Innovations and industrial renewal in Finland - Back to basics in innovation studies

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Communication to

European Meeting on Applied Evolutionary Economics

7 - 9 June 1999, Grenoble, France

Organised by the Institute for Energy Politics and Economics

Organisé par l'Institut d'Economie et de Politique de l'Energie /

IEPE, BP 47, 38040 Grenoble Cedex 9, France

And the INRA-Unit of Sociology and Economics of Research and Development

Et l'unité Sociologie et Economie de la Recherche Développement de l'INRA

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Abstract

This paper presents an ongoing research project, which takes individual innovations as the point of departure for an in-depth and comprehensive analysis of recent industrial renewal processes in Finland.[1] For this purpose we are constructing a database of some 2000 innovations commercialised during the 1980s and 1990s. We are also collecting detailed data on the innovations through a mail survey. We discuss theoretical and methodological approaches, which have shaped the design of the project, the pros and cons of our novel methodological approach, and present the content of the database. Furthermore, we envision some avenues for in-depth analyses of industrial renewal based on our data. First results of the project are due in autumn 1999.

Keywords: industrial renewal, innovations, object-approach, variety, competencies

[1] The project is financed by the Technology Development Centre of Finland (Tekes).

1 Introduction

The process of industrial renewal is fundamental for economic growth and development. Innovations, commercialised by new or old and established firms, are at the core of this process. If we want to analyse the emergence and decline of different industries over time the focal point should be on the commercialisation of innovations in their entrepreneurial context, in line with Schumpeterian and evolutionary economics.

This paper presents an ongoing research project at the VTT Group for Technology Studies named Finnish Innovations (Sfinno), which takes precisely this caveat as the point of departure. The aim of the Sfinno-project is to provide a deeper and more comprehensive understanding of industrial renewal processes in Finland from the point of view of individual innovations. For this purpose we are constructing a large and unique database consisting of some 2000 innovations commercialised during the 1980s and 1990s. The database will contain basic data on the innovations and commercialising firm. It will also contain data on the origin and diffusion of innovation, R&D collaboration, public support and commercial significance of the innovation. Subsequently, this data will be complemented with more in-depth studies of both quantitative and qualitative nature.

The Sfinno-project finds relevance in the context of the recent renewal of Finnish industry, which foremost is characterised by the relatively rapid growth of high technology-intensive industries with high value added during the 1980s and 1990s. These developments are spearheaded in particular by the telecommunications industry and the rapid growth of Nokia.

Even though the traditional pulp&paper and metal products industries still form the backbone of Finnish industry, the rapid growth of GDP during the latter half of the 1990s is typically related more or less linearly to the emergence of high-tech industries as captured in aggregate trade and production statistics. In the political rhetoric, the persistence of these positive trends has been expressed as a necessary transition towards the information society, and Finland has recently aimed at increasing R&D expenditures to one of the highest levels in the OECD countries (Science and Technology Policy Council 1996).

Nonetheless, there is still a lack of in-depth understanding of the background structures and mechanisms behind these aggregate developments, also taking into account that Nokia accounts for a lion's share of R&D and exports in Finland. This concerns in particular a micro-level understanding of the nature, origin, commercialisation and diffusion of innovations in specific narrowly defined industrial sectors. Structural change in the Finnish economy has hencefar mainly been studied from the perspective of industrial clusters and macro-economic indicators (see e.g. Ruovinen et. al. 1996), whereby single technologies and innovations remain invisible for policy intervention. On the other hand, studies using firm-level data, such as the CIS, suffer from the fact that indirect proxies are used to capture the actual objects of firms' strategy and actions, the innovations as outputs of firm's innovative activity (see e.g. Smith 1997).

This paper is a first report on the Sfinno-project and therefore merely focuses on definitional, theoretical and methodological issues, which have shaped the overall design of the project. The aim of the paper is to review theoretical and methodological approaches that we feel are particularly relevant for our innovation-centred approach to analysing industrial renewal in Finland. We also present our novel methodological approach, the content of our innovation database, and discuss tentatively some possible avenues of more in-depth research focusing on specific aspects of industrial renewal using our data. The database will be finalised during summer 1999 and first results of the project are due in autumn 1999.

