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*Karolin Sjöö, Josef Taalbi, Astrid Kander, Jonas Ljungberg*

# SWINNO: A Database of Swedish Innovations, 1970-2007

## 1. Introduction

The aim of this paper is to present and discuss a new database of Swedish innovations, called SWINNO. This database has been produced in a VINNOVA- funded project, primarily by Karolin Sjöö and Josef Taalbi, with Astrid Kander and Jonas Ljungberg as advisors and project leaders. SWINNO presently covers the years 1970-2007, but the plan is to continuously update the database, as well as extend it further back in time. Sjöö and Taalbi have written their PhD theses on the basis of SWINNO. These are published and defended during 2014.

We have decided to make the SWINNO database publicly available to the benefit of other researchers and policymakers.[1] The database can be accessed at: http://www.ekh.lu.se/en/research/swinno. The reference source for SWINNO is the present working paper.

The organization of the working paper is as follows. Section 2 gives a snapshot of SWINNO and its Finnish predecessor. Section 3 discusses different innovation indicators with an emphasis on the measurement of innovation output. Section 4 provides a detailed account of the database construction. Section 5 presents a brief description of some results. Section 6 discusses the validity of the dataset: what kind of innovations are captured. Section 7 concludes the paper with a brief summary and points at future research possibilities.

## 2. SWINNO and SFINNO

SWINNO contains extensive information about single product innovations commercialized by Swedish manufacturing firms between 1970 and 2007. SWINNO is an unprecedented source of information about Swedish innovation in combining depth and width; the database contains detailed information about 4145 innovations, to which come more than 500 inventions or

[1] However, the public SWINNO database contains primary data collected by Sjöö and Taalbi. The data on firms (see p. 29 and Appendix 1B), provided by SCB to the SWINNO project, we are not allowed to publish.

projects that had, so far (by end of 2007), not been commercialized.. The new data gives hitherto unparalleled opportunities to picture technological and industrial developments in the Swedish manufacturing sector over an eventful thirty-eight year period. The richness in detail combined with the large number of observations makes the new data suitable to both quantitative and qualitative analyses. SWINNO is modeled after the Finnish SFINNO database (Palmberg 2003; Saarinen 2005). SFINNO contains some 3400 innovations commercialized by Finnish firms between 1985 and 2009. In addition to SFINNO there is another Finnish database: H-Inno which contains 1593 observations of innovations commercialized between 1945 and 1984. H-Inno was constructed as part of a PhD project at this department by Jani Saarinen (2005). H-Inno can be accessed at http://www.ekh.lu.se/en/research/swinno, with the reference source: Jani Saarinen, *Innovations and Industrial Performance in Finland, 1945-1998* (Lund Studies in Economic History no. 34, 2005). As both the Finnish and Swedish databases were collected using the same object-based innovation output approach (Kleinknecht and Bain 1993) there is great scope for comparative studies of innovation in the two countries. Such studies could shed light on similarities and differences between two countries that typically achieve among the highest rankings on the EU's Innovation Scoreboard (European Commission 2005, 2008, 2013).

## 3. Innovation indicators and measurements

Back in 1962 Kuznets noted that innovation is an elusive phenomenon that we had better understand if answers were sought to questions about the economic role of technological change (Kuznets 1962). According to Patel and Pavitt (1997 p. 143) "[t]echnological artifacts, and the organizational [sic] and economic worlds in which they are embedded, are *complex* and *everchanging*: they each comprise so many variables and interactions that it is impossible to fully model, predict and control their behavior through explicit and codified theories and guidelines". The inherent difficulties in metering innovation together with the step-motherly treatment thereof in neoclassical economics have spurred a sizeable group of scholars to try breaking up the "black box" of innovation (Rosenberg 1982; Archibugi 1988). The ardent wish to understand innovation has made researchers approach various dimensions of the phenomenon. Today a set of science, technology, and innovation indicators are available to innovation scholars. Kleinknecht and colleagues (2002) conclude that depending on what indicator that is chosen, researchers may arrive at very different conclusions. The indicators reviewed here can be characterized according to whether they are input, output, or intermediary output indicators and whether they are object- or subject based. Input indicators measure what goes into the innovation process, for instance research time. Output indicators measure actual innovations, what comes out of the innovation process. Intermediary output indicators are something in situated closer to 'invention' rather than to innovation. Object and subject based indicators both measure actual innovations, but the object based variety focus upon technical innovation per se, while the subject based type places emphasis on the innovating firm.

### *3.1 The innovation process: what goes in and what comes out*

Research and development (R&D) is probably the most often used innovation indicator. The notion incorporates both the production- and application of new knowledge (OECD 2002). It is commonly measured as expenditures or the share of personnel or hours worked that are devoted to R&D activities (Smith 2005). Its popularity can be explained by availability, long time series (going back to the early 1960s when OECD started to systematically collect data, see the present Frascati Manual for a brief history (OECD 2002)[2]), opportunities for various comparisons, and its increasing sophistication (Van der Panne 2007).[3] Recognizing that not all expenditures related to innovation are classified as traditional R&D (and therefore go unnoticed) Brouwer and Kleinknecht (1997) sought to estimate total innovation expenditures. As measurements of innovation, R&D or total innovation expenditures are both classified as input indicators and are only proxies of actual innovation.

Patents are another widely used indicator, which is classified as intermediary output indicator (Griliches 1990; Archibugi 1992; Nagaoka et al. 2010).[4] The patent system aims to protect the property rights of firms and individuals to new technologies which they have been responsible for developing. The 'public good' nature of knowledge often makes technologies easy to imitate. Patents give a temporary legal proprietorship (monopoly) to a new technology. In doing so the patent system counters the tendency of underinvestment in new knowledge.

The benefits of patent data include easy access and a vast number of observations. Patent data and patent citations enable rich information on the cumulative flow of knowledge in the economy, and the characteristics of technologies. Furthermore, the fact that applicants

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[2] Also UNESCO was engaged in the collection of R&D data, see Godin (2001) and Sirilli (1980)

[3] It is nowadays possible to distinguish product from process R&D as well as to split data into basic research, applied research and development work (Kleinknecht et al. 2002).

[4] See Schmookler (1950; 1953) for early accounts discussing the use of patent statistics.

consider it a worthy pursuit to invest the funds and time to apply for a patent, await the decision of a patent office, and meanwhile risk the latter's disapproval indicates some perceived economic and/or technological significance (Kuznets 1962 p. 36).[5] While a patent is an output of a development process it first and foremost measures *invention* rather than a Schumpeterian *innovation* (Basberg 1987; Griliches 1990). Not all patented inventions will be commercialized and all innovations of the population will not be patented (Archibugi and Pianta 1996; Arundel and Kabla 1998; Brouwer and Kleinknecht 1999; Arora et al. 2001; Kleinknecht et al. 2002).[6]

Depending on the research question the above-mentioned innovation indicators may be sufficient and preferred; R&D feeds innovation and patents result from R&D processes. Still, a linear relationship, in which actual innovation can be traced by reference to R&D and patents, is difficult to isolate in practice. The same remark has been made regarding other innovation proxies such as licenses, scientific publications, trademarks, and utility models (Mendonça et al. 2004; Beneito 2006; Nelson 2009).[7] As measurements of actual innovation, none of them are is acceptable.

Imperfections aside, R&D and patents are the most often used innovation indicators today. However, their prominence has been contested for several decades. Especially, the 1960s and 1970s saw an intense debate and various measurement approaches. The discussion revolved around the benefits of input and various output approaches and engaged the OECD as well as national authorities (Godin 2002).[8] Suggested output approaches focused on the outcome of innovation processes through the identification plus counting of, and following up on commercialized technological innovations.

The British Association for the Advancement of Science was among the first to engage in the systematic collection of innovation output data in the late 1950s (see Carter and Williams 1957, 1958 for reports). The U.S. National Science Foundation and various academic institutions followed suit in the 1960s (see Myers and Marquis 1969 for a report on the NSF project; see Godin 2002 for an overview of early studies). Output studies have used various

[5] The varying value of patents have been put forth as a point of critique against the use of patents as an indicator of novelty and inventiveness (Beneito 2006; Kleinknecht et al. 2002). Different methods have been used to address the varying value of patents, for example composite index of patent value (Lanjouw and Schankerman 2004) or quality indices based on citations (Ejermo 2009; Ejermo and Kander 2011). See Narin and Olivastra (1988) for an approach similar to that of Ejermo and colleagues.

[6] That said, there are undoubtedly patents that are important to the accumulation and development of knowledge and thus contribute to the development of subsequent innovations. See Macleod (1988) and Sullivan (1990) for accounts of the role of patent systems to the accumulation of knowledge and the development of technology during the industrial revolution.

[7] Increases in factor productivity has also been used as an innovation indicator (Hall 2011).

[8] See OECD (1968) for an early OECD publication relying on innovation output data.

methods of measurement; interviews (Myers and Marquis 1969), surveys, interviews, the opinions of experts (Gellman Research Associates 1976; Townsend et al. 1981), or the screening of trade journals (Gellman Research Associates 1982), sometimes all approaches have been applied simultaneously in the same study (Edwards and Gordon 1984).

### *3.1.1 Output indicators: subjects or objects*

Innovation output indicators can, be classified as either subject or object based (Archibugi 1988; Arundel and Smith 2013). Subject-based indicators approach innovation output from the point of view of the innovating agent, a firm, an organization, or a single entrepreneur responds to questions in relation to the innovation(s) for which they are responsible. Object-based indicators examine various characteristics of innovation objects themselves without referral to the innovating agent. In the history of object-based indicators, primarily two types of sources have been used; interviews with industry experts and periodicals.

Both subject and object based indicators have advantages and disadvantages. Subject-based indicators may pick up a lot of innovations and answer questions related to innovation activities in firms regardless of whether a successful outcome has been achieved or not. Object-based indicators normally capture innovations of a certain importance and do not over exaggerate innovation in the way subject-based indicators can do. Object-based methods of capturing innovation output (e.g. expert-opinion and literature searches) are argued to have been overshadowed by subject-based methods. The two following sections discuss the relative merits of the two approaches relating to output measurement.

### *3.1.2 Voices of innovating subjects*

Through innovation surveys firms are asked, for example, to estimate their innovation output and the sales share of this output (Kleinknecht et al. 2002). The first surveys were conducted in the 1950s and 1960s but it was not until the 1970s that surveys gained momentum as the preferred method of output measurement in OECD, the U.S. National Science Foundation and other influential organizations (Godin 2002; Mairesse and Mohnen 2010). Since then, surveys have become the dominant source of information about innovations (Smith 2005; Sauermann and Roach 2013). The EUROSTAT-managed Community Innovation Survey (CIS) has in particular, since it was first launched in 1993, provided ample opportunities to analyze topics related to various phases of the innovation process.[9]

[9] See the Oslo Manual for definitional and methodological issues related to CIS (OECD2005). See Smith (2005) for a list of journal publications using CIS data.

Surveys sent to innovating firms contain unlimited options regarding the subject to be addressed and assuming that the questions therein are fine-tuned and firm confidentiality is guaranteed, there exists strong potential to obtain useful answers. Surveys make detailed micro-level data available to researchers and enable thorough analysis of innovation processes and performance through benchmarking and monitoring.

While firsthand information regarding innovation processes and outcomes is attractive, it is not devoid of problems. The results may suffer from cognitive bias. Such bias would concern a situation where individuals, often managers with high-level responsibilities, are asked to make performance assessments. Survey answers are thus perceptual rather than objective measures. There is an extensive volume of literature on the problems related to self-reporting (see e.g. Donaldson and Grant-Vallone 2002; Stone et al. 2000; or Podsakoff and Organ 1986).[10] One major issue, widely observed in the literature, is that respondents tend to answer in such a way that is socially desirable or in a manner that makes them appear in a favorable light ( Zerbe and Paulhus 1987; Moorman and Podsakoff 1992). Asking an R&D manager to assess the output of R&D efforts is by nature an alternative method of asking this person to evaluate his or her own work. Finding themselves in an exposed position, managers may be prone to exaggerate performance, and the innovativeness of firms may thus be overestimated. An enclosed definition of innovation (or other items for that matter) is commonplace but the likelihood of over-reporting may be augmented by the fact that respondents are left with the task of assessing whether their own new products comply with the definition or not (Landy and Farr 1980; Mairessen and Mohnen 2010). An illustration of the difficulties in retrieving valid items is provided by a real situation in which *two* completed survey forms were sent back from *one* firm (Kleinknecht 1993). Two separate respondents had filled out the same form unknowingly, which nullified the validity of the survey. The number of innovations reported (by representatives of the same firm) in the forms differed to such an extent that the researchers found no other solution but to drop that particular question in subsequent surveys.

Hence, a problematic issue is that survey answers are highly sensitive to the questions asked and how they are expressed (Spector 1994; Schwarz 1999). Poor construct validity will have significant influence on what conclusions that can be inferred. Thus, when the share of innovation studies based on for example CIS increases a problem of common method variance bias may impair our knowledge about innovation (Podsakoff et al. 2003; Spector 2006). An increasing use of surveys in innovation research must thus be accompanied with

[10] See Spector (1987, 2006) for a critical discussion of any method variance bias in self-report survey answers. For a reply to Spector´s 1987 work see Williams et al. (1989).

continuous discussions about the validity of constructs. Other issues that influence the quality of survey data include varying response rate and response biases (Sauermann and Roach 2013).

### *3.1.3 Messages from innovation objects*

Object-based innovation output approaches were developed to shed light on the relationship between new technologies, industry dynamics, and economic development by counting individual innovations (Archibugi and Pianta 1996). The first-hand focus on the output objects of innovation processes has been argued to enable a measure of *innovation proper* (Godin 2002). The data retrieved may be complemented with information about the firms to which the identified innovation is assigned.

As already noted, different sources have been used to identify innovation objects. The developed approaches can be divided into two classes; those based on the opinions of industry experts and those based on the surveying of trade journals, the latter approach has been referred to as a literature-based innovation output method (henceforth LBIO) (Kleinknecht and Bain 1993). The expert-opinion method is self-explanatory. Industry experts are asked to list important innovations in their field and name the developing firms (Townsend et al. 1981). The bulk of LBIO studies draw primarily on industry periodicals but researchers have also relied on other historical sources. Both the expert-opinion and the LBIO method are dependent on the assessments of one or more individuals (experts, editors, or authors); an innovation that goes unnoticed by these individuals will not end up in the database. Object-based methods are thus, like subject-based methods, relying on perceptual judgments. Still, object-based methods escape the risk of over-reporting since experts of periodical editors are independent (i.e. they are not tied to any particular firm). The filtering of information through the perception and assessments of individuals result in a "significance" bias in the data (i.e. only innovations with a certain level of significance are reported) (Edwards and Gordon 1984 p. 14-15; Makkonen and Van der Have 2013; a thorough discussion of methodological considerations below in section 6).

Besides escaping of the drawbacks of self-reporting, object-based approaches have a number of advantages. In relying on literature sources such approaches may reveal a plethora of information concerning the innovation in question; novelty, complexity, origin, knowledge-base, development, user industries, collaborations etc., all of which are variables that can be extracted from articles in trade journals.[11] LBIO approaches enable the retrospect construction of longitudinal innovation databases with maintained quality if it is based on literature that has been published in real-time (Coombs et al. 1996). Constructing a longitudinal database on the basis of surveys retrospectively, demands sufficiently competent individual and organizational memory. In certain firms, there may be no single individual still employed to whom questions could be addressed relating to innovations and innovation processes that took place some decades ago. Some firms may not even exist anymore. In capturing all innovations that were at one point in time deemed significant enough to report, the LBIO method will also include innovations from firms that have not survived or those which have continued business under another trading name. The method thus presents an opportunity to assemble a dataset that has not been corroded by time or the exaggeration of reporting subjects.

Object, or count, approaches go back a long time. In 1972 Langrish et al. produced an exhaustive coverage of 84 innovations that had been given the Queens Award for technological innovation in 1966 and 1967. Detailed case studies of each individual innovation were undertaken. Gellman Research Associates (1976) presented one of the first longitudinal innovation output databases. 500 innovations that had been commercialized in several countries between 1953 and 1973 were identified. The innovations counted were "the most significant new industrial products and processes, in terms of their technological importance and economic and social impact" (National Science Board 1975 p. 100). The innovations in this National Science Foundation funded (U.S.) project were identified by an international panel of experts. The Gellman Research Associates put together another output-based data set some years later (1982), this time based on the screening of fourteen U.S. trade journals published between 1970 and 1979.[12] In total, they identified 590 innovations.[13] The Science and Policy Research Unit at the University of Sussex undertook the hitherto most ambitious effort when researchers during a fifteen-year-long period built an expert-opinion-based dataset with information pertaining to 4378 innovations commercialized between 1945 and 1983 (Townsend et al. 1981; Pavitt et al. 1987). The Futures Group, commissioned by the U.S. Small Business Administration put together a dataset with 8074 innovations (of which 4476 originating from manufacturing firms) commercialized in 1982 (Edwards and

[11] Some LBIO studies (e.g. Edwards and Gordon 1984; Acs and Audretsch 1990) rely on data collected from new product announcement sections. The possibility to distill information from such limited news items is clearly restricted compared to authored articles.
[12] Requested by the U.S. Small Business Administration.
[13] In addition to these 590, 45 innovations from the earlier study were included (Acs and Audretsch (1990 p. 23).

