will decrease	K093a K093b
Yes/No	1=Yes 2=No	K034b1- K034b22 K041c1- K041c5 K051b5 K051b6 K052a1-6, K052a7, K052a8-12 K06 K071 K071b1- K071b7 K08b1- K08b15 K08c1 K08c2

2. Firms

Field name	**Content**	**Variables**
LY	See above	LY
Firmna	Name of the firm	Text
K023a	Type of firm	K023a

Kons	If the firm is part of a concern, then name of the concern	Text
K023c	Homeland of the concern	K023c

Explanation of variables

Variable	Explanation	Fields where used
Ko23a	1=Independent 2=Parent company of a concern 3=Other part of a concern	K023a
K023c	Abbreviations according to the Valtiot ja maat 1998. Statistics Finland, Handbooks	K023c

3. Contact persons

Field name	Content	Variables
InnoID	See above	Number
Code	Phase of the mail questionnaire	Code
Mail	Survey status	Mailing
Finame	First name	Text
Faname	Family name	Text
Affil	Affiliation	Text
Posit	Position	Number
Street	Street address	Text
Postco	Postal code	Number
Postof	Post office	Text
Phone	Phone number	Number
Fax	Fax number	Text
Email	Email address	Text
Internet	Internet address	Text
Archive	Material in the Sfinno-archive	Text
Duplicate	Not significant innovation or duplicate	Yes/No

Explanation of variables

Variable	Explanation		Fields where used
Code	01	Extension of the response time	Code
	02	No remarks	
	03	Refused	
	04	Contact failed	
	05	Questionnaire mailed	
	06	LY not in register	
	07	To be mailed	
	08	Removed from the sample	
	09	Additional information received	
	10	Responded	
	11	Responded, OK	
	12	Responded, asked for additional information	
	13	Firm has gone bankrupt	
Mailing	10	1.Mailing	Mail
	11	1.Mailing 1.Reminder	
	12	1.Mailing 2.Reminder	
	13	1.Mailing 3.Reminder by email	
	20	2.Mailing	
	21	2.Mailing 1.Reminder	
	22	2.Mailing 2.Reminder	
	23	2.Mailing 3.Reminder by email	
	30	3.Mailing	
	31	3.Mailing 1.Reminder	
	32	3.Mailing 2.Reminder	
	33	3.Mailing 3.Reminder by Email	
	100	Mail survey directed at large firms/concerns	
	200	Field trial interview	

3. Data on firms

Field name	**Content**
LY	See Above
Alopvm	Start-up date
Nimi	Name of the firm
Puhs	Areal code for phone number
Puhnro	Phone number
Faksisu	Areal code for fax number
Faksinro	Fax number
Posoite	Postal address
Pno	Postal code
Ptp	Post office
Kuntakoodi	City code
Kunta	City
Seutukunta	Region
Maakunta	Province
TE-keskus	Employment and Economic Development Centre
TOL95	Industrial field-code based on NACE
TOLnimi	Industrial field name
Puhtausprosentti	Percentage of purity
Oikeusmuoto	Legal status
Omistajatyyppi	Ownership status
Ulkomaankauppa	Exports
Krnro	Trade register number
Henkilöstö	Employee's
Liikevaihto	Turnover
Toimipaikkojen lkm	Number of affiliate firms/units

4. Patent data

Field name	Content
InnoID	InnoID is given, if the patent is related to innovation in Sfinno. For additional information, see above
LY	LY of the applicant, if a firm and Finnish. For additional information, see above
AD	Application date
AN	Application number
AP	Publication date of application
DP	Publication date of grant
FT	Finnish title
IC	Other IPC classes
IN	Inventor
KI	Kind of document
MC	Main IPC class
NP	Priority information
PA	Patent assignee
PD	Priority date
PN	Patent number
ST	Swedish title
WO	PCT information

Appendix 4: the questionnaire

[Graphics]

FINNISH INNOVATION

Name of respondent
Address

CONFIDENTIAL

Please return by *dd.mm.yyyy*

ID number

1. Background information

The questionnaire concerns the innovation mentioned below and the firm commercialising it. Some of the information is pre-completed; please correct it if necessary.

Name of the innovation

____

Description of the innovation

____

____

____

____

[VTT Group for Technology Studies logo]
[Contact information]

2. Firm commercialising the innovation in 1998

Firm name ____

Firm registration number ____

Is the firm

Independent	x
Parent company of a group	x
Other part of a group	x

Name of group ____

Domicile of group's parent company	Finland	x

Other country, which ? _________________

Has any other firm been responsible for the development or commercialisation of the innovation at some earlier time?

If so, which firm/firms and when ?

Name of firm	Period
___________________________________	_________________
___________________________________	_________________
___________________________________	_________________

3. Characteristics of the innovation

The time at which the innovation was first brought to market is the reference point for assessing the degree of novelty.