2 A theoretical and conceptual framework - the departure from Schumpeter

2.1 Definitions of innovation

A cornerstone for understanding industrial renewal is a definition of innovations. This is especially relevant in our innovation-centred approach where we 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 the policymaker - indeed this variety and complexity is a central proposition of evolutionary theory.

One might speak of Schumpeterian definitions or taxonomies of innovations, since they all remain surprisingly loyal to Schumpeter, despite the fact that Schumpeter defined innovations rather vaguely. The bottom line in any Schumpeterian definition is the distinction between inventions, and their commercialisation as innovations through entrepreneurial activity. Based on this, it is possible to identify (at least) three such taxonomies, with differing relevance for empirical studies.

Product vs. process innovations - the definitional dilemma

The first taxonomy makes a straightforward distinction between product and process innovations from the viewpoint of the demand characteristics or use of innovations (the demand theoretic approach). In Schumpeter's 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"*, while a process innovation is *"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). Nonetheless, on a disaggregated level of individual innovations, a practical application of this basic distinction is not unproblematic and in fact little attention has been paid to the analytical clarity of these definitions.

The primary point of confusion relates to the fact that product and process innovations typically are interrelated (Abernathy & Utterback 1975). 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. Moreover, the intersectoral flows of innovations complicates matters, since a product innovation in one sector (e.g. an industrial robot) might be a process innovation in another sector (e.g. in the automobile industry). (Grupp

1998). What comes out of the discussion is that a differentiation between products 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 single innovations (compare to Archibugi et. al. 1994). Grupp (1998) proposes one way to circumvent some of the definitional dilemmas, which is particularly applicable for our approach. This approach regards all innovations as being product innovations and merely differentiates them according to final demand. Intermediate or investment goods which are used by other firms are regarded as process innovation, while consumer goods used by private households are regarded as product innovations (in this case households, as non-productive units, are assumed to never be process innovative).

Incremental vs. radical innovations

Another empirical problem is to assess the degree of novelty of innovations. Here the point of departure has been Schumpeter's distinction between incremental and radical innovations (see e.g. Mensch 1975, Abernathy & Clark 1985, Utterback 1994). The standard taxonomy which has been applied in this context is the one proposed by Freeman & Perez (1988), which defines innovations according to their socio-economic effects and patterns of diffusion. They distinguish between incremental innovations, radical innovations, changes in technology systems, and changes in techno-economic paradigm. Of these four definitions, incremental and radical innovation in particular have been readily applied in empirical studies and surveys in particular, while the two latter clearly refer to structural change and diffusion of innovations at the intersectoral level.

Freeman & Perez (1988, 45-46) define incremental innovations as occurring *"more or less continuously in any industry or service activity although at different rates in different industries and different countries, depending upon a combination of demand pressures, socio-*

cultural factors, technological opportunities and trajectories". They are often the result of unintended learning processes through learning by using and learning by doing. Radical innovations, on the other hand, are *"discontinuous events"* and usually *"the result of a deliberate research and development activity in enterprise and/or in university and government laboratories"*. They might *"often involve a combined product, process and organisational innovation"*. Despite the clear distinction between the two on a conceptual level, an empirical application in concrete cases is tricky especially in industries where product life cycles are short and major discontinuous innovations are rare (the mobile phones industry might be a good example).

In the literature a particularly important contribution is by Saviotti & Metcalfe (1984). They develop a theoretical approach using matrices describing specific characteristics of innovations that could be applied for measuring the 'distance' between innovations in these characteristics. The similar logic is applied in the Oslo Manual (OECD 1997, 48-49), where radical innovations are defined as innovations which involve *"radically new technologies, can be based on combining existing technologies in new uses, or can be derived from the use of new knowledge"*, while an incremental innovation is a technologically significantly improved innovation through e.g. *"use of higher performance components or materials" or "partial changes to one of the sub-systems"*.