Gordon 1984; Acs and Audretsch 1990).[14] The Futures Group screened over one hundred trade journals in search for innovations.

A number of object-based studies using primarily the LBIO-method were conducted during the 1990s. A volume edited by Kleinknecht and Bain (1993) collect studies on Austria (Fleissner et al. 1993), Ireland (Cogan 1993), the Netherlands (Kleinknecht et al. 1993), and the U.S. (Acs and Audretsch 1993). Later, studies on the UK (Coombs et al. 1996), Italy (Santarelli and Piergiovanni 1996), Spain (Flor and Oltra 2004), and Finland (Palmberg 2003; Saarinen 2005) have been published. A recent study on Schumpeterian swarms of breakthrough inventions sourced data from the journal "Research & Development", which since 1963 reward hundred innovations that stand out in terms of technological significance (Fontana et al. 2012).

There are also LBIO studies on single industries and sectors: shipbuilding (Greve 2003), logistics (Grawe 2009), and public service organizations (Walker et al. 2002). Makkonen and van der Have (2013) and Acs with colleagues (2002) discuss and use innovation counts to benchmark regional innovation performance. The only other LBIO database that contains long term coverage and which is continuously updated is, to the knowledge of the authors, the Finnish SFINNO (Suomi Finland Innovations) database. This database contains innovations commercialized from 1945 and onwards.

### *3.1.4 Object-based studies of Swedish innovations*

To date, there is only one major object-based dataset with observations of Swedish innovations. In the early 1980s Torkel Wallmark and Douglas McQueen at Chalmers University of Technology put together a dataset of the 100 most important Swedish innovations between 1945 and 1980 by screening annual reports of the Royal Swedish Academy of Engineering Sciences (IVA). The innovations identified by Wallmark and McQueen are, in the words of the authors: "the cream of the crop". The authors applied an ex post requirement of economic importance, they filtered innovations that by the year 1980 accounted for a minimum of $3.5 million of the innovating firm's turnover.[15] In 1979 the 100 innovations accounted for about 5 percent of value added in Swedish industry and 2.5 percent of GNP (Granstrand and Alänge 1995). As a result of the criterion set for inclusion, Wallmark and McQueen's rate of innovation decreases towards the end of the period.

[14] The high number of innovation commercialized during one year only is explained by the Futures Group's choice to collect their data from new product announcements. Other studies (SWINNO included) collect data from articles authored by journal editors only.

[15] In 1980 year's prices. Wallmark and McQueen 1988, 1991

With regard to the level of technological significance, Wallmark and McQueen only consider patented innovations. To a large extent, the patent criterion excludes process and system innovations from being observed as such innovations are not patented as regularly as product innovation (Granstrand and Alänge 1995). Furthermore, the Wallmark McQueen data does not consider military innovations. The dataset differs from SWINNO not only in terms of the number of observations, but also in several other aspects, not least the inclusion criterion. While the Wallmark McQueen data only represent innovations that have had a true impact, SWINNO captures every type of innovation output that was at one point in time assessed to have updated or modified the structure of the innovating firm's product portfolio to a significant extent. In addition to the Wallmark McQueen data, there is a Swedish Institute publication authored by Kjell Sedig (under the category of 'popular science') covering 59 major Swedish innovations between 1900 and 2002 (Sedig 2002).

## 4. Building the SWINNO database

The SWINNO database was constructed using the literature-based innovation output (LBIO) approach explained in brief above. This section describes and discusses the method applied and choices that were made in the process of collecting and constructing the data.

### *4.1 Data and capta*

Working with primary sources takes both time and effort. The American economic historian Deirdre McCloskey has made the remark that the output of such work should be labeled *capta* (Latin for *things taken* or *seized*) rather than *data* (Latin for *things given*) (McCloskey 1986). The SWINNO data was not given, but very much taken. Putting together a LBIO database is an endeavor which is particularly labor intensive. Several years were spent reading trade journals alone. In total, thirty-eight volumes (1970-2007) of fifteen different journals were screened, the number of issues exceeds 8600. The majority of journals were published monthly, with some issued on a bi-weekly and others on a weekly basis. A non-negligible share of these was read on more than one occasion. Eventually, information from over 6000 articles was recorded and categorized but the number of articles read naturally exceeds that number by far.[16]

[16] More than a thousand innovations were mentioned in more than one journal article, thus the number of articles exceeds the number of different innovations.

### *4.2 Selecting journals*

Kleinknecht et al. (2002) emphasize that the adequacy and relevance of the journals are crucial for the quality of a LBIO database. The identification of appropriate sources was thus a major concern. Sweden poses not only a long industrial tradition but also a long tradition of periodical publications picturing the technological development in different industries. There are examples of both specialized and general journals. Specialized journals include *Jern-kontorets annaler: tidskrift för svenska bergshanteringen* (mining, iron, and steel, founded 1817), *Kemiska Notiser* (chemistry, founded 1887), *Svensk trävaru-tidning* (wood and timber, founded 1885) and *Trävaruindustrien* (wood, founded 1915).[17] General technology periodicals include *Verkstäderna* (founded 1905) and *Ny Teknik* (continuation of *Teknisk Tidskrift.* founded 1929).

Trade associations were contacted in order to learn and thereby obtain assistance regarding suitable journals to choose for the construction of the database. Through these contacts a relevant sample of journals could be mapped. One criterion for selection was that the journal was not associated with any particular company or was similarly biased.[18] Some of the journals had ties to trade associations while others were independent from such organizations.[19] Ties to trade associations were not considered inappropriate nor to affect the reliability of a journal. Another selection criterion was an editorial mission to report on the technological development of the industry. This criterion disqualified some journals selected in a first round. Journals on the general technological development in Swedish industries were included to ensure a broad coverage and to capture infant industries and nascent technologies that would otherwise risk go unnoticed (e.g. nano technology). The guiding principle was that overlap would be preferable to the existence of blind spots. The resulting data was checked for duplicates. In cases where an innovation was noted in more than one journal the quality of the data could be improved since information was often complementary.

The majority of the journals had been established long before the investigated period. Three journals started in the period that is being investigated: *Automation* (journal no. 1 in table 1)

[17] The present names of the journals are (in the same order): Jernkontorets Annaler and Bergsmannen, Kemisk Tidskrift (followed by Kemivärlden), Svensk Trävaru- och Pappersmassetidning (followed by Svensk Papperstidning), and Sågverken (followed by NTT).

[18] A borderline case was Livsmedelsteknik/Livsmedel i Fokus which is owned by a foundation in turn owned by some 150 firms within the foodstuff industry. A telephone interview with a longstanding editor eased the major fear of a journal biased by reporting about the indirect owners. Still, the editor admitted that a totally independent journal might have looked different, but the comment was made in regard to critical reporting of the industry not in regard to reports about innovations.

[19] For example, Ny Teknik, which is every week sent to all members of Sveriges Ingenjörer, a union of engineers.

started in 1973, *Telekom Idag* (journal no. 12) in 1994, and *Aktuell Grafisk Information* (journal no. 15) in 1972. As regards *Automation* and *Telekom Idag*, the founding of these magazines reflects the technological and industrial development with increasing importance of ICT.[20] The 1970s saw an increase in both demand for, and supply of, automation technologies. The same remark can be made about telecommunications in the early 1990s. An exception is *Aktuell Grafisk Information*, reporting from an industry of age although started in 1972. Hence, there might be som important graphical innovation in 1970 or 1971 that are missing in SWINNO. .

***Table 1. Journals in SWINNO, their change of names, orientation and main field of technology***

| Journal | Type | Main coverage |
|---|---|---|
| 1. Automation 1973-2007 | General | Automation- and general production process technology, e.g. robots, industrial surveillance systems and computers. |
| 2. Ny Teknik 1970-2007 | General | Electro-technology, chemistry, mining, mechanics, shipbuilding, automobile- and power technology, construction of roads, houses and hydronomy, automation technology. |
| 3. Verkstäderna 1970-2007 | General | Machinery and equipment for the production of various products. Products from engineering industries. |
| 4. Modern Elektronik 1970-1992 » Elektroniktidningen 1992-2007/Elteknik 1970-1992 » Elektroniktidningen 1992-2007 | Specialized | Electronic components and equipment, telecommunication equipment. |
| 5. Kemisk Tidskrift 1970-1992 » Kemivärlden 1992 » Kemisk Tidskrift 1992-1999 » Kemivärlden 1999-2007 | Specialized | Chemical- and pharmaceutical products, machinery and equipment for the production of chemicals and pharmaceuticals. |
| 6. Livsmedelsteknik 1970-2003 » Livsmedel i Fokus 2003-2007 | Specialized | Foodstuff, machinery and equipment for the production of foodstuff, packaging machines- and products |
| 7. Plastforum 1970-1977 » Plastforum Scandinavia 1977-1992 » Plastforum 1992-2000 » Plastforum Nordica 2000-2003 » Plastforum | Specialized | Qualities of plastics and rubber, plastic- and rubber products. Machines for the production of plastics and rubber. |

[20] The technological development in these nascent industries did not go unnoticed prior to the founding of the journals. Automation innovations were reported in both general and specialized journals prior to the founding of Automation. As regards telecommunications such innovations were captured by for example Elektroniktidningen and its predecessors.

| | | | |
|---|---|---|---|
| | 2003-2007 | | |
| 8. | Sågverken, Trävaruindustrien 1970-1974 » Sågverken 1974-1999 » NTT Såg and NTT Trä 1999-2002 » NTT Såg & Trä 2002-2007 | Specialized | Wood and wood products, wood cutting machines and similar. |
| 9. | VVS 1970-1982 » VVS & Energi 1983-1989 » Energi & Miljö 1990-2007 | Specialized | Ventilation systems, equipment for the installation of pipes and ventilation systems in households and industries |
| 10. | Transport teknik 1970-1984 » Skandinavisk Transportteknik 1984-1986 » Transport Teknik Scandinavia 1986-1989 » Teknik i Transport 1989-1992 » Transport Idag 1992-2007 | Specialized | Transport innovations in land, air and shipping transportation, transport and automotive equipment, automotive innovations, packaging innovations |
| 11. | Bergsmannen 1970-1977 » Jernkontorets annaler med Bergsmannen 1978-1981 » JkA: Jernkontorets annaler 1981-1987 » Bergsmannen med Jernkontorets annaler 1987-2007 | Specialized | New metals, equipment and machines for mining, equipment and machines for the production of metals. |
| 12. | Telekom Idag 1994 » 2007 | Specialized | Information- and communication technology, software. |
| 13. | Svensk trävaru- och pappermassetidning 1970-1990 » Svensk Papperstidning 1990-2007 | Specialized | Machines and processes for the production and processing of wood, paper and pulp. |
| 14. | Textil och konfektion 1970-1983 » TEFO-Nytt: Special konfektion 1983-1986 Teko-Aktuellt från TEFO 1987-1993 » Struktur 1994-2007 | Specialized | Textiles, machinery and equipment for the production of textiles and clothes |
| 15. | AGI Aktuell Grafisk Information 1972 » 2007 | Specialized | Printing machines and machinery related to publishing and printing activities |

The selection of journals was made with the aim to cover all major 2-digit manufacturing industries as classified by ISIC (International Standard Industrial Classification) or the

Swedish counterpart SNI (Svensk Näringsgrensindelning).[21] Table 2 shows which industries were covered by the particular journals. Van der Panne (2007) argues that a drawback of the LBIO-method is that small industries may not be sufficiently covered since there is a risk that a dedicated trade journal is lacking. In the case of SWINNO such concerns are raised with regard to 'Other non-metallic minerals' (26) which is a category without a related trade journal. Some innovations from the industry were found in generic journals but the coverage may all the while be disputed.[22] 'Computer related activities' (72) and 'Other business activities' (74) are traditionally not considered part of the manufacturing sector but were included to assure sufficient reporting about innovations related to the ICT revolution.

***Table 2. 2-digit manufacturing industries and their respective journal coverage. For name of journals see table 1***

| ISIC/SNI | Industry | Journal(s) |
|---|---|---|
| **15t16** | Food, beverages, and tobacco | 6 |
| **17t18** | Textiles and apparel | 14 |
| **19** | Leather and footwear | 14 |
| **20** | Wood and wood products | 8 |
| **21** | Pulp and paper | 13 |
| **22** | Printing and publishing | 15, 2 |
| **23** | Coke, refined petroleum products and nuclear fuel | 5 |
| **24** | Chemicals and chemical prod | 5 |
| **25** | Rubber and plastics | 5,7 |
| **26** | Other non-metallic minerals | 11 |
| **27** | Basic metals | 11 |
| **28** | Fabricated metal products | 3 |
| **29** | Machinery and equipment | All journals |
| **30** | Office machinery and equipment | 1,2,3,4,15 |
| **31** | Electrical machinery and apparatus | 1,2,3 |
| **32** | Radio, televisions, and communication equipment | 1,2,3,4, 12 |
| **33** | Medical, precision, and optical instruments | All journals |
| **34** | Motor vehicles, trailers, and semi-trailers | 10,2 |
| **35** | Other transport equipment | 10,2 |
| **36** | Other manufaturing | 2,3,9 |
| **72** | Computer and related activities | All journals |
| **74** | Other business activities | All journals |

### *4.3 Journal contents*

The selected trade journals all generally contain the same structure. An editorial on the general state of the industry, or a specifically relevant issue typically opens the journal. Thereafter longer and shorter notes and articles follow with focus on the development of

[21] SNI2002 is used throughout, unless something else is indicated.
[22] Since the total population of innovations in the industry cannot be known it is difficult to assess just how limited the coverage is.

demand, competition, supply markets, technology, regulations, and other factors affecting firms in the industry. The trade journals typically end with a section concentrating on new product announcements. Received LBIO datasets differ in terms of what type of journal content they draw upon. The Futures Group database 8,074 innovations (Edwards and Gordon 1984; Acs and Audretsch 1990) is based on new product announcements whereas SFINNO and SWINNO rely on articles authored by journal editors and journalists. Hence, new product announcements were bypassed and only authored articles were considered exclusively. This stance was adopted because it is assumed to increase the chance of capturing significant innovations rather than minor improvements and new product vintages with only marginal effect on the competitive landscape.[23] The latter assumption is the very rationale of the methodology: since the editorial mission of trade journals is to report on important developments in their respective industry they should be able to separate those from the unimportant developments. Editors are assumed to be able to make judgments about which innovations are important innovations, either from a technological, firm, or industry perspective, or all three together. When assessing the nature of trade journal contents it is important to keep their readership in mind. Business-to-business firms (which include both firms in the industry plus their customers) and suppliers are likely to value reports about *any change that alters the competitive landscape*. As goes for any firm or industry, a trade journal had better meet demand to stay relevant. This approach does not rule out the possibility that incremental innovations can be significant. Still, the chance of being featured in a journal article is assumed to increase with the level of radicalness and thus most minor improvements and adjustments are believed to be filtered out by the methodology (Van der Panne 2007). Further, omitting new product announcements should decrease the risk that firms with a forceful PR-department will get too big a share of the innovations in the database.

### *4.4 SWINNO innovations*

While the editorial selection processes described above filtered significant innovations the constructors of the SWINNO database were not exempted from the necessity to make a selection themselves. Far from every new product that trade journals reported ended up in the SWINNO database. Several selection principles were applied for the collection of data. The following subsections will discuss the choices made to ensure a purposive sampling of innovation.

[23] In addition, Van der Panne (2007) observed that counting new product announcements grossly overestimated domestic innovations because sales agencies reported diligently about foreign innovations.

#### *4.4.1 Included innovations*

Three selection principles were applied in order to capture significant innovations exclusively. The first principle was to filter out innovations rather than inventions. The principle follows Schumpeter´s (1939 p. 84-85) remark that inventions in themselves do not necessarily imply an economically relevant effect while an innovation is an invention that has been commercialized. In practice for an innovation to be included, it had to be possible to trace its commercializing agent, a firm. The second principle separates product from process innovations. A process innovation is defined as being withheld from the market and applied in-house only. As soon as a process innovation is brought to the market, it is defined as a product or service innovation and included. This principle was given by the low probability that trade journals would cover process innovations in a satisfactory way. Production processes may be a key to a firm's competitive advantage and there may thus be little incentive to submit information about them unless they are going to be sold. Unfortunately, this criterion limits the possibility to pick up innovation in industries where process innovations are more important than product innovations (Pavitt 1984). However, some process innovaions have been included, amounting to a few per cent of the total. SWINNO is thus not exclusively limited to product innovations and besides a few process innovations also a few service innovations are included. A growing body of literature highlights the increasing importance of offering services as complements to products (Davies 2004; Henkel et al. 2004; Howells 2004; Neu and Brown 2005; Fölster and Johansson Grahn 2005; Berggren et al. 2005; Kowalkowski 2006; Penttinen and Palmer 2007; Gebauer et al. 2010). Whenever reported in the trade journals, service innovations were included in the database. Regrettably, their nature of being intangible with low levels of uniformity and high levels of customization as well as their role as complements to products make them all too often bypass the radars of trade journal editors, why only a few are captured in SWINNO.

