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## PATENTS AND TECHNOLOGICAL CHANGE – A REVIEW WITH FOCUS ON THE FEPOCI DATABASE

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**ABSTRACT:** Technological change and innovation is driven by the generation and accumulation of new knowledge. However, these processes are elusive from an empirical viewpoint and economists have put a lot of effort into identifying and developing appropriate indicators to measure knowledge and its development. The purpose of this paper is to provide insights into the use of patents as a generally accepted indicator of new knowledge and intermediate outputs of innovative activity more generally. It is intended as a background paper for further analysis based on the new, so-called FEPOCI, database on Finnish patents and related citations granted at the European Patent Office (EPO) from the years 1991-2004. We discuss the patent system and its general characteristics, identify patents as indicators of new knowledge and innovative activities, briefly review previous research using patent data, and introduce the FEPOCI database through presenting the search criteria used for the data retrieval, the included variables, and some basic descriptive statistics of the data for validation purposes.

**KEYWORDS:** Patents, citations, innovation, technological change, Finland.

**NIKULAINEN**, Tuomo **– PAJARINEN**, Mika – **PALMBERG,** Christopher, **PATENTIT JA TEKNOLOGINEN KEHITYS – KATSAUS KIRJALLISUUTEEN JA FEPOCI-TIETOKANNAN KUVAUS**. Helsinki: ETLA, Elinkeinoelämän Tutkimuslaitos, The Research Institute of the Finnish Economy, 2005, 26 s. (Keskusteluaiheita, Discussion Papers, ISSN, 0781-6847; No. 984).

**TIIVISTELMÄ:** Uuden tiedon ja osaamisen kertyminen on keskeistä teknologisen kehityksen ja innovaatiotoiminnan kannalta. Osaamisen ja tiedon mittaaminen on kuitenkin empiirisesti hankalaa ja taloustieteessä onkin panostettu paljon sopivien indikaattorien löytämiseksi. Yksi yleisesti hyväksytty indikaattori ovat patentit. Tämän työpaperin tavoitteena on esitellä patenttien käyttömahdollisuuksia innovaatiotoiminnan analysoinnissa. Lisäksi työpaperin tarkoituksena on olla käsikirja Etlatiedon uuden patenttiaineiston (FEPOCI) käyttöön. Aineisto sisältää Euroopan patenttiviraston (EPO) myöntämät patentit suomalaisille yrityksille ja keksijöille vuosilta 1991-2004. Tutkimuksen alussa tarkastelemme patentointijärjestelmää ja patenttien käyttöä innovaatiotoiminnan indikaattorina sekä teemme katsauksen patenttiaineistoja hyödyntäneeseen aikaisempaan taloustieteelliseen tutkimukseen. Sen jälkeen kuvaamme FEPOCI-aineiston sisältöä ja käyttömahdollisuuksia.

**AVAINSANAT:** Patentit, sitaatit, innovaatiot, teknologinen kehitys, Suomi.

# CONTENTS

# 1. INTRODUCTION

Knowledge has become the foundation for productivity advances and economic growth. This insight is now well anchored in theoretical and empirical research and it is also reflected in the widespread appeal of various policy concepts, such as "innovation systems", the "learning economy" or the "knowledge economy". New theoretical, empirical and policy developments do reflect a real transformation in the sense that knowledge – not labor, machines, land or natural resources – now is the key economic asset of industrialized countries. This holds true especially for Finland following the rapid transformation from essentially resource-, and investment-driven stages of growth into a knowledge-intensive economy, mainly through the success in the field of ICT (Dahlman, Routti and Ylä-Anttila, 2005).

Knowledge is an intangible asset which closely relates to technological change and innovation, the fundamental knowledge-generating processes in contemporary economies. Nonetheless, these processes are elusive from an empirical viewpoint. The late Joseph Schumpeter was a pioneer in the field and he took the first steps towards identifying some core aspects of technological change and innovation, especially through his definition of inventions, innovations and entrepreneurship (Schumpeter 1911/68, 1942/76). Subsequently, economists have put a lot of effort in developing indicators to elaborate further on these basic Schumpeterian insights. Patents have been an especially important source in this context.

A patent gives its owner a temporary monopoly over the knowledge involved. A patent embodies aspects of technological novelty, and is therefore often considered as an intermediate innovation-output indicator. Further, patent records contain a wealth of information that enables an extensive analysis of the origin, structure, diffusion and effects of innovative activities in industry. Since this type of information is available in long time series and cover a whole range of industries due to the general importance of patenting, patents are presently one of the prime indicators in the tradition of the economics of technological change and innovation.

The aim of this paper is to introduce a new database of patents developed at ETLA/Etlatieto for the purpose of analyzing various aspects of recent patterns of technological change in Finnish industries. The paper discusses the nature of patents in chapter 2, defines and reviews broad areas of previous empirical research in the field in chapter 3, and provides some basic description of the data in chapter 4 for data validation purposes. This paper also serves as a manual to the database to facilitate further research, discussed briefly in chapter 5.

# 2. The Patent System and Its Characteristics

## 2.1. INTELLECTUAL PROPERTY RIGHTS AND PATENTS

Intellectual property rights (IPRs) are essential for ensuring technological development and motivating innovative activities. Patents, copyright, utility models and trademarks are the most common legal methods for providing protection for ideas, inventions and innovations. The level of protection, reinforcement of rights and application areas are different for each of the property rights, but we will focus the discussion solely on the patent rights.

As suggested above, patents are the most interesting intellectual property rights, especially from the viewpoint of economics research. Patents provide us with abundance of information relating to actual inventions, related innovators, firms and other parties involved. In the following we will discuss the legal and economic meaning of patents, the role and the characteristics of the patent system and the actual patenting process.

Definition of a patent:
*"A document issued by authorized governmental agency, granting the right to exclude anyone else from the production or use of a specific device, apparatus, or process for a stated number of years [usually 20 years]", Griliches (1990)*

The patent system was developed to enhance the appropriability of inventions. Inventors need a mechanism to ensure financial and other benefits gained from their inventions and the patent system has so far provided a most useful method for achieving this goal. A patent provides monopoly rights over invention for a maximum of 20 years (there is some variation between different countries). Although a patent is an exclusive right, licensing of the patented technology is also allowed. In case of illegal reproduction or similar activities, it is the patent owner's responsibility to take action. No other party can enforce the patent rights and the disputes are settled in the court of law.

To maintain the patent the owner of the patent must annually pay a renewal fee up to maximum of 20 years. The amount paid increases over time in order to ensure that only patents with economic value higher then the annual renewable fee are maintained. The idea behind the patent system is to grant exclusive rights for the inventor, while at the same time compensate society for the monopoly status which the inventor has received by requiring disclosure of all the elements of the invention in the patent application. Through this disclosure it is ensured that the patented invention is reproducible, and provides a basis for rapid technological development, new inventions and technology diffusion.

A patent can be granted for an invention that is novel and nontrivial, and has a commercial application.[1] There are important limitations to the use of patent data, the most noticeable being the fact that not all inventions are patented. First, all inventions do not meet the novelty criteria set by patent offices. Sometimes the applicant might be

[1] Note than an invention typically is defined as a new idea, while an innovation is defined as a commercialized invention. This definition traces back to the seminal writings of Schumpeter (1911/1968).

unaware of this since he/she does not possess complete insights of the patent pool, or of the competitors themselves. Second, a patentable invention needs to be nontrivial, which implies that persons working in the same field also have the possibility to oppose the patent. Third, the invention also has to be reproducible in a commercial sense, and it must have a stated commercial application.