Competence enhancing vs. competence destroying innovations

The third approach takes the point of departure in a partial critique of basic Schumpeterian distinctions between incremental and radical innovations, since these arguably overemphasise the technical novelty and radicalness of innovations and wrongfully ignore the competitive implications of different types of innovation for firms' competencies. Authors within this tradition introduce a multi-faceted view of innovations that is particularly useful for innovation studies, since it essentially 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 architectural complexity, which in turn illustrates nicely the complexity of the underlying knowledge base that firms need to master. They make the important distinction between the product innovation as a set of interrelated core components (modular innovations) and as a system (architectural innovation). Hence, complex innovations might involve both incremental change in the components and radical change in the architecture of the overall system that might destroy some aspects of firm competence and enhance others, or vice versa. The main implication for empirical studies is that it is important to differentiate between the perspective of the firm and the market in assessing the degree of novelty. This basic notion of competence enhancing vs. competence destroying innovations has been incorporated in more general models of industrial evolution that attempt to explain how patterns of innovations change competition and structures within industries (for an overview see Tushman et. al. (1997)). 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 its functional parts.

2.2 Basic issues in industrial renewal

Once we have defined innovations, acknowledged their variety 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 pattern of innovation. In other words, what accounts for differences in the rate and types of innovation, transformation and growth in different industries? Why are some industries more conductive for innovation and why do industries differ in their patterns of innovation?

Here reference is often made to Schumpeter's (1912, 1942) so-called Mark I model, where inventive activity is partly considered exogenous through the central role that entrepreneurs (small firms) play in the application of inventions and the commercialisation of innovations, and the Mark II model, where R&D is institutionalised within professionalised and persistently more innovative large firms

Science and technology-push vs. demand pull

The Schumpeterian Mark I model has been interpreted to support a linear model of innovation, which predicts that inventions primarily emerge from scientific research, and are transferred into innovations through entrepreneurial activity and subsequently diffuse in the economy. Later, in the 1960s and 1970s, the role of market demand and users was emphasised as the main source, likewise in a linear fashion (Schmookler 1966). In the 1980s and 1990s in particular, these linear models of innovation have been replaced by various feedback models and network approaches, which stress the importance of functional interrelationships and complementary assets between firms, as well as other actors and institutions during the innovation process (Rothwell 1994, Lemola 1994). Particularly important contributions in this context are Mowery & Rosenberg (1979), Kline & Rosenberg (1986), von Hippel (1988) and Lundvall (1992), who stress from different perspectives the interactive nature of innovation, the role of users and interrelationships between science and technology in systems of innovation.

Even though this debate about the relative role of science and technology-push versus demand-pull factors has reached consensus that innovations originate at the intersection of supply and demand, and subject to the influence of a range of other social and institutional factors, the practice of technology policy continues to be strongly influenced by a linear/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 and distribution of R&D and innovations. Hence, the question of the origin of innovations viewed from this 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 firms or large firms contribute more to innovation output. This question is particularly relevant in innovation-centred approaches, such as ours, since it seemingly requires innovation-count data rather than indirect proxies for innovations alone, such as R&D expenditures and patents. The relationship between firm size and innovation is also especially topical in Finland where relatively large production intensive firms within the pulp&paper and metal products industry have played a dominant role in the 1970s and 1980s. On the other hand, the 1990s has witnessed the emergence of new firms in particular in the field of software, biotechnology and electronics.

The relationship between firm size and innovation is highlighted by the apparent contradiction between Mark I and Mark II. The interpretation of Schumpeter is that he was primarily impressed by the qualitative differences between the innovative activities of small, entrepreneurial firms and the large, modern corporations with formal R&D laboratories. The logical conclusion of this was that innovative activity increases more than proportionately with firm size, whereby concentrated markets characterised by imperfect competition should yield more innovations. Moreover, reference is frequently made to Galbraith (1956) who argued that large firms confer among other things an advantage in innovation, since they are more capable of financing risky R&D projects. Others have provided counter-arguments, suggesting that as firms grow large, efficiency in R&D and learning is undermined by managerial inertia and path dependency phenomena. (see Cohen (1995), Andersson et. al. (1997) and the references therein).