The third principle relates to the assessment of novelty of innovations. It is commonplace in the innovation literature to rate innovations according to their impact or characteristics. Innovations may be different in both respects with regards to technology (Henderson and Clark 1990), the innovating firm (March 1991; Greve 2007), as well as its influence on the competitive landscape (Bower and Christensen 1995; Tushman and Anderson 1986). The innovations in SWINNO were collected because they signal novelty in some of the above respects. It may be a groundbreaking new technology, an entrant with an overthrowing innovation, an existing firm diversifying by applying technology in a novel way. Regrettably the received typologies to assess novelty are dichotomous, novel or not, while oftentimes in reality scales are grey. SWINNO included innovations for which there was an explicit statement in the journal about novelty. A number of variables were constructed to assure that different dimensions of novelty were being captured. An inclusive definition of the innovations in SWINNO is thus *an entirely new or significantly improved good, process, or service that is, or is going to be transacted on the market*. The same definition is used to operationalize innovation in the Finnish SFINNO database.

***Table 3 Practical inclusion criteria for SWINNO***

| **Criteria** | |
|---|---|
| **Innovation** | • Following the Schumpeterian definition of innovation mere inventions were excluded and only innovations already out on the market or in the process of being commercialized were included. |
| **Innovating firm** | • The origin of the innovation had to be identified. No "orphan" innovations were thus included. Nor were innovations from research institutes without a commercial interface included. In cases where no innovation firm, but only a sales agency or company could be identified the innovation was still included but assigned to the commercial agent.. |
| **Product innovation** | • The scope was limited to product innovations. A product innovation was defined as any good, process, or service that had been or was going to be transacted on a market. |
| **Novelty** | • Explicitly stated dimension of novelty. |

### *4.4.2 The end of the innovation pipeline*

At any point in time a firm may have a varying number of products in the pipeline. At the fuzzy front end embryonic products are dismissed on a (ir)regular basis. Of all ideas generated within a firm a selected few will materialize and make it to the market. In SWINNO all observed innovations have made it through or are near the end of the pipeline. The data provides therefore no indication of innovation *activities*, only of the actual *output* of such activities. It is assumed that firms are less willing to submit information about early-stage projects in order not to risk imitation. The LBIO method is consequently not entirely well-suited to cover innovation activity in a broad sense and some argue that the LBIO method has a success bias (Aldrich and Ruef 2006 p. 32).

The journal articles on which SWINNO is based are there-and-then snapshots of innovations. The raison-d'être of trade journals is to provide the readership with topical news. Any editor in chief would want to be able to predict the impact of an innovation so as to prove the journal’s relevance. In reality some innovations were reported about before they reached the market, other by the time of market introduction, and still others after having been around for quite some time. In the two former cases an innovation is not assessed in terms of its actual impact on the competitive landscape or its economic significance but in terms of its *expected* impact and significance, while in the latter case such assessments could be made *a posteriori*. The picture given by the collected material and the interviews with journal editors was that the majority of innovation reports are made close to the market introduction and more seldom after the passing of a considerable time period.[24] Thus, the majority of innovations in SWINNO have been reported in order to signal an expected impact on competitiveness.[25] As a result, some of the innovations recorded would fail expectations; other would meet them, while a third category would exceed them.

#### *4.4.3 Swedish innovations*

The ambition of constructing SWINNO was to assemble a dataset that could be used for extensive analysis of long-term industrial transformation in Sweden. Firm strategies and the development of industries are influenced by both domestic and foreign factors (see Porter 1990). As a small open economy Sweden is sensitive to foreign influence. Foreign innovation may alter the competitive landscape for Swedish firms. Yet, the scope of SWINNO is limited to the innovation output produced by Swedish firms. The scope is restricted because the editorial mission of the trade journals is more or less confined to the Swedish market. A number of the journals have sections with longer and shorter notes about foreign markets but it has to be assumed that this treatment is not comparable with that of the Swedish market. Hence, foreign innovation is not included in SWINNO.

The quest to identify Swedish innovations required a definition of what is a Swedish innovation. A Swedish innovation is defined as developed by at least one firm with its headquarters or a major development facility in Sweden. Another criterion is that the main part of the development of the innovation had taken place in Sweden. If it could be suspected that the firm given in the article had not developed the innovation, the firm's principal activities were checked in the Swedish firm register and a search was undertaken on the internet. The procedure allowed for an identification of sales agencies that could be

[24] All the while there is a risk that the number of innovations observed enduring the last years of the time period is underestimated since there are cases in which innovations are observed some time after market introduction (Geroski and Walters 1995). Thus, innovations commercialized in say 2006 and 2007 have had less time to have been noted in trade journals.

[25] Several innovations were followed-up in later article and it was possible to assess the result in terms of effects on competition and economic significance.

disqualified as innovators. The innovations in SWINNO are commercialized in Sweden, or in foreign markets, or both.

## 5. Variables and results

The SWINNO database contains a range of variables that enable a comprehensive analysis of innovations, innovation processes and innovating firms. The following subsections will describe the variables in the database and present some central findings.

The structure of the SWINNO database is based on the information about the innovations given in the trade journals. A large amount of textual information has been codified and classified into categorical and ordinal variables. The most fundamental data recorded are: the description of the innovation, the name of the innovation and the name of the innovating firm. An example of the basic information of the database is given in table 4 below.

***Table 4 Example of qualitative description of one innovation in SWINNO.***

| **Name** | **Description (translated from Swedish)** | **Innovating firm** | **Year of commercialization** |
|---|---|---|---|
| **AXE** | Software memory controlled PBX, i.e. its work is governed and controlled by computers. The control system includes a central computer and less 'regional' computers that handle routine functions. The switch module is divided in terms of both hardware and software, which means that one can add features without the other being affected. The PBX also allows a choice between analog switching technology with relays and fully digital switching technology with integrated circuits. | Ellemtel | 1977 |

A list of the main variables included in the SWINNO-database is found in Table 5. In addition, a formal description of all variables contained in the database can be found in Appendix 1.

***Table 5 Overview of variables in SWINNO***

| ***Data*** | ***Variable*** | ***Description*** |
|---|---|---|
| ***Innovation process*** | Type | Commercialized 1970-2007 = 1, To be commercialized = 2, Process innovation = 3, Under development = 4, Commercialized before 1970 = 5 |

| | | |
|---|---|---|
| | Basic idea | Year of basic idea |
| | Development_year | Year that development started |
| | Prototype | Year of first prototype |
| | Commercialization | Year of commercialization |
| | Inventor | Name of inventor(s) |
| | Science_spinoff | Name of university and/or research institute |
| | Collaboration | See separate Table |
| | Origin of innovation | Factors contributing to the development of the innovation.<br>See separate Table |
| | User | Sectors of use of the innovation (SNI 2002) |
| | Tech_know | Technological know-how involved in the development of the innovation |
| | Patented | Has the innovation been patented? (If so, what in what country?) |
| | Patent_firm | Firm holding the patent |
| | Patent_person | Person holding the patent |
| | Export | Countries to which the innovation has been exported |
| | External Finance | Did the innovating firm receive external finance for the development of the innovation? If so, from what actor? |
| ***Innovation characteristics*** | Product Classification (SNI) | 5-digit level SNI 2002 |
| | Description | Qualitative description of the innovation. |
| | Artefactual complexity | High = 1, Medium = 2, Low = 3 |
| | Developmental complexity | High = 1, Medium = 2, Low = 3 |
| | Firm Novelty | Entirely new = 1, Major Improvement = 2, Incremental = 3 |
| | Market Novelty | New to the Swedish market = 1, New to the world market = 2 |
| ***Innovating firm*** | Firm_name | Name of innovating firm |

| | | |
|---|---|---|
| | Firm_start | Firm was started to commercialize the innovation |
| | Employment class | 16 employment classes, by plants |
| | Turnover class | 12 turnover classes, by plants |
| | Start Year | Year of registration of the plant |
| | Geographical location | The municipality of the plant |
| | Other_Dev(1-3) | Name of firm previously responsible for the development of the innovation. Up to three (3) firms possible |

### *5.1. What and when: types of innovation and patterns of innovation activity over time*

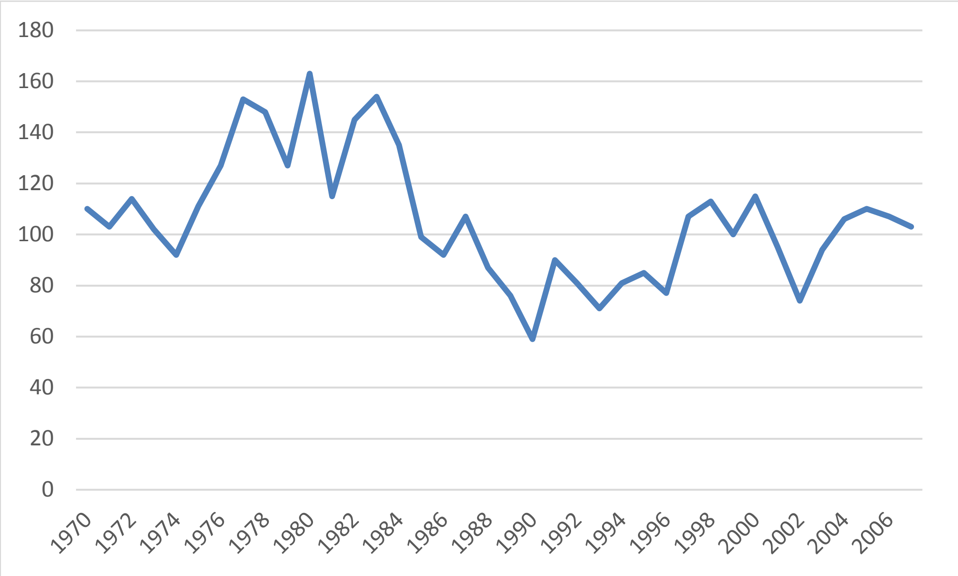
The database contains 4852 observations of innovation activity. The innovations known to have been commercialized during the period make up 4035 of these observations. For another 471 observations, the innovations were predicted to be commercialized at a later stage. 225 other observations were reported to be in a state of early development (constructing prototypes, or, as many pharmaceuticals, being tested with a long period of gestation). In addition to the mentioned varieties table 6 also shows the number of process innovations and innovations reported by the journals in 1970 or later but actually commercialized before 1970. For all of the 4035 commercialized innovations, a commercialization year has been recorded based upon the information given in the articles. For the large majority the year of commercialization was explicitly mentioned. When this was not the case, the publication year of the first article that mentions the innovation as being commercialized has been used as a proxy. Sometimes, information has also been recorded at the time of the basic idea (110 observations), or when development of the innovation started (402 observations) or when the first prototype was completed (264 observations).

**Table 6 Numbers of innovations in SWINNO**

| Type | Count |
|---|---|
| Commercialized | 4035 |
| To be commercialized | 462 |
| Process innovations | 109 |
| Under development | 222 |
| Commercialized before 1970 | 24 |
| Total | 4852 |

The pattern of innovation activity over time is presented in Figure 1. Innovations peak during the structural crisis of the late 1970s and the first half of the 1980s. The lowest count of innovations during the period was 59 in 1990. From the early 1990s there is a recovery but the level of the years around 1980 is not regained in our period.

***Figure 1. Number of innovations in SWINNO commercialized per year, 1970-2007***




### *5.2 Innovations by product groups*

It is widely acknowledged that innovation differs greatly across industries and by product groups (Utterbach 1996; Marsili 2001; Malerba 2002). Much effort in the construction of SWINNO has therefore been put into coding the innovations according to product classifications. All innovations are given a five-digit code according to the Swedish standard industrial nomenclature SNI 2002 (*Svensk Näringslivsindelning* 2002).[26] This standard corresponds to the international standard nomenclatures NACE rev 1.1. and ISIC rev. 3.

The coding of the innovations ia based on the descriptions in the journals. In most cases a classification on the five digit-level is straightforward, but still the procedure involves several decisions to achieve consistency. For example, as a result of technological change and product development the boundaries between some product groups may dissolve over time. The distinction between computers and telephones is a case in point. While the difference between

[26] The Swedish product classification nomenclature SPIN (Svensk Produktindelning för Näringslivet) 2002 is completely based on SNI 2002 for the five digit level.

computers and telephones was clear cut in the beginning of the period, mobile telephones, computers and cameras have since the beginning of the 1990s often been integrated into one product. A portable hand computer in the beginning of the 1990s for instance could refer to a computer (30020), whereas a hand computer towards the end of the period could refer to a telephone with advanced computer functions (32200). An account of important choices made is given in Appendix 2.

The SNI codes of process innovations or new methods commercialized are another issue. The choice of SNI code is determined by the output of the method or process. Accordingly, a process for the production of steel was classified as steel (27100) However, this principle did not concern new technologies or methods *auxiliary* to the production of goods. A new technology or method that only improves or facilitates steel production was counted as consultancy services (74202).

Table 7 presents the main results from the product classification, by counts and the trend over the period (1970-2007). Manufacturing products (SNI 15-36) make up the bulk of the innovations. However, the database also captures a large number of software (Computer and related activities, SNI 72), telecommunication network (Post and telecommunications, SNI 64) and method innovations classified as technical consultancy (Other business activities SNI 74).

The largest product groups on the two digit level is Machinery and equipment (SNI 29) constituting a good fourth of the total, followed by Measuring instruments (SNI 33) and Telecommunication equipment (SNI 32). A glimpse of the changing composition of product groups is given by the trend $\beta$ for the different product groups 1970-2007, corresponding to the average annual change in the count of innovations (absolute numbers), see table 7. $\beta=-0.934$ for machinery and equipment thus means that the number of innovations diminished by close to one innovation, on average, per year. Computer and related activities, with $\beta=0.470$, increased on the other hand, on average, with close to one innovation every second year. The overall innovation pattern displays a negative trend throughout the period (see figure 1). This negative trend characterizes traditional manufacturing industries, such as basic metals, fabricated metals and machinery equipment. Product groups with a positive trend in absolute numbers were chemicals (SNI 24), telecommunication equipment (SNI 32), measuring instruments (SNI 33) and software (SNI 72), but also product groups such as wood products (SNI 20) and paper and pulp (SNI 21).

*Table 7 Number of commercialized innovations per product group, SNI 2002 and $\beta$ coefficient for $\eta_t = \alpha + \beta t$ for the period 1970-2007*

| SNI 2-digit | Count | % | $\beta$ |
|---|---|---|---|
| Agriculture and hunting (01) | 2 | 0.0% | 0.000 |
| Mining of coal and lignite; extraction of peat (10) | 3 | 0.1% | -0.005 |
| Mining of metal ores (13) | 1 | 0.0% | 0.003 |
| Other mining and quarrying (14) | 1 | 0.0% | -0.004 |
| Food products and beverages (15) | 71 | 1.8% | -0.048 |
| Textiles (17) | 22 | 0.5% | -0.003 |
| Wearing apparel; dressing and dyeing of fur (18) | 5 | 0.1% | -0.004 |
| Tanning and dressing of leather (19) | 3 | 0.1% | -0.004 |
| Wood and wood products, except furniture (20) | 65 | 1.6% | 0.043 |
| Pulp, paper and paper products (21) | 58 | 1.4% | 0.041 |
| Publishing, printing and reproduction of recorded media (22) | 3 | 0.1% | 0.000 |
| Coke, refined petroleum products and nuclear fuel (23) | 6 | 0.1% | -0.008 |
| Chemicals and chemical products (24) | 157 | 3.9% | 0.028 |
| Rubber and plastic products (25) | 194 | 4.8% | -0.189 |
| Other non-metallic mineral products (26) | 34 | 0.8% | -0.051 |
| Basic metals (27) | 92 | 2.3% | -0.023 |
| Fabricated metal products, except machinery and equipment (28) | 210 | 5.2% | -0.123 |
| Machinery and eq (29) | 1175 | 29.2% | -0.936 |
| Office machinery and computers (30) | 246 | 6.1% | -0.104 |
| Electrical machinery and apparatus n.e.c. (31) | 180 | 4.5% | -0.062 |
| Radio, television and communication eq (32) | 283 | 7.0% | 0.266 |
| Medical, precision and optical instruments, watches and clocks (33) | 598 | 14.8% | 0.009 |
| Motor vehicles, trailers and semi-trailers (34) | 143 | 3.5% | -0.049 |
| Other transport eq (35) | 90 | 2.2% | -0.047 |
| Furniture, manufacturing n.e.c. (36) | 32 | 0.8% | -0.016 |
| Recycling (37) | 14 | 0.3% | -0.020 |
| Electricity, gas, steam and hot water supply (40) | 1 | 0.0% | 0.000 |
| Construction (45) | 5 | 0.1% | -0.012 |
| Retail trade, except of motor vehicles and motorcycles; repair of personal and household goods (50-52) | 2 | 0.0% | 0.006 |
| Post and telecommunications (64) | 13 | 0.3% | 0.016 |
| Financial intermediation (65) | 1 | 0.0% | 0.002 |
| Real estate activities (70) | 1 | 0.0% | 0.000 |
| Computer and related activities (72) | 221 | 5.5% | 0.456 |
| Research and development (73) | 4 | 0.1% | 0.006 |
| Other business activities (74) | 92 | 2.3% | -0.050 |
| Health and social work (85) | 1 | 0.0% | 0.004 |
| Recreational, cultural and sporting activities (92) | 1 | 0.0% | 0.004 |

### *5.3. The complexity and novelty of innovations*

Two pivotal dimensions along which innovations may be graded are their complexity and their degree of novelty (Kleinknecht et al 1993). Particular classifications have been constructed for these dimensions and the information given in the journal articles have been accordingly interpreted.