Typically inventions are categorized into products or processes. Process inventions rely heavily on other methods of protecting intellectual property rights, such as secrecy or tacit knowledge. For product inventions the use of these strategic options is much harder as the product enters the market and is vulnerable for e.g. reverse engineering. Hence, products are often protected by patents as discussed in Cohen et al. (2000).

## 2.2. THE PATENT SYSTEM

Patents are usually granted by government related institutions, of which the most important are USPTO (Unites States Patent and Trademark Office), EPO (European Patent Office) and JPO (Japan Patent Office) due to the size and importance of these markets. Patent rights are commonly granted for a certain geographic area - e.g. the USPTO covers the US and EPO covers the European countries. In Finland the corresponding national agency is The National Board of Patents and Registration (PRH – Patentti- ja rekisterihallitus).

The role of these institutions is, among other things, to grant patent rights and provide guidelines how to acquire and uphold them. As mentioned, most of these institutions work on a national level, while EPO operates slightly differently. EPO has an intermediary role with respect to national patent offices, since it pre-examines patents on a European level and can process patent application to a stage where, in principle, only formal ratification of patent grants in any one member states is required. EPO thereby contributes to streamlining patent application procedures at the European level for the common good of the member countries. This EPO procedure is described below in more detail. Currently EPO has 31 member countries and they represent all the major economies of Europe.

### *Patenting Process in Finland*

The first task for the applicant is to apply for a patent. In case of two similar patent applications, the first applicant has the advantage. In the application phase the patent application receives a priority number that will always follow the application, even in foreign patent systems.[2] The first part of the application process lasts around 18 months during which time the inventor and patent examiner at the PRH amend the application to its final form. Usually the application is communicated back and forth between the applicant and the PRH a few times before it achieves the final format. After 18 months of receiving the patent application the amended application is made public.

[2] When using patents in research, it has become a "standard" to use priority date in estimations as it is closest to the actual date of the invention.

In case of potential infringement, opposition against the patent should be made within nine months following the publication. The application can be amended or denied due to opposition during this phase of the patenting process. If the process proceeds without any problems, the patent rights can be granted and are valid for 20 years (if the renewal fees are paid annually).

*Patenting Process Abroad*

If the Finnish applicant has an interest in patenting the invention abroad, the application process is initiated during the national application phase. The most common way to patent outside Finland is to use the so-called PCT-route.[3] The application of patent rights directly to different countries is time consuming and costly. Therefore most of the applicants choose to use the PCT-route.[4]

The PCT-treaty provides an easier method for applying property rights in foreign countries. The PCT functions as a common step for foreign patenting. The first step is to apply for the PCT examination during the application process in the national patent system. The PCT-application is sent to another patent office (in case of Finland, to Sweden or EPO) where the application is re-examined. [5] After the re-examination, the PCT-application is approved and made public. The PCT publication is not equivalent to a patent right by default, but the PCT-route allows faster examination process in individual countries that recognize the treaty. After applying for a patent in a specific country, e.g. in the US the next step in the process is the publication of the patent application, after possible amendments to the application.[6] The time reserved for opposing the patent is around 9 months, and varies depending of the country in question. After the opposition period the patent is either amended, refused or granted.

The EPO patenting process, as analyzed in this paper, proceeds quite similarly as the PCT-route although with two exceptions. In an EPO-member country the inventor has the choice of either applying for a European patent through the 'PCT-route', or applying directly to EPO and after this register the patent in inventor's home country (this is the so-called 'direct EPO route'). The second difference is that after the EPO grant the patent has to be ratified in each member country to which the patent has been designated. However, there is no separate examination process in the designated countries, and ratification to each designated national patent agency is a relatively routine procedure. Only after this does the EPO patent gives the protection it is designed to provide.

The current trend is to increasingly use the PCT-route, as it provides an easier and faster route to patent internationally. In the figure below the patenting process is illustrated on the national and international level. For the same figure the patent family concept becomes clearer. A patent family term is defined to be a group of equivalent

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[3] The PCT (Patent Cooperation Treaty) is designed to facilitate international patenting through the World Intellectual Property Organization (WIPO).

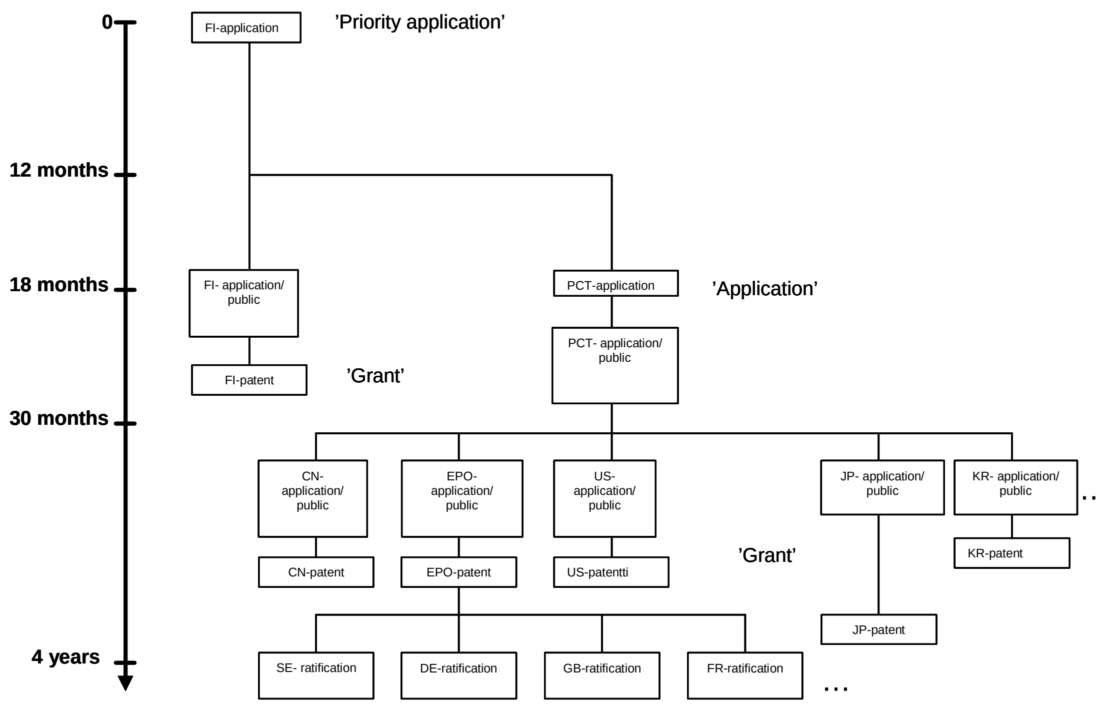
[4] The PCT-route is increasingly popular with the applicants and nowadays most international applications are done through this route.

[5] Recently (4th of April 2005) PRH has received the right to do PCT-examinations. Applicants can still ask for re-examination in Sweden or EPO.

[6] In the U.S. the applications were not made public before the year 2001.

patents granted in several countries for the same invention as a result of applications in those countries. A patent family cites the priority application of the original invention as the unique identification number common to all patent members of the family. Through the use of priority applications and numbers the patent families can thus be identified.[7]

Figure 1. A Typical Patenting Process




Notes: Adapted from Housh (1998).

# 3. The Use of Patent Data

## 3.1. Patents as Indicators

Patents are regarded as one of the most important indicators of innovative activity. This relates to the fact that patents by definition are inventions and represent technological change and development. The other reason why patents are used in economics research is the availability of the data as it is systematically collected, covers long time series, is electronically available and classified to technology specific categories[8].

There are also other S&T (science and technology) and innovation indicators such as R&D expenditures or R&D man-months collected through surveys such as the

[7] The size of patent family is sometimes used to estimate the economic value of a patent.

[8] IPC (International Patent Classification) indicates the technological category of patent.