In the theoretical discussion the attention has shifted from a dynamic interpretation of the Schumpeterian hypothesis to mostly static analyses of the structure of industries in particular 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)). Despite significant methodological problems and ambiguities in measuring research intensity and market concentration in particular, the overall conclusion seems to be that R&D does not rise proportionally with firm size, and hence, Mark II is not necessarily a correct model in this respect. Nonetheless, a more interesting and robust finding of these studies is that different and persistent size-distributions of firms across industries might in fact reflect differences in the rate, type and direction of innovation, rather than the other way around.

Sectoral patterns of innovation

Explanations for differences in sectoral patterns of innovation elaborate on the studies discussed above and are foremost captured in the concept of technological regime or technological paradigm, which have been developed among others by Nelson & Winter (1977), Dosi (1982, 1988) and Malerba & Orsenigo (1993, 1997).

The concept of technological paradigms is essentially a redefinition of Nelson & Winter's (1977) technological regime and describes the technological opportunities for further innovations and some basic procedures on how to exploit them in the environment of the firm. Dosi emphasised the sectoral differences in technological opportunities, or easiness of innovation (for example the degree to which sectors directly benefit from scientific progress or technological breakthroughs), the degree to which firms can obtain economic returns to innovation (appropriability), and the patterns of demand firms face, which in turn give rise to different modes and organisation of innovation. Central to this framework are also the concepts of natural or technological trajectories that describe the cumulativeness of technological change and innovation in zones close to the existing competencies of firms (compare to Sahal's (1981) technological guideposts).

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 analysis covering a large number of sectors and innovations. A particularly influential contribution in this respect is Pavitt's (1984) taxonomy of sectoral patterns of innovation, based on SPRU's 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 for distinguishing 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 for innovation describing the entry, exit and survival of firms to specific technological classes. (see e.g. Industrial and Corporate Change, Vol. 6, No.1, 1997 for a range of alternative approaches).

3 Methodological approaches

3.1 The subject versus the object approach

If we disregard the enormous amount of case studies undertaken in particular in the 1980s and 1990s (for an extensive review see Freeman (1994)), it is possible to distinguish between two basic methodological approaches which are relevant for collecting quantitative data on innovations: the subject approach and the object approach. Of these two, the subject approach has been the more influential because of its comprehensive application in the EU member countries e.g. through the Community Innovation Survey. Whereas the subject approach collects data at the firm level and typically approximates innovation using indirect proxies, such as R&D expenditure and patents, we clearly are more geared towards applying the object approach in the Sfinno-project.

The object approach deals directly with the output of innovation and produces a richer analysis of the nature of different types of innovations and the underlying technologies and knowledge base, their origin, development and diffusion. Since individual innovations can be traced from historical sources and linked to specific firms in time, the object approach also enables a richer analysis of the relationships between innovations, the entry, exit and growth of firms and industries over time in a truly Schumpeterian sense. There are two principal methodologies used within this approach: expert opinion and literature-based reviews.

3.2 Expert opinion-methodology

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 original paper is by Townsend et. al. (1981)). 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 consultancies representing different sectors of the economy. Thereafter the innovations were traced to the respective firms and basic data on the firm and the innovation was collected using a short survey. The database was subsequently updated on several occasions during the 1970s and 1980s, resulting in a data base of some 4 400 significant UK innovations. The focus was explicitly on innovations featuring a significant technical advance in some respect, whereby incremental innovations were excluded (Townsend et. al. 1981, Freeman & Soete 1997). The SPRU's database of innovations has proved a very valuable source for a very wide range of 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. Furthermore, special care was taken to also include larger firms. A recurrent theme based on the data, in particular during the 1990s, has been the question of sectoral patterns of innovation, as well as firm size, market structure and innovation (see e.g. Pavitt (1984), Pavitt et al. (1987), Tether (1998a, 1998b), Tether et. al (1996), Geroski & Pompoy (1990), Geroski (1994), Geroski & Walters (1995), Geroski et. al. (1997)).