The relationship between the complexity of innovation and the competence, capability and size of firms has spurred interest in the increasingly complex character of innovation (for instance Tushman & Rosenkopf 1992; Soh & Roberts 2003). The complexity of innovations can be understood as two aspects: the artefactual complexity and the complexity of the developmental process. The 'artefactual' complexity is a measure of how composite a product is. This variable differentiates between innovations consisting of only one coherent unit and those that are made up by large systems (cf. Simon 1962). However, some innovations, for example pharmaceuticals, have low artefactual complexity but require a highly complex development process. The variable 'developmental complexity' concerns the knowledge involved in the development of the innovation. The pharmaceutical biotechnology field is a case that can be characterized as the marrying together of several separate fields of scientific knowledge (Pisano 2002). For both artefactual and developmental complexity, innovations were given a value between 1 and 3 where 1 implies high complexity, 2 medium complexity, and 3 low complexity.[27] The definitions are given in table 8.

***Table 8. Definition of complexity in SWINNO***

| | ***Artefactual complexity*** | ***Developmental complexity*** |
|---|---|---|
| ***High*** | Innovation is a system consisting of several parts | More than two disciplines are involved in the development of the innovation. |
| ***Medium*** | Innovation is a unit | Two discipline are involved in the development of the innovation. |
| ***Low*** | Innovation is a single coherent unit | One discipline is involved in the development of the innovation. |

The results from the classification of complexity are summarized in table 9 and 10. The results show that most innovations have had medium complexity both as regards artefactual

[27] Exceptions were process innovations and software innovations that have not been given an artefactual complexity.

and developmental complexity. The association between developmental complexity and artefactual complexity is pictured in table 10. Innovations with low developmental complexity have also tended to have low artefactual complexity, and, conversely, innovations with high developmental complexity have tended to be artefactually complex. However, the converse does not necessarily hold. Artefactually complex innovations were more for instance often of medium developmental complexity than high developmental complexity.

***Table 9. Number of innovations by artefactual and developmental complexity***

| | | Developmental complexity | | | | |
|---|---|---|---|---|---|---|
| | | High | Medium | Low | Missing | TOTAL |
| **Artefactual complexity** | High | 241 | 381 | 12 | 9 | 643 |
| | Medium | 240 | 1739 | 264 | 4 | 2247 |
| | Low | 99 | 489 | 402 | 8 | 998 |
| | Missing | 29 | 105 | 2 | 11 | 147 |
| | TOTAL | 609 | 2714 | 679 | 32 | 4035 |

Note: Missing are those innovations which have not been possible to classify, due to insufficient information or difficulty to classify complexity for the product group, as for software.

***Table 10. Percentage of innovations by artefactual and developmental complexity***

| | | Developmental complexity | | |
|---|---|---|---|---|
| | | High | Medium | Low |
| **Artefactual complexity** | High | 41.6% | 14.6% | 1.8% |
| | Medium | 41.4% | 66.7% | 38.9% |
| | Low | 17.1% | 18.7% | 59.3% |
| | SUM | 100% | 100% | 100% |

In SWINNO innovations have been classified according to their degree of novelty. Just like in previous LBIO-studies, and CIS studies the degree of novelty has been assessed through ‘firm novelty’; whether the innovation is new to the firm, and ‘market novelty’; whether the innovation is new to the market.[28] Firm novelty informs us about nascence conditions; did the innovation spring from some previously developed technology or function within the firm or is it totally new from the firm's perspective? An innovation was classified as 'entirely new' if the firm ventured into a new field of technology and the innovation required a significant reconfiguration of the firm's knowledge base, and/or if the innovation was described as being a breakthrough or significant improvement in a technological or functional sense. An innovation was considered 'a major improvement' if the innovation overlaps with previous products but was described in the article to entail a significant improvement and/or the technology has changed greatly. An incremental improvement is defined as innovations where only minor changes have been made to a previously existing innovation. A summary of these categorizations is given in table 11.

The other type of novelty considered in the database is market novelty where we distinguish between innovations being 'new to the world market' or 'new to the Swedish market". Due to the difficulties inherent in classifying novelty only those innovations explicitly mentioned as new to the world or to the Swedish market were classified. This means that the category "Unknown" may include innovations that are new to the Swedish or even the global market but probably their novelty is less significant.

***Table 11. Novelty categories and criteria in SWINNO***

| **Novelty** | ***Criteria*** |
|---|---|
| ***Entirely new*** | The innovation is described as a breakthrough or significant improvement and requires a reconfiguration of the firm's knowledge base or field of technology, |
| ***Major improvement*** | The innovation is similar to previously introduced products / innovations of the firm but entails significant improvements or exploits new technologies. |
| ***Incremental*** | Mainly minor improvements made of a previous innovation. But also new generations of an existing product, which occasionally may be of great significance. |

Unsurprisingly, the results show that most of the innovations mentioned in the trade journals were either entirely new or a major improvement to the firm, while only 13% were

[28] The LBIO method avoids issues of self-reported information which may exaggerate the novelty of innovations to the firm.

incremental to the firm. A fourth or 1,020 of the innovations were *explicitly* mentioned to be new to the world and another 248 to be new to the Swedish market.

The classification of novelty at both the firm level and the level of the market is not without ambiguity. It is easily realized that an innovation that is entirely new to the firm not always is new to the market. However, the opposite could also be true. For instance, for a firm at the technological frontier an incremental improvement of an existing product may be new to the market. Table 12 gives an overview of the correspondence between degrees of novelty to the firm, and novelty to the market. This is especially the case for large incumbent firms that may introduce innovations which constitute great technical improvements, but which for the firm is merely a new generation of a previous product. An example of this is SSAB Oxelösund's Hardox 550, a successor to the Hardox steel, which was the world's first sheet with a hardness of over 550 Brinell. Accordingly, not all of the 605 incremental innovations in SWINNO are thus incremental in a market or industry perspective.

***Table 12. Firm and market novelty: number of innovations by category***

| | | **Market Novelty** | | | |
|---|---|---|---|---|---|
| | | New to Swedish market | New to the World | Unknown | TOTAL |
| **Firm Novelty** | Entirely New | 108 | 688 | 790 | 1586 |
| | Major improvement | 95 | 186 | 1423 | 1704 |
| | Incremental | 14 | 7 | 563 | 584 |
| | Unknown | 10 | 5 | 146 | 161 |
| | TOTAL | 227 | 886 | 2922 | 4035 |

### *5.4 Data on the innovating firm*

The object based SWINNO database also records information about the innovating firms. The innovating firm is considered to be the firm that has developed the innovation. When several firms have been involved in the development process, the firm which has had the main responsibility has been singled out and the others have been recorded as collaborating firms for which the variable 'collaboration' is used. When a firm leaves the development of an innovation to another firm, both firms are recorded in the database, but only the latter is defined as the innovating firm. The former firm is then recorded as a prior developer of the innovation (variable “Other_Dev”).

The innovating firm has been identified for all except 146 innovations. However, these have been developed in universities or by a single inventor, assigning the production and marketing to a previously uninvolved firm.

Additional data about the innovating firms have been retrieved from Statistics Sweden pertaining to the year of commercialization for a total of 4,469 innovations. In total these encompass 2,651 different plants with a unique organization number.[29] The economic information gathered is summarized in the table 13.

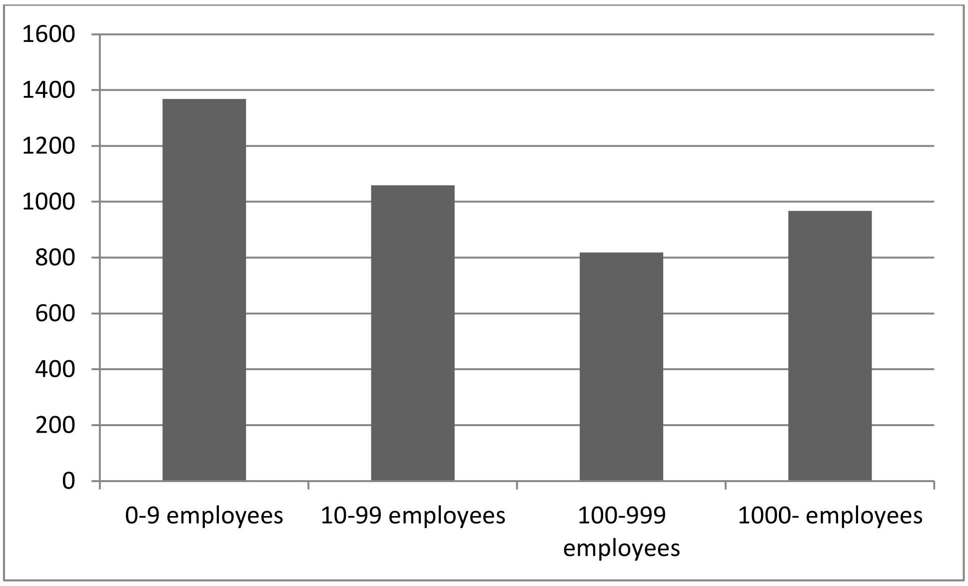
***Table 13. Economic information of the firms in SWINNO***

| | **Description** | **Observation years covered** | **No. observations[30]** |
|---|---|---|---|
| **Employment class** | 16 employment classes | 1970-2007 | 4375 |
| **Branch of economic activity** | 5 digit level SNI69 for 1970-1991, SNI92 for 1992-2001 and SNI2002 for 2002-2007) | 1970-2007 | 4219 |
| **Start Year** | Year of registration of the firm, if registered 1973-2007[31] | 1984-2007 | 2383 |
| **Turnover class** | 12 turnover classes | 1993-2007 | 1558 |
| **Geographical location** | Municipality | 1970-2007 | 4460 |

Since Schumpeter laid forth his conflicting views (1911; 1942) on whether small or large firms were more innovative, the question of how firm-size pertains to innovation activity has become a fundamental feature of the study of innovation. These conflicting accounts have

[29] Please notice that these work-stations however may have been restructured during the course of time, shifted owners or names.
[30] The discrepancies between the number of observations for the variables and the total number of innovations given an organization number (4469) are due to unavailable data in SCBs firm registry.
[31] If registered before 1973 the data conveys a note of registration prior to 1973.

*Figure 1. Number of innovations per firm size classes in SWINNO*




been referred to as the Mark I and Mark II patterns of innovation.[32] The Mark I pattern of innovation denotes a regime of creative accumulation dominated by small and young firms, and the Mark II pattern the opposite pattern dominated by large incumbents. The fundamental results of the SWINNO database are pictured in the diagram below. The emerging pattern clearly favors the small innovating firm. 32% of the innovations were developed in small firms with less than ten employees and roughly 58% in firms with less than 100 employees. Expressed in quartiles, the first quarter of the innovations were developed in small firms with less than five employees. Slightly more than half of the innovations (51%) were developed in firms with less than 50 employees. Certainly, these patterns differ across product groups (see table below). In particular automotive vehicles, basic metals and pulp, paper and paper products depart from the Mark I pattern of innovation observed generally in the database.

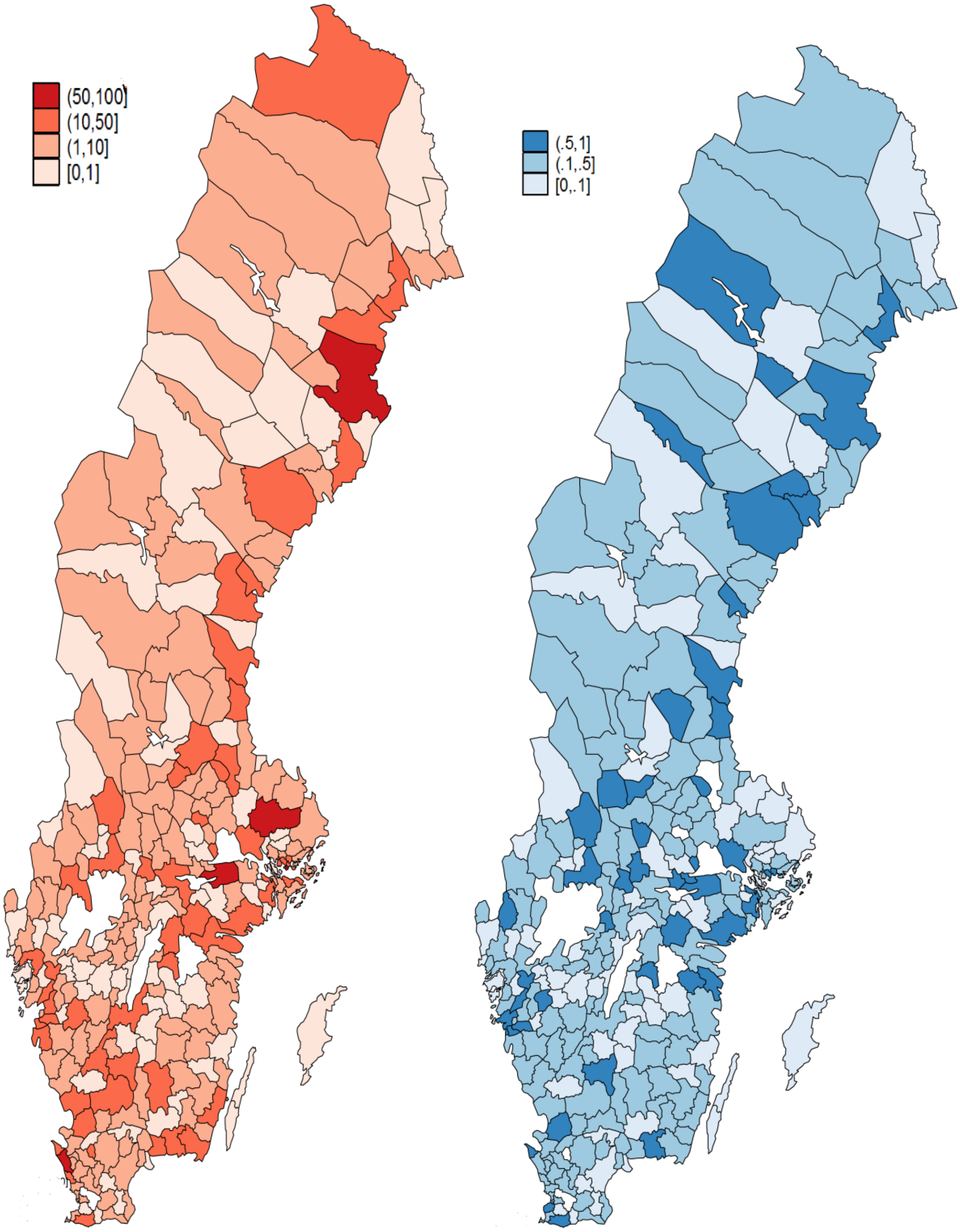
The SWINNO database also contains information about the economic geography of innovation (for an overview of the research field see Asheim & Gertler 2005). The maps in figure 3 provide information about the location of innovations during 1970-2007. When account is taken of population density (right hand map), the differences between different parts of Sweden are not immediately striking. However, taking the top-20 municipalities in innovation performance over 1970-2007 (table 15), it is noteworthy that almost all of the top-20 municipalities either had one or more higher education institution from the start of our

[32] Nelson and Winter (1982) introduced these concepts.