Community Innovation Survey (CIS) by the EU and the Statistical bureaus, literature-based innovation output indicators (LBIO) and significant innovations identified in the literature and/or through expert opinion (for an example in the Finnish context see Palmberg et al. (1999)). These indicators are measuring mostly innovation input and are macro-level data. Some, for example LBIO, are measuring innovation output, but the data acquisition requirements and costs make wide scale research efforts practically difficult.[9] One of the important steps in innovation studies were the OECD innovation manuals, which provided guidelines for innovation studies.[10]

The usefulness of patent data in innovation studies is based on the information that the actual patent document provides. Each patent granted produces a highly structured public document containing detailed information on the invention itself, the technological area to which it belongs, the inventors (e.g. their geographic location), and the organization (if available) to which the inventors assign the patent rights.

In some studies patent applications are used instead of granted patents. The use of patent application is useful when the detailed content of the patent document is less relevant or when the date of invention is in focus.[11] The granted patents provide us with a more diversified picture of the patent and its characteristics. Patents have several advantages when measuring innovative output, but they also have some disadvantages that need to be addressed. In the following these advantages are weighted against the disadvantages commonly discussed in the literature (for further discussions see especially Griliches (1990); Patel & Pavitt (1995); Moed et al. (2004), and in Finland Lovio (1984)).

*Advantages*

The patent information is a *publicly available* document. Most of the patent information is online. Although most databases are either cumbersome to use or rather expensive, the availability of worldwide patent data makes it compelling. The *detailed information* provided in the patent documents enables researches to compare between firms, nations, inventors, etc. The patent information comprises of dates, description/IPC class, assignee, inventors, designated states, citations, legal information, etc. This data cover almost every field of technology and detailed disaggregating is possible. Patent data allows the use of *long time series* that generally start from 1970's or 80's and recently the data has become available in electronic format. The data has a *worldwide geographical coverage*, and with the current changes in data processing the use of data from different regions and patent offices has become possible.

*Disadvantages*

On the other hand, the criticism regarding the use of patent as indicator of innovative activity is also quite widespread. The *patentability* of technologies varies (e.g. pure software, genetically modified substances are not as readily patentable) and hence this

[9] See e.g. Kleinknecht et al. (2002).

[10] See OECD Frascati manuals (`www.oecd.org`), surveys by several authors.

[11] Patent applications have shorter lags than patent grants.

problem needs to recognized in comparisons across different technology fields, industries or firms. Patenting is also a *strategic option*, pending on the specific strategies that firms choose in protecting their intellectual property. This is especially true for process inventions and inventions with short lifecycles which rely on other means of protection (e.g. secrecy or lead-time).

Further, inventions can build on several patents, only part of the invention might be patented or patent builds on several inventions, and hence the *technological meaning* of a patent can be somewhat blurred. *Patenting practices varies* between countries and patent systems, and hence direct comparison without reservations is difficult. For analytical purposes there is problem of lags when using patent data. There exists a lag between application and grant dates (usually 3 years or more). In addition the *identification of technology fields* is tricky if technological knowledge of specific fields is not available.[12] This partially relates to the connection between technology fields and industries – or discrepancies in the origins and use of the invention and the related technologies. Not all patents in a certain technology category relate to same industry and vice versa. Also the costs of acquiring patent data and advanced patent indicators are high (e.g. citation data).

As a conclusion, it could be said that patents provide us with an intermediate output indicator of innovative activity. Balancing between the advantages and disadvantages is to some degree a question of different trade-offs in research. Once careful consideration of the special features of patent data is taken into account, patent-based analysis provides an abundance of new research areas and directions to cover. Also patents are so far the only readily available (intermediate) output indicators of innovative activity.

## 3.2. PATENT CITATIONS

Apart from using patent counts and the basic information that patent data contains, there has recently been an increasing interest towards using patent citations. A patent document comprises of two main elements: the actual information about the patented invention and the citations to other patents. Patent citations perform an important legal function in helping to delimit the patent grant by identifying "prior art" that is not covered by a given patent grant. Studies utilizing patent citations have used both backward and forward citations.

These citations open up the possibility of tracing multiple linkages between inventions, inventors, firms, locations, etc. The backward citations (or citations made) have been linked to the economic value of the patent.[13] The forward citations (or citations received) are linked both to the economic value and technological significance of the invention.[14] In addition, patent data include references to the scientific literature. These literature citations are commonly used to estimate the degree to which inventions rely on scientific knowledge (as opposed to technological/applied knowledge)

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[12] See Moed et al. (2004), chapter 9.

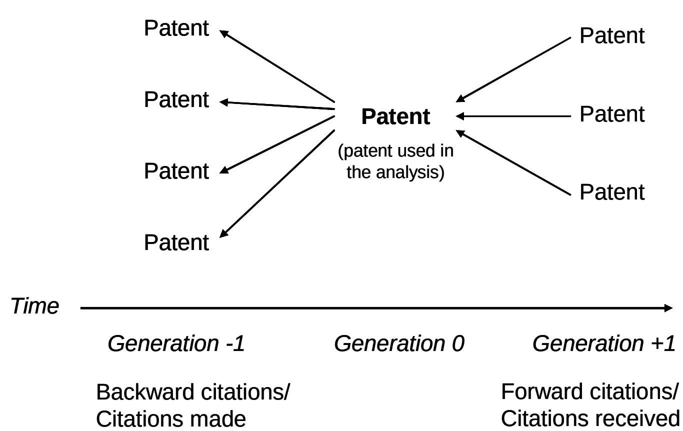
[13] See Harhoff et al. (1999).

[14] See Reitzig (2004).

and thus describe the science-base of inventions.[15] The backward citations are the referred patents that are included in the actual patent document, and the forward citations are the subsequent patents that refer to the patent in question.

The latter, forward, citations are more complex to acquire as they have to be constructed from all existing patents. Since they accumulate over time the most recent patents naturally have fewer citations compared with patents that have been around for several years. This problem can be dealt with by including the time-dimension in the analysis. In the figure below we have illustrated the logic underlying patent citations using a timeline.

Figure 2. The Patent Citations




## 3.3. PREVIOUS RESEARCH USING PATENT DATA

In this chapter we present some of the seminal contributions in economics which make use of patent data. First, we discuss the pioneers in the field and then show what has been done to validate the use of patents in economics. Thereafter we briefly introduce studies on patent value and R&D spillovers. We then move on to studies on science-technology linkages, and discuss the specialization/diversification and the internationalization of R&D as viewed through patent data. In Finland research using patent data has hence far been relatively scant and we only refer to research in which we, ourselves, have been involved in at ETLA/Etlatieto.

*The Pioneers*

The first pioneer in this field is undoubtedly Schmookler (1966) who studied the role of science, technology and growth. He presented demand-pull theories that focused on the benefits that will come from a new innovation. The research question he imposed was does science push technology and growth or is there a market pull of technology and growth? The research methods he used were tedious definitions of capital goods

[15] See Trajtenberg et al. (1992).

inventions with user/market orientation. He estimated patents sorted by industry of use on the value added in the industry of use. The results indicated a positive correlation between value-added and the number of patents, supporting the demand-induced hypothesis. Hence, on that basis we can say that the market pulls technology (and growth).

Another group of pioneers were Scherer (1982,1984) and researchers at the NBER (National Bureau of Economic Research) group in US. [16] One of their main interests was the direction of spillovers and technology flows. They created a technology flow matrix based on 'sector of origin' and 'industry of use' of patents of 443 largest US firms. Their contribution to patent studies was identification of the interrelationships between industries and technology fields. A seminal survey of using patent statistics in economics (that still is the basis for many patent related studies) was done by Griliches (1990).