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, which consisted of 500 major innovations that were introduced into the market between 1953 and 1973 in the US, the United Kingdom, Japan, West Germany, France and Canada. 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'. (Acs & Audretsch 1990). The second one is a database of 100 significant innovations commercialised in Sweden between 1945 and 1980, by researchers at Chalmers University of Technology in collaboration with the Board of Technical Development. This study was designed to produce generalisable results on innovations of particularly important economic impact on the economy. The data was obtained from The Royal Swedish Academy of Engineering Sciences which published annually a list of significant innovative achievement to the president of the Academy based on peer review by experts from different fields (Wallmark & McQueen 1983, 1991).

3.3 Literature-based methodology

The first extensive attempt to collect data on innovations using the literature-based methodology also involved the Gellman Research Association. In this study, the intent was to analyse the role of small firms in innovation. Additional 590 innovations were selected through a systematic review of fourteen industry and trade journals for the period 1970-79, as well as the award-winning innovations described in the Industrial Research and Development magazine. Some years later, a more comprehensive database was established by the Futures Group in the US. The Futures Group collected data on 8074 innovations mentioned in more than one hundred technology, engineering and trade journals published in 1982. The data were then traced to firms and the firms were classified into different size cohorts.

Following these first applications of the literature-based methodology, there has been an increasing interest for this kind of approach in Europe in the 1990s. The original study was conducted in the late 1980s in Holland, and a similar methodology was later used also in Austria, Irland 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. Hencefar, the studies based on a literature-based methodology have primarily focused on a cross-sectional analysis of the relative contribution of small firms vs. large firms and different types of innovations (in terms of their complexity and degree of domesticallity), the sectoral distribution of innovations, as well as intersectoral innovation flows. (see e.g. Acs & Audretsch (1990, 1993), Kleinknecht & Bains (1993), Coombs et. al. (1996), Santarelli & Piergiovanni (1996)).

Despite a number of problems, the literature-based methodology has in a statistical sense also some favourable aspects, which are important from the viewpoint of generalisability. The journals constitute a clearly defined population, and incorporate some kind of assessment of novelty by people knowledgeable in the field. Various types of firms have, in principle, the same probability to have their innovations included. This methodology tends to identify a large number of innovations. Another advantage is that data can be collected from historical sources, as far back in time as the journals are available. Nonetheless, most databases compiled using this methodology, in particular in Europe, tend to consist of a significantly larger share of smaller firms whose products get noticed more frequently by the press.

4 Sfinno - a holistic approach

4.1 The main elements of our approach

Characteristic to the object approach is the fact that as of yet there is no standardised procedure comparable with the Oslo Manual. However, the object approach provides more possibilities for experimentation since a combination of innovation-centred data sources can be used in triangulation in order to secure the inclusion of different types of innovations and firms. This has been the point of departure in the Sfinno-project and we explicitly harness a holistic and novel approach for the identification of innovations and data collection. Figure 1 presents the main elements of our approach.