*Table 14. Number of innovations by product groups and employment class*

| | *0-9 employees* | *10-99 employees* | *100-999 employees* | *1000-* |
|---|---|---|---|---|
| Food products and beverages | 15 | 12 | 27 | 10 |
| Textiles | 4 | 7 | 6 | 5 |
| Wearing apparel; dressing and dyeing of fur | 0 | 2 | 2 | 0 |
| Tanning and dressing of leather | 2 | 1 | 1 | 2 |
| Wood and wood products, except furniture | 29 | 16 | 20 | 4 |
| Pulp, paper and paper products | 16 | 9 | 23 | 12 |
| Publishing, printing and reproduction of recorded media | 2 | 1 | 0 | 0 |
| Coke, refined petroleum products and nuclear fuel | 0 | 2 | 4 | 2 |
| Chemicals and chemical products | 60 | 41 | 40 | 39 |
| Rubber and plastic products | 57 | 48 | 47 | 40 |
| Other non-metallic mineral products | 8 | 10 | 10 | 8 |
| Basic metals | 19 | 8 | 16 | 61 |
| Fabricated metal products, except machinery and equipment | 81 | 51 | 44 | 43 |
| Machinery and equipment | 370 | 335 | 238 | 248 |
| Office machinery and computers | 74 | 87 | 49 | 43 |
| Electrical machinery and apparatus n.e.c. | 60 | 38 | 32 | 57 |
| Radio, television and communication equipment | 94 | 63 | 58 | 90 |
| Medical, precision and optical instruments, watches and clocks | 238 | 169 | 89 | 112 |
| Motor vehicles, trailers and semi-trailers | 21 | 23 | 31 | 89 |
| Other transport equipment | 29 | 17 | 13 | 43 |
| Furniture, manufacturing n.e.c. | 13 | 7 | 10 | 4 |
| Recycling | 1 | 1 | 3 | 6 |
| Computer and related activities | 113 | 71 | 22 | 14 |
| Research and development | 6 | 6 | 1 | 1 |
| Other business activities | 43 | 26 | 24 | 28 |

***Figure 3. Geographical distribution of innovation 1970-2007: Number of innovations in total (left hand map) and the number of innovations per thousand inhabitants (Right hand map)***




Note: Coloured according to the categories 0, 1-9, 10-49 and above 50 innovations (Left) and by 0-0,1, 0,1-0,5 and above 0,5.

*Table 15 Number of innovations 1970-2007 in the top-20 municipalities*

| **Municipality** | **Count of innovations** | **Higher education institution** |
|---|---|---|
| Stockholm | 799 | X |
| Göteborg | 366 | X |
| Västerås | 201 | 0 (x) |
| Linköping | 136 | X |
| Lund | 136 | X |
| Malmö | 135 | 0 (x) |
| Nacka | 108 | 0 |
| Uppsala | 73 | X |
| Solna | 68 | X |
| Skellefteå | 64 | 0 (x) |
| Helsingborg | 54 | 0 (x) |
| Eskilstuna | 53 | 0 (x) |
| Södertälje | 45 | 0 (x) |
| Jönköping | 44 | 0 (x) |
| Luleå | 44 | 0 (x) |
| Sandviken | 44 | 0(x) |
| Lidingö | 44 | 0(x) |
| Karlstad | 40 | 0 (x) |
| Täby | 40 | 0(x) |

Note: X in the categoriy for Higher education institution means that at least one such institution has been located in the municipality at least since 1970s. 0(x) means that one or more such institution has been established during 1970-2007.

period, or established one (or more) during the period. It is also noteworthy that the top-20, among a total of 290 municipalities, were the home of nearly 60 per cent of all innovations, and Stockholm’s share was almost one fifth. Actually, Nacka, Solna, Lidingö and Täby are very close to Stockholm and together their share is 25 per cent.

Table 16 displays the number of innovations distributed on counties. Stockholm county is taking close to a third while Västra Götaland (Gothenburg) and Skåne (Malmö-Lund) are lagging further behind. However, this is a summary over the whole period 1970-2007 and tells nothing about changes in the location pattern that may have occurred along with other changes.

***Table 16. Innovations distributed over counties (län) of Sweden***

| Region | Number of innovations 1970-2007 |
|---|---|
| Stockholms län | 1317 |
| Uppsala län | 100 |
| Södermanlands län | 114 |
| Östergötlands län | 234 |
| Jönköpings län | 109 |
| Kronobergs län | 60 |
| Kalmar län | 48 |
| Gotlands län | 1 |
| Blekinge län | 53 |
| Skåne län | 499 |
| Hallands län | 72 |
| Västra Götalands län | 644 |
| Värmlands län | 109 |
| Örebro län | 80 |
| Västmanlands län | 259 |
| Dalarnas län | 87 |
| Gävleborgs län | 128 |
| Västernorrlands län | 85 |
| Jämtlands län | 22 |
| Västerbottens län | 107 |
| Norrbottens län | 96 |
| Total | 4224 |

### *5.5. Other variables*

#### *5.5.1. Users of innovation*

The articles enable a consistent and detailed account of the intended and actual use of innovations in different sectors. This information may be employed to analyze the flow of innovations across industries. Mappings of the production versus use of inventions or innovations have been carried out since the 1980s, using patent data (Scherer 1982; Verspagen 1997; Van Meijl 1997; Nomaler & Verspagen 2008) and innovation output data (Robson et al 1988; Pavitt 1988; DeBresson 1996). A key difference with respect to the Brittish SAPPHO database (Robson et al 1988) is that survey material was largely used to map this variable. In the Finnish SFINNO database the 'user sector' is defined as a sector in which innovation *has* actually been used based on surveys (Saarinen 2005). Since the SWINNO data so far is not complemented with survey data, the information about the sector of use is taken to be the sector that the innovation has been marketed to. The limitations of this variable lie also in the difficulties in discriminating when an innovation began to be used in a certain sector. Thus, the user variable should be interpreted and applied with some caution.

The User sectors in SWINNO are classified according to SNI 2002 at the lowest possible industry level. Apart from the given SNI codes two additional categories have been used: final consumers (101) and general industry (100). An innovation is allowed to have up to eight different user sectors. A general purpose innovation could thus either have been classified as 100, or be given a sizeable number of user sectors. Several user sectors have been preferred, if explicitly mentioned, before classifying the innovation as an innovation of general use, unless it is clear that the innovation may be used in any industry.

In table 17 it is shown that 968 innovations were aimed for general industrial use and 562 for final consumption. Besides these, the major user sectors were the construction sector (SNI 45), motor vehicles (SNI 34), fabricated metal products (SNI 29), food and beverage industry (SNI 15), machinery and equipment (SNI 29), and health and social work (SNI 85). It is clear that many user sectors are not confined within the manufacturing industry.

*Table 17. Innovations used in sectors (two digit SNI 2002), numbers and shares*

| ***User sector*** | *Number* | *%* | ***User sector*** | *Number* | *%* |
|---|---|---|---|---|---|
| Agriculture and hunting | 42 | 0.8% | Electricity. gas. steam and hot water supply | 91 | 1.6% |
| Forestry | 84 | 1.5% | Collection. purification and distribution of water | 2 | 0.0% |
| Fishing | 12 | 0.2% | Construction | 319 | 5.7% |
| Extraction of crude petroleum and natural gas | 32 | 0.6% | Sale. maintenance and repair of motor vehicles and motorcycles; retail sale of automotive fuel | 22 | 0.4% |
| Mining of uranium and thorium ores | 3 | 0.1% | Wholesale trade and commission trade | 12 | 0.2% |
| Mining of metal ores | 68 | 1.2% | Retail trade. except of motor vehicles and motorcycles; repair of personal and household goods | 26 | 0.6% |
| Other mining and quarrying | 22 | 0.4% | Hotels and restaurants | 45 | 0.8% |
| Food products and beverages | 230 | 4.1% | Land transport | 166 | 3.0% |
| Textiles | 30 | 0.5% | Water transport | 64 | 1.1% |
| Wearing apparel; dressing and dyeing of fur | 24 | 0.4% | Air transport | 22 | 0.4% |
| Tanning and dressing of leather | 4 | 0.1% | Supporting and auxiliary transport activities; activities of travel agencies | 80 | 1.4% |
| Wood and wood products, except furniture | 140 | 2.5% | Post and telecommunications | 39 | 0.7% |
| Pulp, paper and paper products | 176 | 3.2% | Financial intermediation | 13 | 0.2% |
| Publishing, printing and reproduction of recorded media | 122 | 2.2% | Insurance and pension funding | 2 | 0.0% |
| Coke, refined petroleum products and nuclear fuel | 22 | 0.4% | Real estate activities | 20 | 0.4% |
| Chemicals and chemical products | 155 | 2.8% | Renting of machinery and eq. personal and household goods | 4 | 0.1% |
| Rubber and plastic products | 92 | 1.7% | Computer and related activities | 14 | 0.3% |
| Other non-metallic mineral products | 27 | 0.5% | Research and development | 58 | 1.4% |

| | | | | | |
|---|---|---|---|---|---|
| Basic metals | 131 | 2.4% | Other business activities | 103 | 1.8% |
| Fabricated metal products, except machinery and equipment | 237 | 4.3% | Public administration and defence | 132 | 2.4% |
| Machinery and eq | 221 | 4.0% | Education | 8 | 0.1% |
| Office machinery and computers | 32 | 0.6% | Health and social work | 177 | 3.2% |
| Electrical machinery and apparatus n.e.c. | 54 | 1.0% | Sewage and refuse disposal. sanitation and similar activities | 74 | 1.3% |
| Radio, television and communication eq | 116 | 2.1% | Recreational, cultural and sporting activities | 16 | 0.3% |
| Medical, precision and optical instruments, watches and clocks | 58 | 1.0% | Other service activities | 2 | 0.0% |
| Motor vehicles, trailers and semi-trailers | 257 | 4.6% | General industry | 939 | 16.9% |
| Other transport eq | 130 | 2.3% | Final consumption | 532 | 9.6% |
| Furniture, manufacturing n.e.c. | 53 | 1.0% | | | |
| Recycling | 7 | 0.1% | | | |

### *5.5.2. Origin of innovation*

A central issue in the literature about the innovation process is the role played by demand factors, competition or performance, as well as scientific and technology shift factors. This concerns the driving forces behind innovation. The variable, called "origin of innovation", in SWINNO entails a classification of innovations into the factors that contributed to the development of innovations. The variable is primarily classified according to the explicit information in the articles. The different factors that have contributed to the innovation process or the initiation of the innovation process can be subdivided into four broad categories: 1) competitive factors, 2) demand factors, 3) regulation and environmental factors and 4) scientific and technological factors. The alternatives classified under these headlines are summarized in table 18.

The criteria for the classification of the origin of innovation are in most cases straightforward: the journal article must explicitly state the cause or that the innovation was developed *under the influence of* some factor. However, in some cases the origin is based on implicit

***Table 18. Origin of innovation in SWINNO***

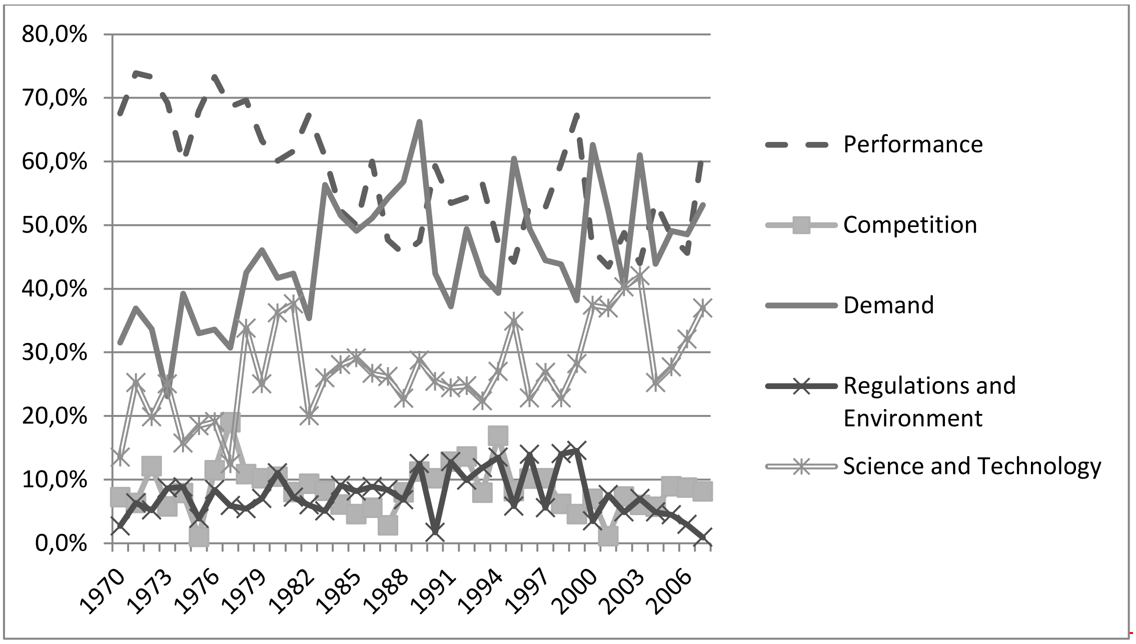
| ***Competition*** | ***Demand*** | ***Regulations and environment*** | ***Science and technology*** | ***Other factors*** |
|---|---|---|---|---|
| Price competition | Role of customers | Public research or technology program | New scientific breakthrough | Other factors |
| Competition in performance | Observation of market niche | Environmental factors | New technologies or materials | |
| Threat posed by rival innovations | Public procurement | Official regulations, legislation and standards | Trial and error | |
| Shrinking market share or demand | | Availability of license | Solution for a problem | |
| Rationalization of production methods | | | Spinoff | |
| Enable lower prices | | | | |
| Performance | | | | |

information and an interpretation of the context described in the journal. Several factors can, of course, have a role in the origin of an innovation and are recorded in SWINNO.

Finally, in some cases it was desirable to specify further information than just classification into types of origin. For instance, when the development of the innovation was stated to have been catalyzed by a new technology or some new material, a description of the technology was recorded.

Figure 4 shows the share of innovations by origin over time. As most innovations have been developed to improve the performance of a product this is shown as a separate category. 58% of all innovations were developed aspiring to improve the performance of a good. However, over time the importance of this factor declined, from around 70 per cent in the early years to below 50 per cent most of the years after the turn of the millennium. Other competitive factors contributed only 8 per cent to the origin of innovations and these factors showed no clear trend. Demand factors, such as customer initiatives, or the observation of a market niche have contributed to the development of 45 per cent of the innovations. Most of these were the observation of a market niche, which has been interpreted broadly as the observation of an unfulfilled need. However, it is noticeable, from figure 4, that demand factors were present in less than 40 per cent of the innovation processes in the 1970s but increased after the structural crisis and from the early 1980s onwards fluctuated around 50 per cent. The increased role of demand notwithstanding, the share of innovations spurred by supply side factors like Science and technology, saw a rise over the period from 13.5% in 1970 to 37% in 2007.

***Figure 4.Origin of innovations, 1970-2007***



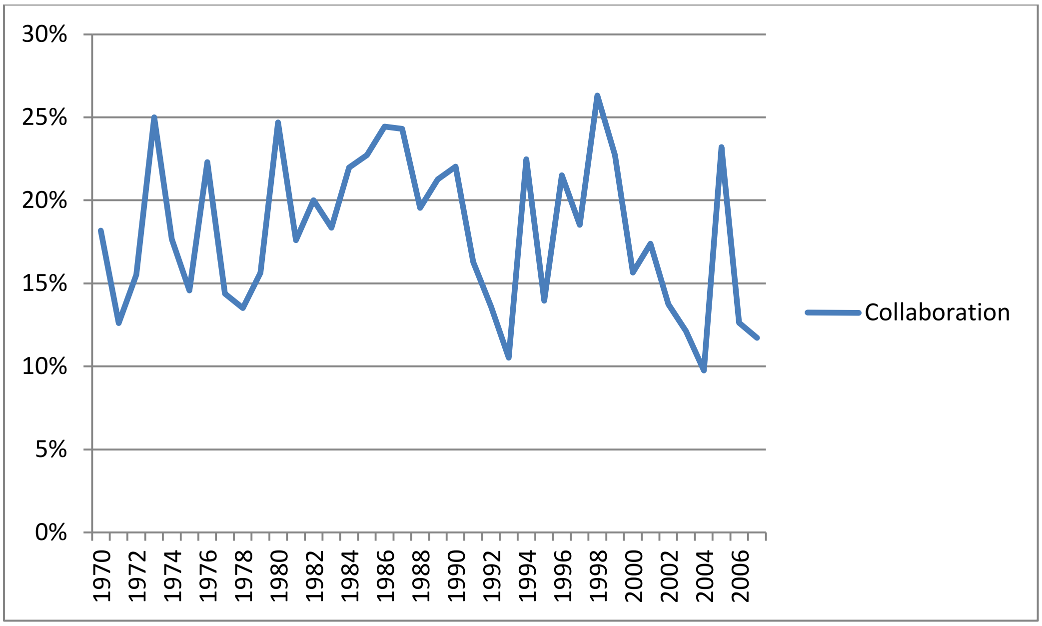

Note: Since any innovation can be influenced by several of these factors the percentages add up to more than 100%

### *2.4.5.3. Collaboration*

There is an established view that innovations do not take place in isolation. An innovating firm is part of an environment upon which it is more or less dependent. Competing firms, customers, suppliers, educational institutions, administrative authorities are examples of actors that may be found in what has been called a system of innovation (Edquist 1997). It has been argued that increased specialization has led firms to become more dependent upon their surroundings over time (Robertson and Langlois 1995; Brusoni et al. 2001; Becker and Dietz 2004).