*Validation Exercises*

The research of spillovers and technology flows was followed by validation exercises conducted by, among others, Pakes & Griliches (1984), Scherer (1983), Hall et al. (1986) and Acs & Audretsch (1989). These exercises aimed to answer the question – what do patents really measure? To answer this they used correlations between patents and R&D, productivity growth, profitability, stock market value of firms, etc. Among their conclusions were that patents are roughly proportional to R&D inputs, with ratio varying by industry and being higher for small firms. Patents are more weakly correlated with performance when compared with R&D.

*Patent Values*

During the same time with the validation exercises a lively discussion of patent values started and the research in this field is still very active. There is a vast amount of literature and research on patent values. The works of Pakes & Schankerman (1984,1986), Schankerman (1998), Lerner (1994), Lanjouw (1998), Harhoff et al. (1999) and Reitzig (2003,2004) have shed light on the dilemma of patent value. The questions they addressed related to the differing economic significance of patents and the value of patent portfolios. The topic was approached from several different angles through investigations of renewal rates, relationship to profits/stock market value, backward/forward citations, family size and legal disputes.

The conclusions from these studies are as diversified as the methods used. The results indicate that value estimates derivable from patent data differ greatly and have context-specific practical implications.

*R&D Spillovers*

The research area of R&D spillovers emerged alongside with the two previously presented topics. Some of the most noticeable contributions in this field include Jaffe (1984,1986), Trajtenberg et al. (1997) and Jaffe et al. (2002). They addressed the issue by

[16] Especially Zvi Griliches, Brownyn Hall, Manuel Trajtenberg, and Adam Jaffe.

examining the extent, direction and geographical concentration of spillovers. To analyze R&D spillovers various indicators were constructed around data on patent citations: generality (dispersion of patent citation received over technological classes), originality (calculated on the basis of citations made), self-citations, etc.

The major contributions of these studies were new indicators, a discussion of the characteristics of university and industry patents, evaluations of university research, identification of technology clusters, country comparisons, etc. [17] The research field of R&D spillovers is very active and this topic has gained momentum especially in Europe. With the increasing discussion of globalization and relocation of business activities the role of spillovers has growing effect on innovation activities.

*Science-Technology Linkages*

Patent data is also used to analyze the relationship between science and technology. These studies are based on bibliometric, technometric and citation analysis. This field of innovation studies was pioneered by Carpenter et al. (1981), Narin & Olivastro (1988), Narin (1993) Trajtenberg (1987), Trajtenberg et al. (1997), Jaffe (2002) and Dietmar Harhoff and Ulrich Schmoch at the Fraunhofer Institute for Systems and Innovation Research (Fhg-ISI), among others (see Moed et al. (2004)). The research questions are related to the strength of relationships between science and technology, sectoral/national patterns, and related S&T policy issues. The estimations are based on analysis of citations to other patents and the non-patent literature.

The contribution of these studies is the identification of the science-base and interdisciplinarity of industries, the development of the science-base of countries and the concordance between industry and technology classifications. In this field of patent studies some Finnish actors have been quite active.

*Specialization and Diversification*

One can also identify an empirical field that foremost takes an interest in the actual technologies covered by patents, as described by the patent classification system. This field of research focuses on patterns of technological diversification at the firm, industry or country level, of which prominent examples include Kodama (1986), Pavitt et al. (1989), Patel & Pavitt (1990,1994), Granstrand et al. (1997), Cantwell & Piscitello (2000), and Fai (2003), and Breschi et al. (2003). This literature usually takes a point of departure in resource-based viewpoints of the firm, which stresses the path-dependent nature of diversification. In Finland Palmberg & Martikainen (2004) studied the technological diversification of the telecom sector through combining patent and R&D alliance data.

The main contribution of this literature has been to highlight and explain converging or diverging patterns of technological diversification, and develop various methodologies and indicators for defining technological specialization and distance in a cognitive dimension.

[17] The NBER database.

*Internationalization of R&D*

A related topic to the one above has been the issue of the global dispersion and structure of R&D activities of firms (see especially Special Issue in Research Policy (Research Policy 28 (1999)); Serapio and Hayashi (2004)). In this field of empirical research, the inventor records of patent data are used to define the geographical origin of inventions and the structure of international inventor networks. It takes advantages of the fact that the assignee and the inventors of a patent often have different countries of origin since especially multinational firms often disperse their R&D to multiple sites globally. This field of research takes an interest in the nature of internationalization of R&D, as captured by the patent data. In Finland Palmberg and Pajarinen (2004) studied the global dispersion of the innovative activities of large Finnish firms from this perspective. This field of research also investigates issues related to international spillovers.

This research has contributed with a better understanding of the trends and nature of the internationalization of R&D of multinational firms, and has provided original 'hard' micro data on these developments to complement case studies and analysis of trade and investment patterns.

# 4. THE FEPOCI-DATABASE

## 4.1. SEARCH CRITERIA AND DATA RETRIEVAL

Patent data is available from various sources. The patent offices worldwide host the raw data in varying format, and some also offer on-line access to certain files. In addition, several intermediaries provide edited data with value-added features. These intermediaries foremost serve corporate customers and typically charge a high price. The existence of many different patenting routes also complicates data acquisition, since many different databases usually have to be pooled depending on the search criteria applied. Prominent patent data intermediaries include STN, Derwent and Questel.

A first issue to be tackled in data acquisition is the definition of the geographical coverage. Usually the patenting patterns of firms are similar to those of their main geographical markets, since firms seek IPRs in those markets where they sell products. Nonetheless, the USPTO is often considered as the most important patent office due to the technological sophistication and large market of the US. The EPO is likewise important due to the European coverage, especially for European firms. The importance of other national patent offices varies by the significant of the respective countries in terms of market size and growth. In the case of Finland, especially larger firms tend to patent at the USPTO in the first instance, while also smaller firms patent at the EPO and national offices. Our objectives were to gain the broadest possible coverage of Finnish firms, whereby EPO was considered the most relevant.

A complicating factor in this context is the fact that EPO patents might be granted either through the direct EPO route, or through the PCT route as discussed above (see figure 1). As will become evident also from the subsequent presentation of the data, Finnish patenting through the PCT route has picked up significantly since the early 2000s. As a consequence we decided to cover both so-called direct EPO grants and PCT grants.

The patent data for the FEPOCI-database was acquired from Questel Orbit upon recommendations from other researchers working with patent data to complement already existing data on EPO applications at ETLA.[18] The initial contact was in June 2004, while the complete data was delivered in December 2004. The acquisition process included several rounds of data specifications in order to specify the search criteria used. The primary data specification was the Finnish nationality of patents. We defined Finnish patents as those patents with either the inventor (any of the inventors involved in the patent) or the assignee (the legal entity holding the patent) country as Finnish. This is a common approach in the definition of the nationality of patents.[19]

Usually patent applications are more current than granted patents, since the application (and the priority) date are closer in time to the date of invention when compared with the grant date due to lengthy patent processing times. Since our primary interest was in citation data contained in the patent files to complement the data on applications, we had to take the point of departure in granted patents. Citation details are typically added to the patent fields during the processing period, but the complete citation data are best available in the files of granted patents. The search criteria included both forward and backward citation data. Nonetheless, the analysis can also be anchored to the priority or application date if this is deemed better, even though the database does not contain those patent applications which have not received a grant.

Apart from these considerations we narrowed down data retrieval to only cover the period starting from 1.1.1991. As will also become evident from the subsequent presentation of the data, Finnish patenting activity really only starts in the early 1990s (this is also the case for Finnish patenting at the USPTO) whereby prior years would not have added noteworthy number of patents. It should nonetheless be noted that priority and application dates of the granted patents might, and typically do, extent back to the 1980s due to longish data application processing procedures (the time to process patent applications to granted patents at the EPO is 30-70 months). [20] Further, the citation data also extends beyond the 1990s especially for patents granted in the early or mid 1990s.