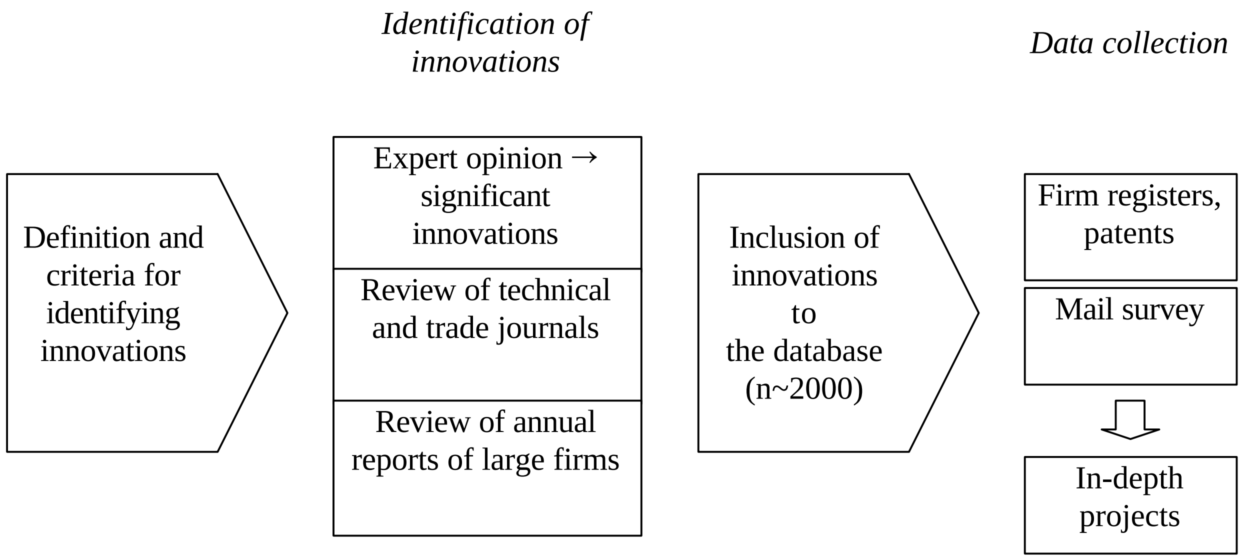

Figure 1. The Sfinno approach.

4.2 Basic definitions and criteria for identifying innovations

The object approach is considered more useful for collecting data on product innovations since process innovations developed by firms for their own use are often secretive and are not reported in sufficient detail e.g. in trade and technical journals. This fact has constrained the scope of our project and therefore, we primarily focus on product innovations, defined according to the final-demand approach. Through this exclusion we have also sought to avoid the various definitional problems related to distinguishing between product and process innovations (see chapter 2.1. and below).

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, although this aspect has been more important in cases where an innovation has been included in the database through expert opinion.

We have tried to define innovations as concise objects, which can be named and separated 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 whereby the identification of only one concrete innovation is difficult. 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 and services are sometimes intertwined and the innovation is in fact 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 Manuals from 1997. Hence, we define an innovation as a technologically new or significantly enhanced product, which might involve the use of new materials, intermediate products, functional parts, or which might use radically new technology or possess 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 the knowledge base of the firm. This is compatible with evolutionary theories, which stress the complex set of interactions between innovation and the dynamic competencies of the firm (Henderson & Clark 1990, Teece 1988, Teece et. al. 1994).

For those innovations in our database that we have data from the questionnaire, a practical assessment of the degree of novelty can be considered straightforward since the respondents themselves have distinguished between incrementally improved or completely new innovations (from the firm perspective). Our methodology explicitly aims at the exclusion of product differentiation. The bottom-line acceptance of an innovation into the database can be established as 'incremental technological product innovation new to the firm'. Assessing the degree of novelty is, ofcourse, particularly tricky in the case of new firms, when the viewpoint of the firm is taken, as these per definition always are innovators. We have partly circumvented this problem since the new firms are not included on the basis of their own evaluation but because of some external criteria based on the characteristics of their products that is inherent in both the expert opinion and the literature-based methodology.

Domestic content of innovations

Our focus on Finnish innovations implies that we are interested in innovations of domestic origin, that is, innovations developed in the context of the Finnish economy. We define an innovation as having originated from 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 various borderline cases where technology transfer, licensing and international collaboration is involved, still might present problems in certain cases. Specifically, this definition includes subsidiaries of foreign firms, registered in Finland, even though they might conduct a large share of R&D and product development at their home base abroad. Moreover, the definition excludes innovations, which have been commercialised by foreign subsidiaries to domestic firms, even in such cases where these might have primarily been developed domestically. We have also been flexible and resorted to case-by-case judgement in cases of doubt using additional data sources. One precautions has been to exclude all merchant houses and retailers which assumably mainly sell importables.

Distinction between product innovation and process innovation

The fact that we exclude in-house process innovations during the identification of innovations does not mean that process innovations are ignored altogether from an analytical point of view.