There were 864 cases of explicit collaboration in SWINNO which means that 18 per cent of the innovations resulted from collaboration. In all but ten cases there is explicit information about the nationality and/or type of at least one partner with whom the innovating firm teamed up. In those ten cases there were collaboration going on, but the journal article did not provide any further details on the arrangement.  All in all 1051 partners where identified. In eight cases information about the nationality of the partner is missing. In one case the nationality was known, but not the partner type. In the ten cases with no name on the collaborating partner, it was assumed that there was only one partner. In 75 percent of all cases firms collaborated with only one partner.

***Figure 5. The share of innovations stemming from collaborations, 1970-2007***




The share of innovations stemming from some collaboration is shown in figure 5. Contrary to expectations, there is no sign of an increase in the share of collaborating ventures over time. This is worth stressing, in light of the current emphasis on collaboration, and facilitation of innovation systems.  Table 20 shows the 16 classes of collaborating partners that SWINNO contains. The largest class is other domestic firms (12), followed by domestic consumers (2) and domestic universities (8).

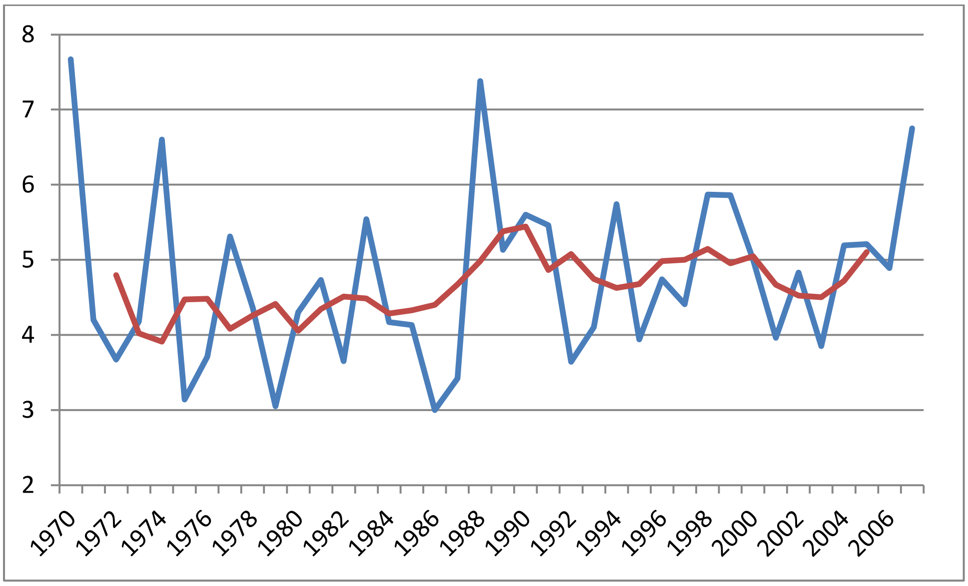
***Table 20. Numbers and shares of collaborating firms by categories of collaboration in SWINNO.***

| | Count | % |
|---|---|---|
| 1. Other firms belonging to the same concern | 23 | 2% |
| 2. Domestic costumers | 125 | 13% |
| 3. Foreign costumers | 18 | 2% |
| 4. Domestic consults | 56 | 6% |
| 5. Foreign consults | 5 | 1% |
| 6. Domestic subcontractors | 35 | 4% |
| 7. Foreign subcontractors | 2 | 0% |
| 8. Domestic universities | 123 | 13% |
| 9. Foreign universities | 15 | 2% |
| 10. Domestic research institutes | 41 | 4% |
| 11. Foreign research institutes | 7 | 1% |
| 12. Domestic firm | 289 | 30% |
| 13. Foreign firm | 117 | 12% |
| 14. Public institution | 73 | 7% |
| 15. Publicly owned company | 13 | 1% |
| 16. Other | 36 | 4% |
| | 978 | 100% |

### *2.4.5.4. Development time*

For a small but non-negligible share (704 of the 4035 commercialized innovations), data on the initiation of the innovation process was available. These data enables an aggregate analysis of the development time of innovations. Over the entire period the average time to develop an innovation was four years and 259 days (4.71 years). Although rather volatile from year to year, the annual series of development time of innovation shows no clear trend, as seen in figure 6. However, one should be careful with the interpretation since for each year there are between 15 and 30 innovations with development time recorded, and small numbers may be a cause for the volatility and could also influence the trend, or lack of trend. By calculation of the weighted averages over a period of some years, one could reduce the sensitivity for the low numbers in certain years. The less volatile curve in figure 6 is thus the weighted average over five years, shown as a centered moving average.  From this calculation, development time became longer towards the end of the 1980s and stayed at a higher level. The increase is not impressive, from about four years and 4 months until the mid-1980s to four years and 10 months in the fifteen years up to 2007. The presumption that development time has significantly increased during the third industrial revolution can scarcely be supported by these results.

***Figure 6. Average development time of innovation, 1970-2007***




*Note:* Observations in year of commercialization; annual data and five year centered and weighted moving averages (thus missing for 1970-71 and 2006-2007).

## 6. Methodological concerns and critical assessment

In this final section we will address some methodological concerns regarding the data. There are in principle two ways to approach the data.

A first approach is to regard the data as illustrative cases. The SWINNO database contains rich and detailed information, relevant in their own right as examples or illustrations of historical innovation processes. Similarly, industry studies, such as Greve (2003), may be considered relatively unproblematic, as long as the sampling method raises no suspicion of bias towards certain types of firms. Adhering strictly to this point of view would make the restriction on inference from the database unnecessarily severe.

The second approach is that the innovations in SWINNO could be considered a subset of important innovations within the larger population of all innovations. From this view follows two methodological issues. The subset does not fulfill standard statistical properties in relation to the population of all innovations (Kleinknecht 1993; Kleinknecht et al 2002). The full population of innovation is unknown, if not unknowable, which complicates standard statistical analysis (Archibugi & Pianta 1996, p. 454).This can be remedied by comparing the data with other innovation indicators (Palmberg et al 2000; van der Panne 2007), or by assessing the sensitivity of results with respect to the exclusion of trade journals. Furthermore, trade journal publishing policies and changes therein can be investigated in order to understand exactly what kind of innovations the database captures.

The SWINNO database is a selection of significant innovations. A comparison with the Wallmark and McQueen (1991) and Svenska Institutets publication *Svenska Innovationer* (see appendix 3) indicates a large coverage (74% and 86% respectively) of the innovations that in retrospect turned out to be highly important. Thus, the SWINNO database is better understood as a sample of significant innovations than a sample of innovations in general, and we have reasons to expect a reasonable coverage rate of important innovations. This however does not exempt the SWINNO database from the methodological considerations dealt with in previous studies.

There are four issues that have been raised in the literature as regards representativeness and validity of LBIO data. First, there is a possibility that LBIO may overestimate the number of domestic innovations if based on product announcements which, as a matter of fact, not always accurately report the developing firm (van der Panne 2007). As the SWINNO database does not rely on product announcements at all, but rather edited articles in which the developing firm is mentioned as such, this problem has no bearing on SWINNO.

Second, it is possible that trade journals report innovations from large companies to a lesser degree than innovations from small companies. This may be the case due to the potential lack of incentives for larger companies to advertise new products through public channels (Coombs et al 1996, p. 405; Santarelli and Piergiovanni 1996). Large firms may also be more likely to have their products recognized by journals, (Acs and Audretsch 1990; Tether 1998). Edwards & Gordon (1984) raised concerns about the opposite direction of bias, as small firms may lack the necessary resources to produce press releases. This direction of bias is however not clear. This possible bias in one way or the other, however concerned data assembled on the basis of new product announcements (relying heavily on press releases), whereas

SWINNO is based on edited articles, making such bias unlikely. In a comparison of SFINNO data with CIS data, Van der Panne (2007) and Palmberg et al (2000) found no bias in any direction with respect to firm size.

Third, bias may be introduced by changes in publication policies of trade journals and public relation policies of firms (Kleinknecht et al 2002, p. 116). It is for instance possible that trade journals report differently over time about innovations, due to changes in publication policies. The selection of journals was discussed in section 4.2. Editorial policies and changes therein are addressed in section 6.2.

### *6.1. Validity: comparisons with other innovation data sources*

Similar to Palmberg et al (2000) and van der Panne (2007), a comparative analysis is carried out for LIO and CIS, here SWINNO and CIS 1998-2006. Due to methodological differences between SWINNO and CIS data the comparison serves as a basis for discussion, rather than a direct test for bias.

The size distribution of firms and the distribution of the number of innovations across product groups can be compared with Swedish CIS data for the benchmark years of 1998-2000, 2002-2004 and 2004-2006. The comparisons are made in terms of the relative frequency of innovating firms in employment classes and sectors. As the CIS data do not concern the number of innovations, but rather the number of innovating firms (both process and product innovations) the latter form the basis of comparison. Also, the basis of comparison is the number of firms engaging in product innovation.

For a comparison of the size of innovating firms we are focusing on the CIS of 1998-2000 as the later surveys present only broad employment categories. Even in CIS 1998-2000 the smallest class of enterprises, with less than 10 employees, is not surveyed.

A discrepancy probably arises from the methodological differences. The self-reported surveys make CIS pick up innovations which are new to the firm, but to a lesser degree new to the market, whereas SWINNO only captures significant innovations.

The most striking difference is that CIS 1998-2000 reports a total number of innovations that is about twenty times higher than SWINNO for the same years. The difference is actually even higher since CIS does not include the smallest firms which, in SWINNO, provide 38 per cent of all innovating firms in 1998-2000. Making the counterfactual assumption that an equally big share, for the smallest firms, would have been reported by CIS if these firms were included in CIS, would add almost 3,200 to the CIS number of innovating firms and increase the differential to more than 30 times. It is clear that CIS and SWINNO deal with innovations of different sorts.  Moreover, different editions of the CIS are not directly comparable as highlighted by the fall of “innovation firms” from 4,324 in 1998-2000 to 2,502 in 2004-2006 (see table 22).

Table 21 shows the numbers of innovating firms in CIS and SWINNO as well as the distribution on firm sizes – including with the counterfactual assumption that CIS would have relatively the same share of firms with less than 10 employees. However compared, the difference remains and consists in a much higher share of innovating firms among the larger firms, and a smaller share of the firms with 10-19 employees, in SWINNO. Had it not been for the substantial share, 38 per cent, among the smallest firms with less than 10 employees, one would have suspected that SWINNO is biased towards big enterprises. Now, a conclusion is that the journals on which SWINNO is based, neither neglects big nor small firms. The difference in numbers could be interpreted as a reflection of the self-reporting firms in CIS whereas the journals have recorded the more significant innovations in SWINNO. Whether the distribution also is fairly representative is, however, another question and only by continuing the comparison we can at least get a reasonable picture of the representativeness and validity of SWINNO.

Another aspect of the distribution of innovation is how they are allocated between sectors. If we presume that the propensity to innovate is related to the level of technology, then we would, irrespective of the difference in numbers, expect a correlation between the sectoral allocation of innovations in CIS and SWINNO. Table 22 shows the distribution of innovating firms across sectors according to three different editions of CIS, and the corresponding years of SWINNO. Overall, the distribution is quite broad in both measures. One difference catches the eye, and that is the relative share of machinery and equipment (SNI 29) and ICT industries (SNI 30-33) which is 10 percentage points, or more, higher in SWINNO than in CIS. It could be that these sectors attract more interest from the journals but since these are selected as representative for all sectors it could as well indicate that machinery and ICT provide relatively more significant innovations. The correlation between sectors is, however, rather close between CIS and SWINNO, as can be seen from the bottom line in table 22. In conclusion, given that the innovative firms are several times more in CIS than in SWINNO which is taken as an indication that the latter contains the more significant innovations, we find no seriously disturbing differences in the distribution, neither across firm sizes nor across sectors. There are some questions marks which remain for further research to validate.

*Table 21. Comparison of the size distribution of innovating firms, CIS and SWINNO 1998-2000*

| Firm size: employees | CIS 1998-2000 | Share (%) | Counter-factual | SWINNO 1998-2000 | Share (%) | 0-9 excluded |
|---|---|---|---|---|---|---|
| **0-9** | na | | 38 | 102 | 38 | |
| **10—19** | 2,171 | 42 | 26 | 29 | 11 | 19 |
| **20-49** | 1,588 | 31 | 19 | 44 | 17 | 29 |
| **50-99** | 517 | 10 | 6 | 15 | 6 | 10 |
| **100-499** | 721 | 14 | 9 | 37 | 14 | 24 |
| **500-** | 185 | 4 | 2 | 39 | 15 | 25 |
| **Total** | 5182 | | | 266 | | |

*Table 22. Sectoral distribution of innovating firms in CIS and SWINNO*

| SNI | CIS 1998-2000 | (%) | SWINNO 1998-2000 | (%) |
|---|---|---|---|---|
| **10-14** | | | 1 | 0.40 |
| **15-16** | 174 | 4.02 | 4 | 1.58 |
| **17-19** | 72 | 1.67 | 3 | 1.19 |
| **20** | 97 | 2.24 | 6 | 2.37 |
| **21-22** | 231 | 5.34 | 3 | 1.19 |
| **23-24** | 112 | 2.59 | 6 | 2.37 |
| **25** | | 0.00 | 9 | 3.56 |
| **26** | | 0.00 | 3 | 1.19 |
| **27-28** | 333 | 7.70 | 20 | 7.91 |
| **29** | 484 | 11.19 | 30 | 11.86 |
| **30-33** | 335 | 7.75 | 42 | 16.60 |
| **34-35** | 102 | 2.36 | 8 | 3.16 |
| **36-37** | 136 | 3.15 | 0 | 0.00 |
| **40-41** | 49 | 1.13 | 0 | 0.00 |
| **45** | | 0.00 | 3 | 1.19 |
| **51** | 1463 | 33.83 | 30 | 11.86 |
| **60-64** | 312 | 7.22 | 9 | 3.56 |
| **65-67** | 145 | 3.35 | 0 | 0.00 |
| **70** | | 0.00 | 4 | 1.58 |
| **72** | | 0.00 | 30 | 11.86 |
| **73** | | 0.00 | 18 | 7.11 |
| **74** | 279 | 6.45 | 24 | 9.49 |
| **Total** | 4324 | | 253 | |
| **Korrelation** | | 0.599* | | |

| SNI | CIS 2002-2004 | (%) | SWINNO 2002-2004 | (%) | CIS 2004-2006 | (%) | SWINNO 2004-2006 | (%) |
|---|---|---|---|---|---|---|---|---|
| **01-05** | 0 | 0.00 | 1 | 0.42 | 0 | 0.00 | 1 | 0.36 |
| **10-14** | 4 | 0.14 | 1 | 0.42 | 4 | 0.16 | 0 | 0.00 |
| **15-16** | 116 | 4.09 | 3 | 1.27 | 79 | 3.16 | 3 | 1.08 |
| **17-19** | 39 | 1.37 | 1 | 0.42 | 44 | 1.76 | 2 | 0.72 |
| **20** | 42 | 1.48 | 3 | 1.27 | 43 | 1.72 | 5 | 1.80 |
| **21** | 30 | 1.06 | 6 | 2.53 | 31 | 1.24 | 6 | 2.16 |
| **23** | 0 | 0.00 | 0 | 0.00 | 4 | 0.16 | 0 | 0.00 |
| **24** | 56 | 1.97 | 6 | 2.53 | 49 | 1.96 | 4 | 1.44 |
| **25** | 56 | 1.97 | 5 | 2.11 | 43 | 1.72 | 4 | 1.44 |
| **26** | 23 | 0.81 | 0 | 0.00 | 20 | 0.80 | 1 | 0.36 |
| **27** | 5 | 0.18 | 6 | 2.53 | 17 | 0.68 | 7 | 2.52 |
| **28** | 124 | 4.37 | 9 | 3.80 | 174 | 6.95 | 13 | 4.68 |
| **29** | 207 | 7.29 | 28 | 11.81 | 186 | 7.43 | 34 | 12.23 |
| **30-33** | 120 | 4.23 | 27 | 11.39 | 141 | 5.64 | 32 | 11.51 |
| **34-35** | 80 | 2.82 | 10 | 4.22 | 85 | 3.40 | 9 | 3.24 |
| **22+36-37** | 150 | 5.29 | 5 | 2.11 | 153 | 6.12 | 5 | 1.80 |
| **40-41** | 12 | 0.42 | 0 | 0.00 | 13 | 0.52 | 0 | 0.00 |
| **50-52** | 818 | 28.82 | 26 | 10.97 | 520 | 20.78 | 40 | 14.39 |
| **55** | 0 | 0.00 | 0 | 0.00 | 0 | 0.00 | 1 | 0.36 |
| **60-63** | 80 | 2.82 | 0 | 0.00 | 85 | 3.40 | 0 | 0.00 |
| **64+72** | 338 | 11.91 | 34 | 14.35 | 286 | 11.43 | 30 | 10.79 |
| **65** | 19 | 0.67 | 0 | 0.00 | 35 | 1.40 | 0 | 0.00 |
| **66** | 12 | 0.42 | 0 | 0.00 | 12 | 0.48 | 0 | 0.00 |
| **67** | 18 | 0.63 | 1 | 0.42 | 25 | 1.00 | 0 | 0.00 |
| **73** | 40 | 1.41 | 27 | 11.39 | 40 | 1.60 | 31 | 11.15 |
| **74** | 449 | 15.82 | 39 | 16.46 | 413 | 16.51 | 50 | 17.99 |
| **Total** | 2838 | | 237 | | 2502 | | 278 | |
| **Correlation** | | 0.695*** | | | | 0.828*** | | |

Note: For the correlation coefficients, * denote statistical significance at 5 % level and *** at 0.1 % level.