The data was delivered in Excel-format for easy processing in statistical software programs. In effect, the data includes patents granted between 1.1.1991 and 8.12.2004.

## 4.2. DATA DESCRIPTION

Table 1 presents the variables from the data delivery. The original data consists of two files. The first file includes information on granted EPO and PCT patents over 1991-2004. In the data patents are identified by publication number (XPN); there are also separately publication numbers for EPO (XPN1) and PCT (XPN2) patents. Date infor-

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[18] FEPOCI (**F**innish **EPO**-patents and **Ci**tations).

[19] Moed et al. (2004), chapter 9.

[20] See Moed et al. (2004), chapter 9, p. 216-219 for more detailed discussion. In the case of Finnish applications, our data reveal that the median of the process time was 52 months in the early 1990s increasing to 62 months in the more recent years. The earliest applications in our data are from 1983 and totally 10 percent of applications are from the 1980s. In contrast, the number of applications drops quite substantially since 2000 due to process time: there are in the data over 700 applications from 1999, about 550 from 2000, 230 from 2001, 40 from 2002 and 5 from 2003.

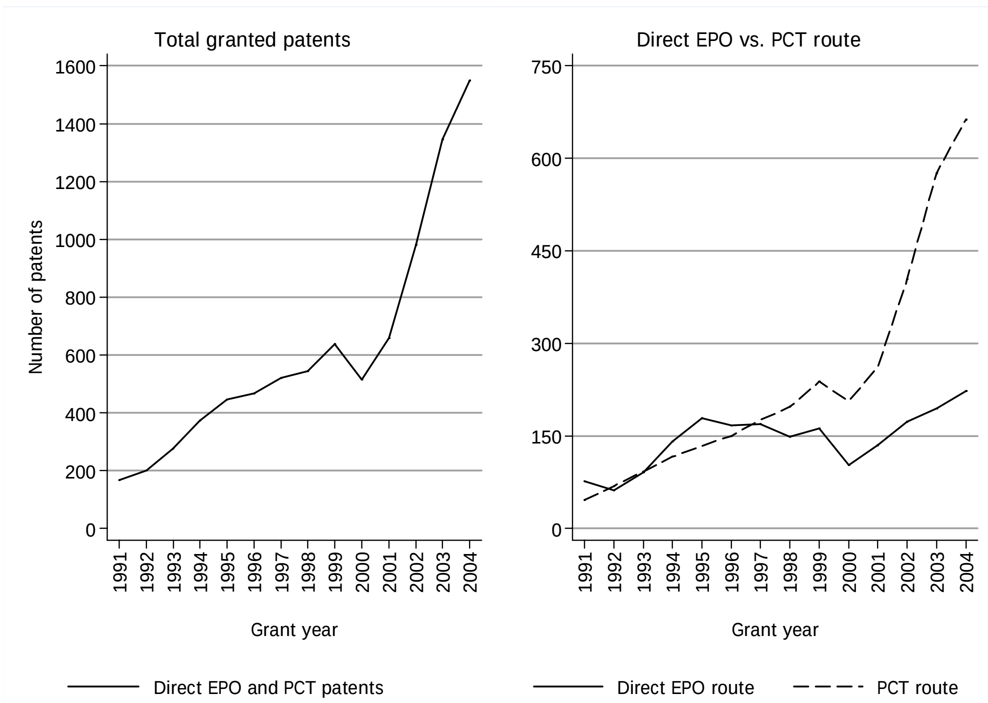
mation includes application, priority, publication and grant dates. The data on inventors contains the names of inventors (INN) and their countries (INC). Regarding assignees, there are the names (PAN) and country codes (PAC). Furthermore, both main and secondary IPC codes, and a short title of the patents are available. The second file consists of citations for granted patents. From each citing/cited patent inventor and assignee names and their countries, IPC codes and publication details (publication number, status code and publication date) are available.

Table 1. List of Variables Acquired from Questel Orbit

| | |
|---|---|
| Information on granted patents | |
| XPN: | standardized publication number |
| EGD: | European grant date |
| XPN1: | standardized publication number of EP publication |
| XPN2: | standardized publication number of PCT publication |
| PN1: | publication details EP document |
| PN2 : | publication details PCT document |
| PD1 : | publication date EP document |
| PD2: | publication date PCT document |
| PRD: | priority date |
| APD: | application date |
| XCT: | standardized publication numbers cited by XPN |
| PAN: | patent assignee |
| PAC: | patent assignee country |
| INN: | inventor name |
| INC: | inventor country |
| IC1: | main IPC code |
| IC2 : | secondary IPC codes |
| TI : | title |
| Information on citations | |
| Basic XPN: | standardized publication number |
| XPN cited: | standardized publication number cited by the "basic XPN" |
| XPN citing: | standardized publication number that cites the "basic XPN" |
| PN: | publication details of the cited/citing publication |
| PAN: | patent assignee in the cited/citing publication |
| PAC: | country of origin of the patent assignee in the cited/citing publication |
| INN: | inventor name in the cited/citing publication |
| INC: | country of origin of the inventor in the cited/citing publication |
| IC: | IPC codes on the cited/citing publication |

The FEPOCI-database contains data on 8791 EPO and PCT patents and 41977 citations for these patents from the years 1991-2004. Due to duplication of patent information, i.e. in cases where a patent has both an EPO and PCT publication number, the number of "unique" patents drops to about 5300.[21] Of these 62 percent have both EPO- and PCT- status and the rest only EPO status. Figure 3 depicts the number of granted patents over time. We can see from the figure that patenting activity has intensified over time. In addition, the PCT route seems to have been more popular staring from the early 2000s when compared with the direct EPO route.

Figure 3. EPO-Patents Granted Through the Direct EPO and PCT Route




Notes: Data source is the FEPOCI-database.

We have augmented the original data in several ways. *First*, we have coded technology field for patents based on Mancusi (2003) and OECD (1994). There are two versions of technology fields, the broader include six fields and the more diversified include 30 fields (see Appendix 1 for details). Figure 4 illustrates the number of granted patents over time by six technology fields. The more diversified categorization is presented in Appendix 3.

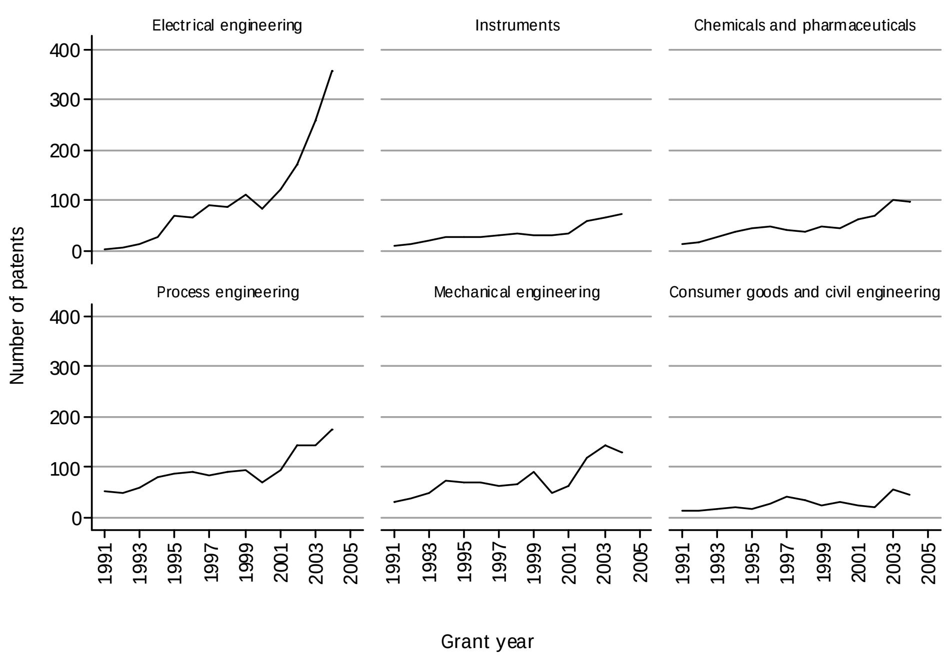
Figure 4 reveals that the patenting activity has increased particularly in the field of electrical engineering, even though we record growth in the other groups as well. The trends and differences are compatible with developments and the structure of Finnish industries. The rapid increase in granted patents in the field of electrical engineering is foremost due to the emergence and international breakthrough of Nokia in the

[21] In the original data the patents having both PCT and EPO grant status are recorded twice in the data sheet. In this descriptive analysis we have dropped duplicates.

field of telecommunications. This also explains why such a large share of granted patents falls into the field of electrical engineering, even though several other smaller firms also patent in this field.