From the perspective of the commercialising firm, the innovation is in terms of its technological content or characteristics

Entirely new	x
A significant improvement	x
A minor improvement	x

The innovation is new

On the Finnish market	x
On the world market	x

Which of the following alternatives best describes the technological know-how associated with the innovation's development ?

Productisation of a particular core technology	x
Development or combination of different types of components or modules	x
Development of production methods	x
Productisation of service concepts	x
Other type, what? ______________________	x

Are or will other firms be using the innovation?

Yes x
No x

If so, in which of the following industries?

Agriculture, forestry and fisheries	x	Transport equipment	x
Mining of minerals	x	Other industry, recycling	x
Food, beverages and tobacco	x	Electricity, gas and water supply	x
Textiles, apparel, leather, footwear	x	Construction	x
Wood and wood products	x	Trade, hotels, restaurants, etc.	x
Pulp and paper	x	Transport	x
Publishing and printing	x	Telecommunications	x
Chemicals, rubber, plastics, oil	x	Financial and insurance services	x
Glass, ceramic products, concrete	x	Data processing services	x
Basic metals, metal products	x	Technical services	x
Machinery and equipment	x	Other services	x
Electrotechnical products	x		

4. Patenting

Has a patent application been submitted for the innovation ?

Yes x
No x

If yes, in the name of which firm/unit or person ?

____

Which of the following patenting authorities have __granted__ patents for the innovation ?

Finland	x
EPO	x
USA	x
Japan	x
Other, which ? ________________	x

5. Commencement of innovation development and the main stages of the development work

Starting dates for the different stages of the innovation's development

	Year	Not yet started
Basic idea proposed	________	
Development stage began	________	
First prototype made ready	________	
Commercialisation began	________	x
Exports began	________	x
Innovation exceeded the profitability threshold	________	x

How significant were the following factors for the commencement of the innovation's development?

	Not important	Minor importance	Important	Great importance
Intensification of price competition	x	x	x	x
Threat posed by rival innovation	x	x	x	x
Observation of a market niche	x	x	x	x
Customers demand	x	x	x	x
Public procurement	x	x	x	x
New scientific breakthrough (what _______?)	x	x	x	x
New technologies (which ______________?)	x	x	x	x
Public research or technology programme	x	x	x	x
Environmentalal factors	x	x	x	x
Official regulations, legislation, standards	x	x	x	x
Availability of a licence	x	x	x	x
Other factor (what ____________________ ?)	x	x	x	x

6. Research and development (R&D)

Has development of the innovation involved intramural R&D?

Yes x
No x

7. Importance of public funding for the innovation's development

Has public support been obtained for the innovation's development ?

Yes x
No x

If yes, please assess the importance of the following sources of funding for the financing of the innovation.

	Not important	Minor importance	Important	Great importance
Technology Development Centre (Tekes)	x	x	x	x
Ministry of Trade and Industry	x	x	x	x
SITRA	x	x	x	x
Regional Development Fund (Kera)	x	x	x	x
Nordiska Industrifonden	x	x	x	x
EU	x	x	x	x
Other,which ________________?	x	x	x	x

8. Collaboration associated with the innovation's development

Has collaboration with other parties taken place at any stage in the innovation's development ?

Yes x
No x

If yes, please assess the importance of the following partners

	Not important	Minor importance	Important	Great Importance
Firms belonging to the same group	x	x	x	x
Domestic customers	x	x	x	x
Foreign customers	x	x	x	x
Domestic consultants	x	x	x	x
Foreign consultants	x	x	x	x
Domestic subcontractors	x	x	x	x
Foreign subcontractors	x	x	x	x
Domestic universities	x	x	x	x
Foreign universities	x	x	x	x
VTT	x	x	x	x
Other domestic research institutes	x	x	x	x
Foreign research institutes	x	x	x	x
Domestic competitors	x	x	x	x
Foreign research institute	x	x	x	x
Domestic competitors				
Foreign competitors	x	x	x	x
Others, who? ________________	x	x	x	x

Has a public technology programme been important as regards collaboration associated with the innovation's development ?

	Yes	No
Tekes programme	x (which one ? __________________________)	x
Other programme	x (which one ? __________________________)	x

9. Economic importance of the innovation

Economic importance for the commercialising firm

The innovation's share of the commercialising firm's turnover and exports in 1998

	0 %	1-5%	5-25%	25-50%	>50%
Share of turnover	x	x	x	x	x
Share of exports	x	x	x	x	x

Development of the innovation's share of turnover and exports, 1996-1998

	Grown	Remained unchanged	Fallen
Turnover	x	x	x
Exports	x	x	x

Development outlook for the innovation's share of turnover and exports, 1999-2001

	Expected to grow	Expected to remain unchanged	Expected to fall
Turnover	x	x	x
Exports	x	x	x

Any notes or additional comments (e.g. about problems concerning the innovation's development)

____

____

____

____

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