We have harnessed two 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 use. Second, we are, in principle, able to sample innovations depending on final demand or the destination of the innovation.

The fact that we treat all innovations which have been commercialised on the market as product innovations is consistent with our exclusion of in-house process innovations. 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 so-called 'business to business innovations' that are used as process innovations by other firms (investment goods or intermediate goods). This group is especially 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 end-consumer (consumer goods). Examples might include foodstuffs, sports equipment or health-monitoring equipment. 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 accompanied services, which in fact are most crucial from a 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 for innovations depending on the methodology used. The different methodologies might also produce certain biases during data collection which have to be taken into consideration in strict statistical and analysis. These biases might, for example, arise since expert opinion methodology tends to focus on significant innovations whereas the literature-based methodology evidently (at least in the case of Finland) identifies relatively more small firms and innovations of the incremental kind. Moreover, the annual reports of large firms are a more subjective source compared to the first two, since firms themselves decide which innovations are covered in annual reports.

Owing to the discrepancies in our methodologies, we have taken special care to enable a separation of different subsets of innovations depending on the source. Since the sources sometimes overlap, some of the innovations enter the database through more than one of the methodologies. The results of different methodologies are saved by updating the source of identification and allowing for more than one source only. Thus, the Sfinno enables studies based on expert opinion or the literature-based data 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 cumulating of innovations started at the VTT Group for Technology Studies already in 1992. In the beginning, a group of more than ten senior researchers of VTT were asked to list the most significant Finnish innovations of their fields commercialised since the beginning of 1980s. This list was supplemented by some experts of the Helsinki University of Technology and 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 the suitable contact person. The main criteria of the innovation was that it had been commercialised on the market. The criteria and definitions were stricter compared to 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 the 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 amount of innovations grew to around 400. This list was supplemented by other data of the Group, and the final list incorporated 450 innovations.

Review of technical and trade journals

The majority of innovations in the database have been identified using the literature-based methodology. From a population of some 60 eligible trade and technical journals we carefully selected 18 to cover the most important industries. These have been systematically reviewed for the period 1985-98.

The journals were reviewed by students. We provided them with our basic definitions and criteria for identifying innovations and discussed problems encountered and borderline cases during frequent meetings and email conversations. A particularly important aspect was that the whole content of the journals was reviewed systematically for the entire period, and we explicitly instructed the students to avoid simple 'new products' listings which have been the prime focus of previous literature-based studies that we have encountered. This was because we wanted to avoid new design, product differentiation and imitations, which frequently seem to figure in the previous studies. On the contrary, we told the students to concentrate on longer stories describing the innovations, which also contained some remarks on the novelty of the innovations. We thus applied a rather time-consuming approach which apparently produced relatively less innovations compared to previous studies undertaken in similarly small countries (see e.g. Cogan (1993) on Irland and Fleissner et. al. (1993) on Austria), but applied stricter criteria on the novelty of the innovations. 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 available, register potential contact persons in the firm for the purpose of the mail survey. They were also asked to carefully consider the domestic content of the innovations and exclude all such cases, which clearly had not, to a major extent, been developed by a domestic firm. This was later double-checked from the firm registers. In contrast e.g. with the studies by Kleinknecht et. al. (1993), Cogan (1993) and Coombs et. al. (1996) 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* taxonomies of innovations.

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 industries, metal products and engineering, which have been the two cornerstones of post-war industrialisation. As was noted in the introduction, the recent growth of the electronics industry and the telecommunications industry in particular has also largely relied on one firm, Nokia.

Although innovations of large firms, concerns and their subsidiaries entered the database through expert opinion and the literature-based review, we decided to approach them on a case-by-case basis in order to assure their inclusion and enable thorough and separate analysis of the role of large firms to industrial renewal. The selection of the firms was done on the basis of their R&D intensity and patenting. We therefore assume that large R&D spenders, with a large number of patents granted in both Finland and the US, also could be considered innovative and hence warranted special coverage during the identification of innovation.