The quite high levels of patenting in process engineering and mechanical engineering are also mainly due to the patenting activity in a couple of fields, particularly thermal processes and handling (see Appendix 3). Both of these two fields are related to the forest-based industries in Finland, which mainly comprise of firms from the pulp & paper and engineering industries.

Figure 4. Patents by Grant Year and Technology Field

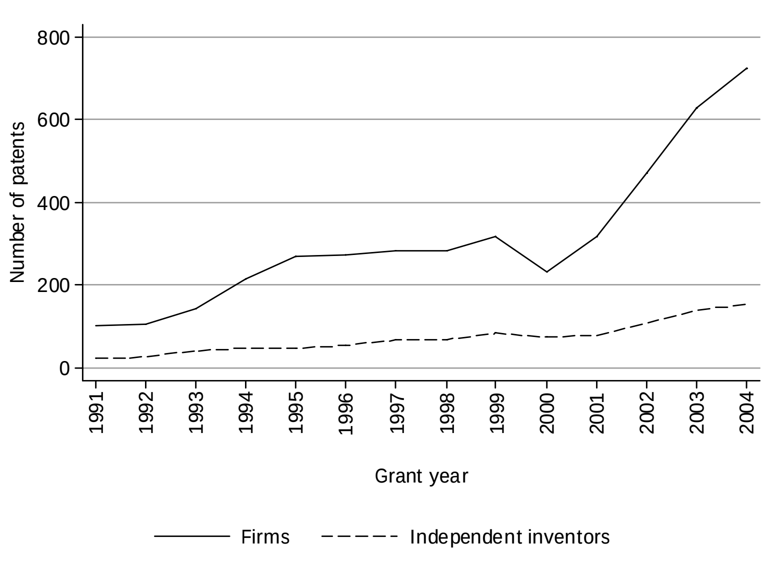



Notes: Data source is the FEPOCI-database. Technology fields are based on Mancusi (2003) and OECD (1994). See Appendix 1 for details and IPC codes. Appendix 3 depicts patenting activity by 30 technology field.

*Second*, the original data fails to separate assignee types (companies versus independent inventors). We have augmented the data by coding an indicator variable for companies. This has been done based on information in the assignee name field and by utilizing the fact that a majority of the firms have some sort of company identity in their names ("oy", "ab", "ky", "osakeyhtiö", etc.). Figure 5 depicts granted patents by assignee type.

We can note from the figure that particularly the number of patents granted for firms have increased dramatically since 2000. Generally speaking, it is clear that the largest share of the increase in patenting activity is due to a more active stance vis-à-vis patenting within firms rather than amongst independent inventors. Nonetheless, independent inventors do also patent persistently and at an increasing rate over time.

Figure 5. Patents by Grant Year and Assignee Type



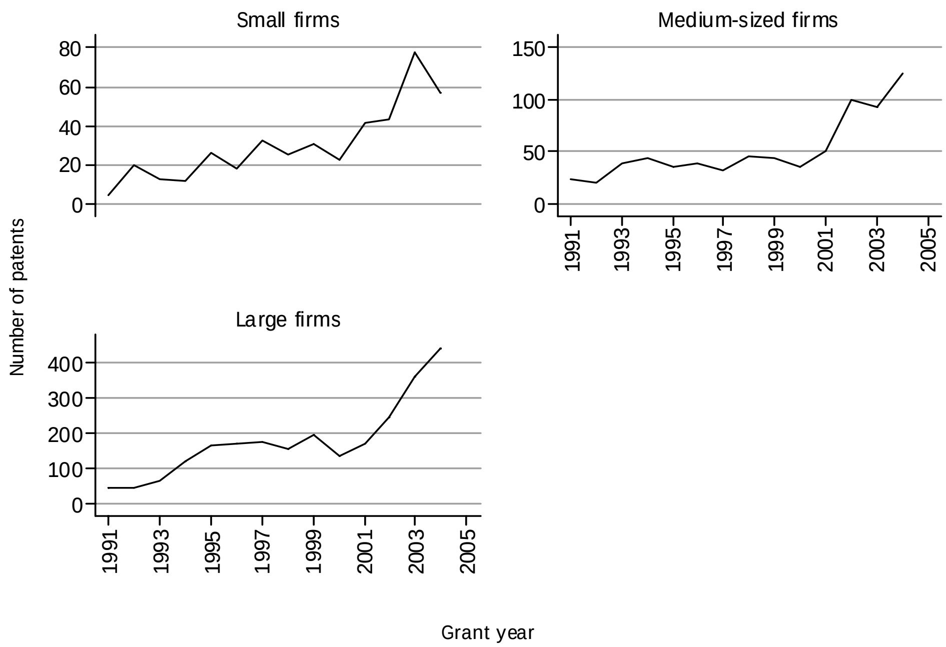

Notes: Data source is the FEPOCI-database.

*Third*, the patent data have been matched with a large company information database originating from Asiakastieto Ltd. This matching process enhances the database by financial statement information for company type of assignees. The matching has been done by using "standardized" company name as a matching variable. The standardization of name field included, for instance, trimming the name (removing all extra white spaces), converting Scandinavian alphabets and equivalents (ä -> a, ae -> a, etc.), removing all special characters (/, *, ', etc.), and dropping company identity indicators ("oy", "ab", "yhtymä", etc.) because their placement and writing style in the name field did not seem to be unique across databases.[22] The matching was finalized by manually checking in some special cases in which there were known name changes.

We have utilized the results of the matching in Figure 6 which illustrates granted patents by firm size group. There is an upward trend in patenting in the each firm size group, with the clearest increase noticeable amongst the large firms. This confirms the insights of the previous figure on the distribution of patents by assignee type. The increasing importance of large firms according to Figure 6 is also compatible with the emergence and growth of Nokia. It is also compatible with the quite high patenting activity in the forest-based engineering industries which are dominated by a few large firms like Metso and Ahlstrom. In addition, Kone Corporation in the field of mechanical engineering, and Neste/Fortum in the field of chemicals are active in patenting. A surprising result is the drop since 2003 in patents granted to small firms. This results calls for further analysis of patenting activity in the small size group.

[22] This kind of matching based on company names is far from perfect for several reasons. For instance, firms change their names over time and these changes are often recorded in the databases with different time lags. Moreover, in the large firm size group the level of aggregation is a problem because there can be a parent company, the whole group and several subsidiaries that have (almost) identical name.