### *6.2. Reliability: interviews and robustness test*

### *6.2.1 Editor interviews*

It was recognized in section 3.1.3 that object-based methodologies, such as the LBIO method do not escape the risk of a selection bias due to the particular perceptions of those reporting them. In order to penetrate this selection process, former and/or present editors of all journals were interviewed about their publication policies. All in all 17 semi-structured telephone interviews were conducted.[33] A first question addressed the sources scanned for information about innovations. The interviewees all voiced that a variety of sources inspired the writing about an innovation. None of the editors reported that their main source of inspiration was press releases. Although press releases were screened on a regular basis, the importance of other sources of information was generally given greater emphasis. Extensive personal networks, industry experts and analysts, researchers, editorial boards, research funding agencies, other journals, attendance at fairs, conferences, as well as information acquired through a general active outreach contributed to the decision to write an article on a particular innovation project. The message given by the interviews was that journal editors make use of not only their own solid industry knowledge but the knowledge possessed by a range of other sources, independent as well as subjective. There are two journals that deviate from this picture. *Struktur* (textiles and apparel, journal no. 14) was first published jointly by employers' organizations and later by the research institute IFP (Institutet för fiber och polymerteknik) and the industry research institute *Svenska textilforskningsinstitutet*. After the take over the content of the journal was influenced by the research institutes and a lot of research results but fewer products were reported. Still, it was claimed in an interview by a former editor that the journal had a broad scope and pictured any relevant development in the industry. The lack of reports about innovations simply reflected the low frequency of innovation in the industry. The other exception is *Bergsmannen med Jernkontorets Annaler* (iron and steel, journal no. 11). A large part of the content of this journal is strongly influenced by the trade association, Jernkontoret, and the mining engineer society Bergsmannaföreningen. The relation between this journal and the two organizations is long and close may be a constraint for the editorial freedom. Still, the interviewee declared a mission to cover any important development in mineral and metal extraction and refinement.

A second question addressed whether the journals report more about innovations from large firms than small firms, or vice versa. None of the editors stated a deliberate ambition to report

[33] Sjöö conducted the interveiws.

about innovations from firms of a particular size. The ambition was rather to cover innovations from all types of firms. This aside, some editors responded that they tended to feature more innovations from large firms than from small firms, for example the editor of *Svensk trävaru- och pappersmassetidning* (pulp and paper, journal no. 13). When asked if this tendency was a reflection of the locus of innovative activity in the industry, the editors approved that this was the case. Editors were content that on average they capture the important innovations, no matter where they come from. However, they admitted that the probability to miss an important innovation from a small firm is higher since large firms are constantly monitored.

A third question addressed if there had been any major changes in the use of different sources, the tendency to report about innovation, and the overall editorial mission of the journal. Naturally, former editors could share more information about historical changes of content and content selection processes than could current ones. None of the editors maintained any major change in these two respects. However, in terms of sources several admitted that the advent of the internet had made scanning a wide range of sources a lot easier. Thus, there is the possibility that the access to a wider set of sources results in the reporting about more innovations and also such innovations that were not picked up when sources of information were more limited. Still, although editors have updated their way of doing research, the same evaluation process applies and there are still limitations in terms of journal space. One can assume that the flood of internet-bound information have equipped editors with an amplified possibility to produce an increased number of shorter notes, but given the limited space and resources, we conclude that it is not likely that the number of innovations featured in articles to any greater extent is influenced by the advent of the internet. Any suggestion that other sources of information would have decreased the relevance of trade journals were curtailed by the interviewees: in the face of competition trade journals have been forced to work even harder to stay relevant. Moreover, their longstanding presence and reputation makes them credible among professionals.

A minor part of the editors reported about changes in the contents of the journals. Such reports often revolved around an introduction of pages devoted to research results from research institutes or similar. Such changes are not considered a problem since these pages rarely reported innovations but mere research results. Other editors, for example those of *Livsmedelsteknik* (6) and *Textil och Konfektion* (14), reported that the number of innovations featured in the journals have increased over the years and they meant that this reflects an increasing innovation activity in the industry.

The interviews conveyed the picture that the content of the journals is balanced with regard to firms of different sizes and sources. The picture given was further that the editorial missions and publication policies have been relatively consistent over time. Content changes were reported to reflect corresponding changes in the industries. [34] As a conclusion from the interviews we contend that the innovations reported in the trade journals are carefully evaluated in terms of newsworthiness; they are singled out from a crowd of innovations commercialized at any point in time. Following from that contention it is assumed that the innovations featured in the articles are special in some sense (from the technological-, firm-, or industry perspective; or all three together). The innovations on which SWINNO is based are thus not representing innovation activity in general but are rather significant innovations assessed as worthy to report about in journals having the explicit ambition to picture the relevant development in the particular industry.

While journals and editors are largely independent sources about innovation, they are still human. It is plausible that editors not always manage to fulfill their ambition. This may be due to resource constraints: financial, cognitive, time or something else. Such constraints are likely to influence the extent to which the editorial mission is met. Although the interviewed editors were generally humble about the fact that editorial missions may not be met to a hundred percent all the time, they were confident that they sooner or later captured the lion part of significant innovations.

However, one may suspect that changes in publication policies and differences in the publication policies across trade journals have influenced the general results of SWINNO. As recorded in the interviews with the journal editors, these argued that no significant changes have taken place and this proposition could be examined with the data. If the results are not significantly sensitive to the inclusion or exclusion of particular journals, then it is possible to say that the results are insensitive to hypothetical changes in publishing policies of particular journals. The underlying idea is that there is an overlapping between the journals and the question is if this is sufficient to compensate for the hypothetical loss of one journal.

For a formal analysis of the robustness of our results to the included trade journals, a simple test has been constructed. The underlying principles can be summarized: let any time series or

[34] Thematical issues, or issues dedicated to a certain field of technology were enclosed with the journals irregularly. Such issues pay attention to a noteworthy development and are thus also assumed to reflect changes in the industries.

descriptive statistic, a vector $X$ over some index (e.g. sectors or time) be composed by a set of components, in our case journals, $i$ which contribute to the statistic according to $X = X_1 + X_2 + \cdots + X_n = \sum_{i=1}^{n} X_i$. If the overall results are robust, removing a journal should not significantly alter them. Certainly, removing a journal will decrease the total count, but it should not alter the distribution over the relevant domain. By successively removing journals and comparing the results one may assess the robustness of the series. We proceed by examining the correlations of all time series or descriptive statistics that are possible to generate by removing all combinations of journals against their respective remnants.[35] We may say that the statistics are robust to arbitrariness in the choice of journals if the average correlation coefficient is significant on the 90%-level. The acceptance of a wider margin of error than with the conventional 95% is due to the expectation that there are some differences, when a journal is excluded, and the accordingly higher risk of a type 1 error (rejecting what is true). As the calculations are tedious in the second case (with 16 journals we must examine 136 possible time series or descriptive statistics), a programming code has been written and carried out in statistical software R.

The tests consider a) number of innovations per year of commercialization in total and by sector, b) the number of innovations by sector, and c) the number of innovations by employment class in total and by sector.

The total number of innovations per year of commercialization follows a distinct pattern with an increase in the total count 1975-1983, a sharp fall until the mid-1990s, and a subsequent increase in the 1990s (see Figure 1 and Figure 7) In the formal test, these results are modestly robust to changes in the journals. The average correlation is 0.11 ($p>0.10$) but the average Z-test from bivariate Poisson regressions is 1.37 ($p<0.10$). It is known that correlation is sensitive to outliers why we can conclude that for some sectors results are sensitive for change in the editorial policy of a particular journal but the overall pattern is robust. Moreover, it is found that machinery innovations (29), fabricated metal innovations (28), plastic and rubber innovations (25), telecommunications (32) and software innovations (72) are insensitive regardless of the journals one chooses. Figure 8 shows that innovations in these product groups not only make out a substantial share of all innovations but also that they contribute to the variations over time. Thus, we may conclude that the aggregate pattern of innovations is a

[35] Since the correlation of $X$ with $X - X_i$ clearly will introduce bias in the estimates it is more sensible to examine whether components $X_i$ are correlated to the remainder $X - X_i$. In principle, a good picture could be given by removing only one journal. A more ambitious and complete approach however is to test the results for the removal of any number and combination of journals.

highly generic result of the database, not pertaining to the idiosyncrasies of any one trade journal.

***Figure 8. Number of innovations, total and of 'the robust product groups'***

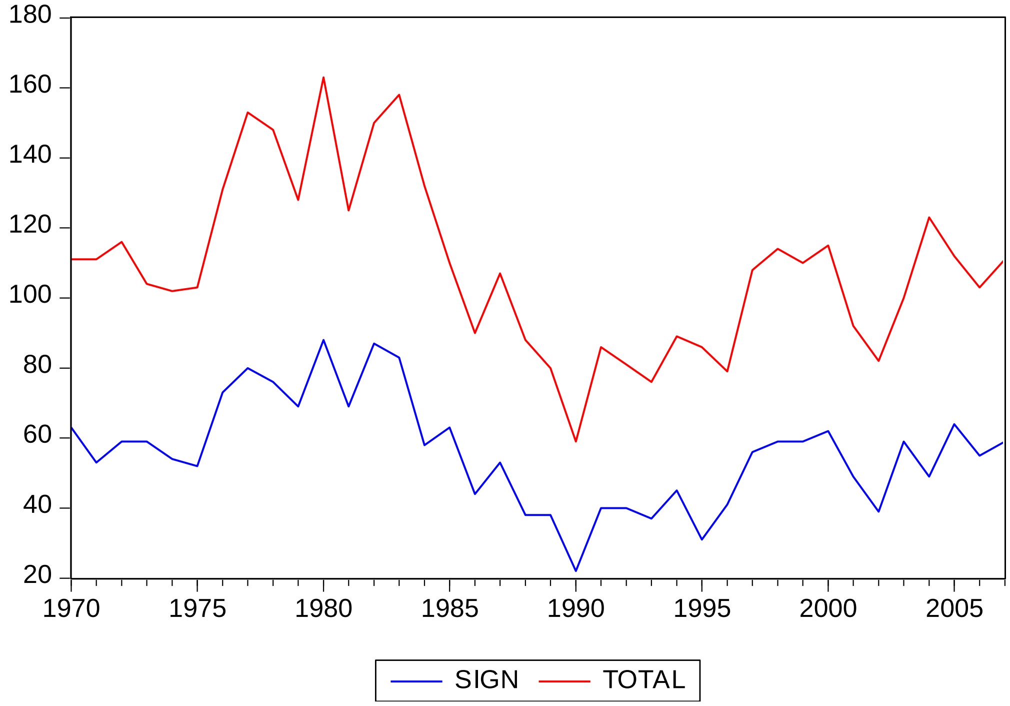


***Table 24. Results from robustness analysis. Figures presented are the average Z-test in bivariate Poisson regressions and Pearson's correlation coefficient (r)***

| | ***Z*** | ***r*** |
|---|---|---|
| **Count of innovations per sector** | 62.02*** | 0.86*** |
| **Commercialized innovations per year, total** | 1.37* | 0.11 |
| **Commercialized innovations per year, SNI** | | |
| **15** | 0.22 | 0.03 |
| **20** | -0.02 | 0.01 |
| **21** | 1.26 | 0.2 |
| **24** | -0.43 | -0.07 |
| **25** | 2.42*** | 0.32** |
| **26** | 0.64 | 0.11 |
| **27** | 0.2 | 0.04 |
| **28** | 1.46* | 0.18 |
| **29** | 5.63*** | 0.47*** |
| **30** | 0.25 | 0.04 |
| **31** | 0.42 | 0.07 |
| **32** | 1.55* | 0.16 |
| **33** | -0.81 | -0.09 |
| **34** | -0.07 | 0 |
| **35** | 0.14 | 0.02 |
| **36** | 0.85 | 0.1 |
| **72** | 5.47*** | 0.5*** |

Another important result of the SWINNO database concerns the distribution of innovating firms. The database allows for discrimination of firms according to 16 employment classes. A majority of the innovations were developed by firms with less than 200 employees. We know however that this is not true of all product groups, and we know from the literature that patterns of innovation differ across sectors.

These aggregate results are very robust to exclusion of an arbitrary number and combination of journals (see table 25). When ordered by product groups, the distribution is robust ($p<0.10$) for three fourths of the product groups. The exceptions are product groups of which most

***Table 25. Results from robustness analysis. Count of innovations per employee class, in total and by product group. Figures presented are the average Z-test in bivariate Poisson regressions and Pearson's correlation coefficients (r)***

| **Count of innovations per employee class (0-16) of the firm** | **47,24***** | **0,96***** |
|---|---|---|
| **Count of innovations per employee class (0-16) of the firm and product group** | Z | r |
| **15** | 0.11 | 0.03 |
| **20** | 3.03*** | 0.32** |
| **21** | 3.57*** | 0.41*** |
| **24** | 1.36* | 0.15 |
| **25** | 1.13 | 0.16 |
| **27** | 1.47* | 0.18 |
| **28** | 3.61*** | 0.38*** |
| **29** | 0.46 | 0.07 |
| **30** | 4.59*** | 0.38*** |
| **31** | 2.12** | 0.28** |
| **32** | -0.75 | -0.12 |
| **33** | 1.49* | 0.23* |
| **34** | 4.27*** | 0.4*** |
| **35** | 4.63*** | 0.5*** |
| **36** | 4.51*** | 0.43*** |
| **72** | 2.23** | 0.28** |

were robust when it comes to number of innovations over time, why we may infer that the editorial interest for the product groups was reasonably stable. The remaining exception is foodstuff (SNI15) which actually is present in a limited number of journals and that would motivate a further check with other sources.

## 7. Concluding remarks

A major result of SWINNO is the uncovering of the time pattern of Swedish innovations since 1970, during periods of altered economic conditions. Thus, the highest number of innovations were commercialized during de structural crisis years around 1980. A major share of these innovations was traditional in the sense that it emanated in the machinery industry, however, very often with a technological content based in ICT. This wave of innovations hence represented a mix of “old” and “new” technology. Then innovations fell to a low in 1990 whereafter a recovery set in, largely based on ICT and related software innovations. It is noteworthy that through to 2007, the present end year of SWINNO, the annual number of innovations had not achieved the previous height of around 1980. Several different characteristics of innovations, documented in SWINNO, are treated in section 5. Two aspects of complexity are recorded, the “developmental” referring to the knowledge base and the “artefactual” referring to the nature of the product itself. The degree of novelty of the innovation is recorded, seen from three horizons: the firm, the Swedish market and the world market. Even if SWINNO only reports significant innovations it is noticeable that a fourth of all were new to the world market. A debated topic is whether big or small firms are the most industrious innovators. SWINNO indicates that a substantial share of innovations have been launched by smaller firms, and as further examined by Sjöö (2014) and Taalbi (2014) the distribution changed over time and from the 1990s smaller firms were the most frequent innovators. Other characteristics which are explored in SWINNO are the geographical diffusion of the innovating firms, the diffusion of innovations to user industries, factors that were important for the origin of the innovation, the extent of collaboration in the development of innovations, and the development time of innovations. The last mentioned characteric was, however, reported in the journal articles for barely a sixth of the total number of innovations. Somewhat unexpectedly, as can be seen in figure 6, these do not suggest any significant increase in the time required to develop an innovation from idea to commercialization.