Again, the selection was limited to the firms and concerns, with headquarters in Finland that could thus be classified as domestic. Thereafter, two students helped us to review systematically the annual reports of these firms during the period 1985-97 with the instructions to produce lists of product launches of the firms belonging to the concern, a short description for each product, the year of commercialisation and the name of the unit or firm which was 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 with a letter asking the R&D managers or other key personnel to check the list of product launches and delimit from the list the most significant innovations from the perspective of the firm, which matched the criteria that we apply for assessing the degree of novelty, the domestic content of the innovations and the distinction between product and process innovations.

The identification of innovations caused some practical problems. A particularly difficult task was to separate product differentiation tailored for specific markets from new product launches. We also faced the problem of differentiating between generations of incrementally developed products. Sometimes the firms commented on these problems and helped us out. Another demanding task was to account for organisational changes within the firm, as well as acquisitions and fusion's which have been particularly frequent in the early 1990s in Finland. Hence, for the survey, each innovation had to be traced to the firm presently commercialising the innovation.

4.4 Data collection and the content of the database

Data on innovations 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 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 for data collection using a questionnaire. Hence, apart from identifying innovations and including them to the database, we have also relied on firm registers and patent databases in order to assure that we at least have certain basic data on all innovations - this is the core of the database.

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, makes it possible to classify innovations to specific disaggregated industrial fields and technological classes. This makes it possible to distinguish the industrial field to which the commercialising firm belongs from the industrial field to which the respective innovation belongs. The technological class of innovations will be based on the International Patent Classification (IPC) codes. They reveal the underlying technology that is embodied in the innovations, which are patented or patentable. This classification thus goes some way towards delimiting the technological competence that the firms have mastered for the development of the innovation.

In addition to classifying innovations to disaggregate industrial fields and technology classes, we use 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 the register, the principle industrial field of activity, 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 name of the original firm as well as the firm, which presently is commercialising the innovation. Hence, it is possible to link time series of these data to specific firms, which have been involved in the development and commercialisation of specific innovation. This is particularly relevant since it enables tracing the demography of innovating firms over time from the perspective of commercialisation of individual innovations, in terms of entry and exit, firm size and growth. Table 1 summarises the basic data that we will have for all 2000 innovations in our database.

Table 1. Basic data on the innovations.

1. Data on the innovation	- Name in Finnish - A short description - Year of commercialisation - TOL 95 disaggregate industrial class[2] - IPC class, name of inventors, short description of patent (?)
2. Data on the firm	- LY identification number - Name and address - TOL 95 disaggregate industrial class - Number of employee's - Turnover

The questionnaire: additional data on the innovations

Our idea has been to include questions in the questionnaire that make it possible to sample between different types of innovations and firms, industrial fields and technology classes. Furthermore, we have included questions on the degree of novelty and the commercial significance of innovations, based on 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. Hence, based on this data we can make some first rough analyses of industrial renewal processes in Finland from the perspective of innovations. Subsequently, this data will also enable a range of more detailed in-depth analyses where some novel approximation and operationalisations e.g. of different

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

types of innovations, science and technology-push versus demand-pull factors, technological paradigm and regimes might be possible (compare to the discussion in chapter 2). 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 2 we present the main sections of the questionnaire.

Table 2. Main sections of the Sfinno-questionnaire.

1. Background data on the innovation	- The Finnish and English name of the innovation - A short 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	

Owing to the various problems related to the extensive time period covered, organisational change within large firms and concerns etc., there was a significant amount of preparatory work involved before the questionnaires could be sent. 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 the journal as the primary source, the www or telephone directories which 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. We were also able to crosscheck our information using the separate large firm reviews. 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. After two reminders, the response rate is slightly above 60%. Overall, we have received surprisingly few incomplete answers, which might indicate that the questions have appeared relevant and interesting (an English version of the questionnaire is available on request).

5 Summing up

Apart from providing a new approach for understanding the microeconomic 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 methodology. 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 survey. This approach is probably particularly conductive in 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 firm competence over time. 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 entry, exit, and growth), whereby the essence of industrial renewal can be studied in a truly Schumpetrian framework.

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