Figure 6. Patents by Grant Year and Firm Size Group

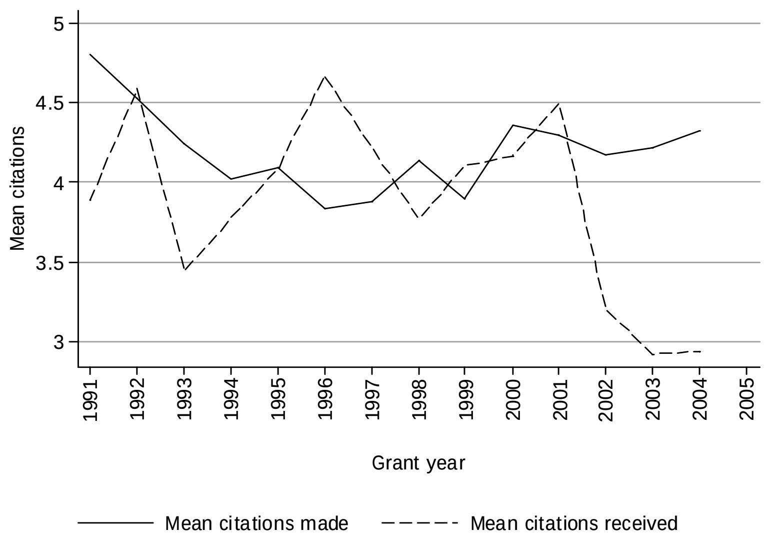



Notes: Data source is the FEPOCI-database. The Y-axis has been rescaled for each group. Groupings are based on the number of employees: small firms have less than 50 employees, medium-sized firms 50-250 employees and large firms over 250 employees.

Figures 7 and 8 illustrate the patent citation data. Figure 7 depicts mean number of citations made and received by granted patents over 1991-2004. We can see that the mean of citations received decreases quite dramatically since 2001. This result is compatible with the fact that mean citations received decreases as a function of time since recently granted patents are given less time to receive citations.

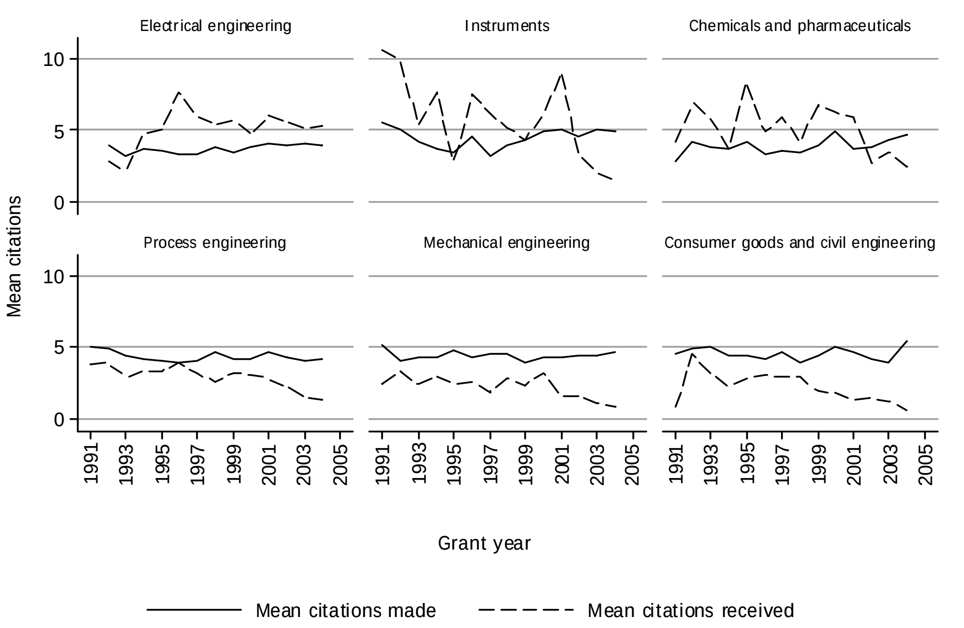
Although we refrain from making any in-depth analysis in this paper, the greater fluctuation in the mean citations received (discounting developments since 2001) might be taken to indicate a greater fluctuation in the perceived technological and commercial importance of Finnish granted patents (see discussion above). This kind of interpretation is especially interesting when looking at mean citations by technology fields in Figure 8. There is a general tendency for the more R&D-intensive fields to have a higher mean for citations received when compared with less R&D-intensive and more traditional technology fields. This result might point to the more generic and enabling nature of the fields of electrical engineering, instruments, and chemicals. This result is compatible with similar analysis in Jaffe and Trajtenberg (2002).

Figure 7. Mean Citations Made and Received by Grant Year




Notes: Data source is the FEPOCI-database.

Figure 8. Mean Citations Made and Received by Grant Year and Technology Field




Notes: Data source is the FEPOCI-database. Technology groups are based on Mancusi (2003) and OECD (1994). See Appendix 1 for details.

## 5. Concluding Discussion

The purpose of this paper was to discuss the use of patents as a generally accepted indicator of new knowledge and intermediate output of innovative activity. We discuss the patent system and its general characteristics, introduce patents as indicators, compare the advantages and disadvantages of using patent data in economics research, and review previous research using patent data. The most important contribution of this paper was to introduce and describe the FEPOCI-database with an eye to further analysis of technological change in the Finnish industries.

The database consists of patents and citations granted by European Patent Office (EPO) that have a Finnish assignee and/or inventor, and complements previous data at ETLA on European patent applications. Basic descriptive statistics of the data reveals that Finnish patenting at EPO has increased significantly, especially since the early 2000s. This increase is primarily due to developments in the field of electrical engineering, and largely relates to the breakthrough of Nokia as the largest firm in the Finnish economy. Nonetheless, patenting has also picked up in other technology fields and firm size groups. The development and structure of patenting is compatible with the overall development of Finnish industries, and thereby validates the data contained in FEPOCI. The level and development of backward and forward citations in also in line with observations from research in other countries, by and large. The FEPOCI database thus appears as a useful data source for further in-depth research.

There are several interesting research areas that can be pursued in this context. In the near future the FEPOCI database will be matched with other firm level data and extant databases at ETLA/Etlatieto. Of the areas of previous research that we discussed in this paper, our primary focus will be on issues researchable through the data on backward and forward citations of granted Finnish patents. These include patent values, R&D spillovers, and the internationalization of R&D.

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# Appendix 1. Technology Fields for Patents (IPC Codes)

I. Electrical engineering
- 1. Electronic devices and Electrical engineering
  - G05F, H01B, H01C, H01F, H01G, H01H, H01J, H01K, H01M, H01R, H01T, H05B, H05C, H05F, H05K, F21, H02
- 2. Audio visual technology
  - G09F, G09G, G11B, H03F, H03G, H03J, H04R, H04S, H04N3, H04N5, H04N9, H04N13, H04N15, H04N17
- 3. Telecommunications
  - G08C, H01P, H01Q, H03B, H03C, H03D, H03H, H03K, H03L, H03M, H04B, H04H, H04J, H04K, H04L, H04M, H04N1, H04N7, H04N11, H04Q
- 4. Information technology
  - G06, G10L, G11C
- 5. Semiconductors
  - H01L

II. Instruments
- 6. Optics
  - G02, G03B, G03C, G03D, G03F, G03G, G03H, H01S
- 7. Control and measurement technology
  - G01B, G01C, G01D, G01F, G01G, G01H, G01J, G01K, G01L, G01M, G01N, G01P, G01R, G01S, G01V, G01W, G04, G05B, G05D, G07, G08B, G08G, G09B, G09C, G09D, G12
- 8. Medical technology
  - A61B, A61C, A61D, A61F, A61G, A61H, A61J, A61L, A61M, A61N