However, comprehensive analyses including a time perspective, of the innovations recorded in SWINNO are provided by Sjöö (2014) and Taalbi (2014). The present paper has the more limited aim to present the new SWINNO database and discuss its representativity, reliability, and validity for innovation research. The data in SWINNO are captured from articles in trade journals and hence the database is dependent on the coverage and the extent of changes in the editorial policies of these journals. The selection of journals is representative of the Swedish industry in broad sense; thus, besides manufacturing also the activity of some services, such as software, are reported. The common editorial policy of these journals is to watch significant developments in the respective trades. When interviewed, the editors of the journals stated that no weighty changes in this policy had been undertaken during the time period covered by SWINNO. Hence, we conclude that the record of innovations extracted from the journals is satisfactorily time consistent. A comparison with other statistics of innovation, such as the EU CIS, shows that Swedish "innovative firms" were far more numerous than the innovations in SWINNO. This underlines that the latter report the more significant innovations. The sectoral distribution of innovative firms, in CIS, and innovations, in SWINNO, are on the other hand broadly similar which suggest that different aspects of the same reality are captured by the measures. SWINNO offers time consistent evidence of actual innovation and this is an important contribution since most analyses, both of causes and consequences of innovation, are based on indirect evidence such as patents and R&D or non-time consistent surveys as the CIS.

SWINNO offers new opportunities for research on innovation. To begin with, a comparison with Finland, for which SFINNO provides the same kind of data, should be undertaken. One question is why the pattern over time is so different, with Sweden having a top in numbers of innovations around 1980 while Finland has had a rising trend since the 1970s and before.

An extension of SWINNO, in time and scope, is also crucial. To continuously update SWINNO beyond the present end year 2007 is a priority. However, innovation is associated with long-term development and to extend SWINNO backwards in time, on the basis of similar sources, would be possible back to the early 20$^{th}$ century. Other aspects of innovation waiting for a closer unravelling are organizational innovation and innovation carried out in the public services. These are to a limited extent captured by the Oslo Manuals criterion about commercialization but nevertheless critical for welfare and therefore important to comprehend.

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# Appendix 1A. Innovation Variables

| *Variable* | *Description* | *Number of innovations* |
|---|---|---|
| **ID** | Unique identification number | 4852 |
| **Name** | Name of the innovation, if any | 2431 |
| **EngName** | Name of the innovation in English, if any | 392 |
| **Descrip** | Description of the innovation, as text. | 4847 |
| **Source** | The article source, e.g. Ny Teknik 1970-1, p. 1-2. Each innovation may have up to ten (11) sources | 4852 |
| **Firm** | Name of the innovating firm, main responsible for the development of the innovation. | 4852 |
| **Contact_person** | Contact person(s) according to the journal article(s). Up to four (4) persons | 2296 |
| **Concern** | Name of the concern of the firm | 617 |
| **Location** | Location of the innovating firm as mentioned in the journal article(s) | 2198 |
| **Other notes** | Other notes. E.g. website address of the firm or quotes from the journal articles. | 597 |
| **Innovator** | Innovator(s), up to four (4). Both in-house innovators and original inventors are taken into account. | 335 |
| **Type** | Status of the innovation, expressed as numbers 1-5. 1 = available on the market, 2 = Not yet available on the market, 3 = Process innovation, 4 = Development not yet finished, 5 = Introduced before 1970 | 4852 |
| **Product code** | Five digit product code of the innovation according to Svensk Näringslivsindelning (SNI) 2002 | 4852 |
| **Art_Comp** | Artefactual complexity, expressed as numbers 1-3. 1 = High, 2 = Medium, 3 = Low. | 4612 |
| **Dev_Dev** | Developmental complexity, expressed as numbers 1-3. 1 = High, 2 = Medium, 3 = Low. | 4805 |
| **Com_Year** | Commercialization year of the innovation | 4177 |
| **Commissioned** | Name of the agent that has commissioned the innovation. | 137 |
| **Prev** | Name of firm previously responsible for the development of the innovation. Up to three (3) firms possible | 110 |

| | | |
|---|---|---|
| **Prev_Year_Start** | Previous developer started the development in year t | 11 |
| **Prev_Year_Stop** | Previous developer stopped the development in year t | 13 |
| **Firm_Nov** | Degree of novelty from the firm perspective, expressed as numbers 1-3. 1 = Totally new, 2 = Major improvement, 3 = Incremental improvement | 4638 |
| **Mark_Nov** | Degree of novelty from the perspective of the Swedish and the global market respectively, expressed as numbers 1-2. 1 = New to the Swedish market, 2 = New to the world market | 1327 |
| **Firm_Start** | The firm was founded to develop or commercialize the innovation. If so 1. | 540 |
| **Tech_Know** | Type(s) of technological know how involved in the development of the innovation. Technological know-how involved in the development of the innovation, expressed as numbers 1-4. 1 = Development of components and modules, 2 = Integration of components and modules, 3 = Development of production methods, 4 = Commercialization of service concepts, 5 = Other. All innovations are allowed four (4) entries. | 4611 |
| **Exploiter** | Names of other firm(s) exploiting the innovation. Up to five (5) firms. | 367 |
| **User** | User sector of the innovation. Up to eight (8) user sectors according to Svensk Näringslivsindelning (SNI) 2002. | 4654 |
| **Pat_App** | Is a patent application existing? 1 if yes. | 179 |
| **Pat_App_Firm** | Name of firm applying for patent. | 102 |
| **Pat_App_Pers** | Name of person applying for patent. | 12 |
| **Pat_Firm** | If a patent has been granted to a firm, name of the assignee (1-4 firms). | 146 |
| **Pat_Pers** | If a patent has been granted to a person, name of the assignee. | 14 |
| **Pat_Grant** | Has patent been granted? 1 if so. | 227 |
| **Pat_Swe** | Patent granted in Sweden, expressed as number "1" | 98 |
| **Pat_EPO** | EPO (European Patent Office) patent, expressed as number "1” | 14 |
| **Pat_USPTO** | USPTO (United States Patent and Trademark Office) patent, expressed as number "1”. | 16 |

| | | |
|---|---|---|
| **Pat_JPO** | Patent granted in JPO (Japan Patent Office), expressed as number "1" | 7 |
| **Pat_Other** | Patent granted elsewhere, expressed as number "1" | 15 |
| **Basic_Year** | The basic idea of the innovation was presented in year t. | 109 |
| **Dev_Year** | The development of the innovation started in year t. | 865 |
| **Prot_Year** | The first prototype was introduced in year t. | 262 |
| **Export_Year** | Export of the innovation began in year t. | 120 |
| **Export** | Export of the innovation has begun, expressed as number "1" if it has begun. | 183 |
| **Export_Nation** | If " Export " is "1", then to which countries, expressed as text according to standard abbreviations. | 58 |
| **Origin** | Which factors contributed to the origin of the innovation, expressed as variables 1-20 (1-5 alternatives). 1 = Price competition, 2 = Competition in performance, 3 = Threat posed by rival innovations, 4 = Shrinking market share or demand, 5 = Rationalization of production methods, 6 = Enable lower prices, 7 = Performance, 8 = Role of customers, 9 = Observation of market niche, 10 = Public procurement, 11 = Public research or technology program, 12 = Environmental factors, 13 = Official regulations, legislation and standards, 14 = Availability of license, 15 = New scientific discovery or breakthrough, 16 = New technologies or materials, 17 = Trial and error, 18 = Solution for a problem, 19 = Spinoff, 20 = Other factors | 4638 |
| **Origin_Alt_7** | Additional information if Origin = 7. | 2099 |
| **Origin_Alt_13** | Additional information if Origin = 13. | 32 |
| **Origin_Alt_15** | Additional information if Origin = 15. | 61 |
| **Origin_Alt_16** | Additional information if Origin = 16. | 383 |
| **Origin_Alt_18** | Additional information if Origin = 18. | 280 |
| **Origin_Alt_20** | Additional information if Origin = 20. | 397 |
| **Science_Spinnoff** | Science spinnoff. Expressed as "1" if yes. | 299 |
| **Science_Spinnoff_inst** | Spinn-off from research institute. Expressed as name of the research institute. Up to two (2) research institutes. | 57 |
| **Science_spinnoff_univ** | Spinn-off from university. Expressed as name of the university. Up to two (2) universities. | 233 |

| | | |
|---|---|---|
| **Prod_Only** | 1 if the firm produces the innovation but has not developed it. | 148 |
| **Collab** | Has the development of the innovation included collaboration with others, "1" if so. | 931 |
| **Collab_Firms** | Name of collaborating firm. | 565 |
| **Collab_Act** | Collaborating actor, expressed as types 1-15. Up to 5 collaborating actors are possible. The types are categorized according to: 1 = Other firms belonging to the same concern, 2 = Domestic costumers, 3 = Foreign costumers, 4 = Domestic consults, 5 = Foreign consults, 6 = Domestic subcontractors, 7 = Foreign subcontractors, 8 = Domestic universities, 9 = Foreign universities, 10 = Domestic research institutes, 11 = Foreign research institutes, 12 = Domestic firm, 13 = Foreign firm, 14 = Public institution, 15 = Publicly owned company, 16 = Other | 921 |
| **Collab_Act_Name** | Name of collaborating actor. Up to five possible. | 893 |
| **Collab_Act_Country** | If "Collab_Act" = 5,7,9,11 or 13, then from which country? | 908 |
| **Public_Prog** | Has a public technology program been involved in the development of the innovation, expressed as "1" if so. | 27 |
| **Public_Prog_Name** | If " Tech_Prog" = "1", then which program? Expressed as text. | 23 |
| **Finance** | Has external funding been received? "Yes" = "1" | 433 |
| **Finance_Source_Name** | If "Inno_Finance", then from where? Expressed as text. | 390 |

## Appendix 1B. Firm Variables (SCB)

***Variables available for the innovating firm and up to six collaborating firms.***

| *Variable* | *Description* |
|---|---|
| **SCB_Year** | Year of the SCB data |
| **Org_nr** | The firm's corporate identity number |
| **SCB_Firm_Name** | Firm's name |
| **Visiting address** | Visiting Address |
| **Vis_City** | City |
| **PostAdress** | Post Address |
| **Postal Code** | Postal Code |
| **Post_City** | City |
| **Telephone** | Telephone number |
| **Mun** | Municipality code, according to the Swedish municipality nomenclature (Rikets indelning). |
| **MunText** | Municipality, description |
| **EmpCl** | Employment class (1-16) according to the following categories: 0 = NA, 1 = 0 employees, 2 = 1 - 4 employees, 3 = 5-9 employees, 4 = 10-19 employees, 5 = 20-49 employees, 6 = 50-99 employees, 7 = 100-199 employees, 8 = 200-499 employees, 9 = 500-999 employees, 10 = 1000-1499 employees, 11 = 1500-1999 employees, 12 = 2000-2999 employees, 13 = 3000-3999 employees, 14 = 4000-4999 employees, 15 = 5000-9999 employees, 16 = 10 000 employees. |
| **EmpCl text** | Employment class, description |
| **Industry1** | Industry of main activity of the firm according to SNI69 (1970-1992), SNI 92 (1993-2002) and SNI 2002 (2003-2007) |
| **Industry1_text** | Industry of main activity of the firm in text |
| **Industry2** | Alternate industry of activity. |
| **Industry3** | Alternate industry of activity. |
| **No_Workstations** | Number of work stations of the firm. |
| **Turn_year** | Year of turnover classification |
| **Turn_class** | Turnover classification according to: 0 = 1 < tkr, 1 = 1-499 tkr, 2 = 500-999 tkr, 3 = 1000-4999 tkr, 4 = 5000-9999 tkr, 5 = 10000-19999 tkr, 6 = 20000- |

| | |
|---|---|
| | 49999 tkr, 7 = 50 000 – 99999 tkr, 8 = 100 000 – 4999 999 tkr, 9 = 500 000 – 999 999 tkr, 10 = 10000 – 4 999 999 tkr, 11 = 5000 000 – 9 999 999 tkr, 12 = > 9 999 999 tkr. |
| **Turn_class_text** | Turnover classification, textual description |
| **Start_year** | Year that the firm started |

## Appendix 2. Decision schedule of the classification of major product groups

| | **Choice** |
|---|---|
| **Cruise control** | Regular cruise controls 34300 for automotive vehicles. Automotive radars functioning as cruise controls are classified as 33200 |
| **Drilling machines** | 29520. If hand held 28622 |
| **Generators** | 31100 if the generator is built on electric power, 29110 if generating mechanic power (e.g. through gas turbines) |
| **Grinding machines** | Hand held 29410. For forming of metal 29420, for sanding of wood products 29430 |
| **Hand computers** | 32200 if designed for telephone or internet communication, otherwise 30020 |
| **Heat pump** | 29210 if for households, 29230 if for industrial use. If both 29210. |
| **Lamps** | 31501, unless a fluorescent (31502) |
| **Machines for printing of etiquettes and barcodes** | 30020 if the machine is a printer or prints bar codes, 29240 if a labeling machine |
| **Metal sheets** | iron sheets 27100, aluminum sheets 27410, 27320 if roof cover panels of self-produced metal sheets , 27330 if roof cover panels of bough metal sheets. |
| **Microwave oven** | 29210 if for industrial use, 29719 if for household use or both |
| **Minesweeper** | 35110 for minesweeping ships, 31620 for mine detectors, 29520 for mine sweepers for use in the mining sector |
| **Modems** | 32200 (not classified among computers, 30020) |

| | |
|---|---|
| **Motors** | Electric motors 31100, Gas turbine, steam turbine and boat engines counted 29110. Hydraulic motors 29120. Car motors 34300. Electric motors for lawn mowers have been categorized as 29230. |
| **Packing machines for clothes and textiles** | 29540 |
| **Planing machines** | Difference between planing machines for wood (29430) and metals (29420) |
| **Printing press machines** | If offset 30010, else 29569 |
| **Saw** | Hand held 28622, motor driven 29410 |
| **Spectrometer** | 33101 if employing X-rays, otherwise 33200 |
| **Systems for identification of fingerprints** | 30020 if computer based, 32100 if a sensor |
| **Systems for industrial control** | 30020 if computer based, otherwise 33300. |
| **Transport containers** | 34200 |
| **Vacuums** | If for household use 29719, else 29240 |
| **Weighbridges (for vehicles)** | 29240 (assumed not to belong to measuring instruments 33200) |

## Appendix 3. Overlap with Wallmark & McQueen (1991)

| **No. in Wallmark & McQueen (1991)** | **Description** | **Firm** | **Year (Wallmark & McQueen)** | **Found in SWINNO (Y/N)** |
|---|---|---|---|---|
| **74** | Pulp cooking, using a new control system | Mo och Domsjö | 1970 | N |
| **75** | The ORIGA cylinder, for linear motion | Origa Cylindrar | 1970 | Y |
| **76** | PENGLOBE, a semi synthetic penicilin | Astra | 1970 | N |
| **77** | SELOKEN, heart medicine, a selective beta blocker which reduces blood pressure and blocks pain signals during heart attacks | Hässle | 1970 | Y |
| **78** | CC-bearing, an improved C-bearing with self steering for reduced friction | SKF | 1972 | Y |
| **79** | Symmetrical door for both left hand and right hand doors | Svensk Dörrteknik | 1971 | N |
| **80** | OPTIVENT, transport and distribution of air in large buildings | Svenska Fläktfabriken | 1972 | Y |
| **81** | Plastic screen, for paper making machines, with two layers for dimensional stability | Nordiska Maskinfilt | 1972 | Y |
| **82** | The DOPPIN feeder, for feeding metal to stamp presses | Volvo Olofströmsverken | 1973 | N |
| **83** | The ASEA robot, especially the mechanical transmission allowing almost 360° rotation | ASEA | 1973 | Y |
| **84** | Electronic level meter for ships, using radar principles | Saab Marine Electronics | 1973 | Y |
| **85** | DIRIVENT, a ventilator using jet streams | Svenska Fläktfabr | 1974 | Y |

| | | | | |
|---|---|---|---|---|
| | | iken | | |
| **86** | Vacuum packaged clothes, for more efficient transport and storage | Tex Innovati on | 1974 | Y |
| **87** | High temperature steel, using rare earth elements | Avesta Jernverk | 1974 | Y |
| **88** | Sifting machine, for sorting material from mines | LKAB | 1974 | N |
| **89** | DEBRISAN, a treatment for sores with cleaning effect | Pharmac ia | 1975 | Y |
| **90** | Hydraulic mining machine, quiet, with recoil damping | Atlas Copco | 1975 | Y |
| **91** | Functional work clothes | Snickers Original | 1975 | N |
| **92** | Shaped corrugated metal products | Groko Maskin | 1975 | Y |
| **93** | Hand held computer terminal, for taking inventory | Micronic | 1976 | Y |
| **94** | The AXE system, a wholly electronic telephone system with functional modules | Ellemtel | 1976 | Y |
| **95** | The SAAB-TURBO, turbochargeed motor for cars | Saab Scania | 1976 | Y |
| **96** | Products made of pressed sheet metal, for example roofing | Kami | 1977 | Y |
| **97** | The CASH ADAPTER, a banking machine for handling bank notes | Inter Innovati on | 1978 | N |
| **98** | Self emptying railway cars, especially for mines and harbors | LKAB | 1978 | Y |
| **99** | SWEDOT, a price marking system for packages, etc | Swedot Systems | 1978 | Y |
| **100** | The steel band process, for making iron ore pellets | LKAB | 1979 | Y |