III. Chemicals and pharmaceuticals
- 9. Organic chemistry
  - C07C, C07D, C07F, C07H, C07J, C07K
- 10. Macromolecular chemistry and Polymers
  - C08B, C08F, C08G, C08H, C08K, C08L, C09D, C09J, C13L
- 11. Pharmaceuticals and Cosmetics
  - A61K
- 12. Biotechnology
  - C07G, C12M, C12N, C12P, C12Q, C12R, C12S
- 13. Materials and Metallurgy
  - B22, C01, C03C, C04, C21,C22
- 14. Food and Agriculture
  - A01H, A21D, A23B, A23C, A23D, A23F, A23G, A23J, A23K, A23L, C12C, C12F, C12G, C12H, C12J, C13D, C13F, C13J, C13K

IV. Process engineering
- 15. Chemical engineering
  - A01N, C05, C07B, C08C, C09B, C09C, C09F, C09G, C09H, C09K, C10B, C10C, C10F, C10G, C10H, C10J, C10K, C10L, C10M, C11B-C-D
- 16. Surfaces
  - B01B, B01D, B01F, B01J, B01L, B02C, B03, B04, B05B, B06, B07, B08, F25J, F26
- 17. Materials processing
  - B05C-D, B32, C23, C25, C30
- 18. Thermal processes
  - A41H, A43D, A46D, B28, B29, B31, C03B, C08J, C14, D01, D02, D03, D04B, D04C, D04G, D04H, D05, D06B, D06C, D06G, D06H, D06J, D06L, D06M, D06P, D06Q, D21
- 19. Oil and Basic material chemistry
  - F22, F23B, F23C, F23D, F23H, F23K, F23L, F23M, F23N, F23Q, F24, F25B, F25C, F27, F28
- 20. Environmental technology
  - A62D, B01D46, B01D47, B01D49, B01D50, B01D51, B01D53, B09, C02, F01N, F23G, F23J

V. Mechanical engineering
- 21. Machines and Tools
  - B21, B23, B24, B26D, B26F, B27, B30
- 22. Engines and Pumps
  - F01B, F01C, F01D, F01K, F01L, F01M, F01P, F02, F03, F04, F23R
- 23. Mechanical elements
  - F15, F16, F17, G05G
- 24. Handling
  - B41, B66, B67, B25J, B65B, B65C, B65D, B65F, B65G, B65H
- 25. Food processing
  - A01B, A01C, A01D, A01F, A01G, A01J, A01K, A01L, A01M, A21B, A21C, A22, A23N, A23P, B02B, C12L, C13C, C13G, C13H
- 26. Transport
  - B60, B61, B62, B63B, B63C, B63H, B63J, B64B, B64C, B64D, B64F
- 27. Nuclear engineering
  - G01T, G21, H05G, H05H
- 28. Space technology
  - B63G, B64G, C06, F41, F42

VI. Consumer goods and civil engineering
- 29. Consumer goods
  - A24, A41B, A41C, A41D, A41F, A41G, A42, A43B, A43C, A44, A45, A46B, A47, A62B, A62C, A63, B25B, B25C, B25D, B25F, B25G, B25H, B26B, B42, B43, B44, B68, D04D, D06F, D06N, D07, F25D, G10B, G10C, G10D, G10F, G10G, G10H, G10K
- 30. Civil engineering
  - E01, E02, E03, E04, E05, E06, E21

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Notes: Technology fields are based on Mancusi (2003) and OECD (1994).

# APPENDIX 2. MEAN CITATIONS MADE AND RECEIVED BY GRANT YEAR AND TECHNOLOGY FIELD

Mean citations made

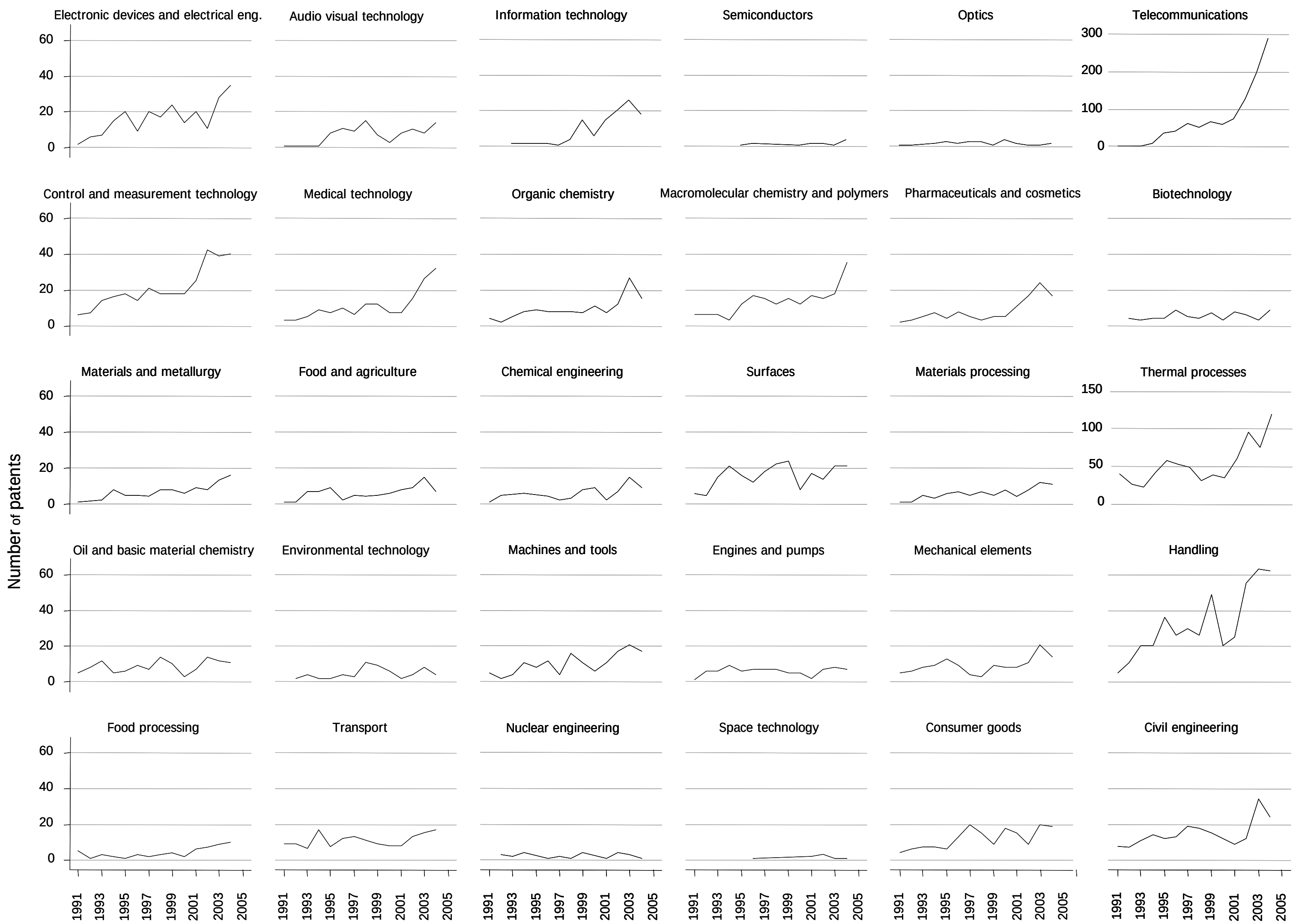
| | Electrical engineering | Instruments | Chemicals | Process engineering | Mechanical engineeri | Consumer goods and civil eng. |
|---|---|---|---|---|---|---|
| 1991 | | 5.60 | 2.86 | 5.04 | 5.24 | 4.50 |
| 1992 | 4.00 | 5.00 | 4.41 | 4.87 | 4.03 | 4.92 |
| 1993 | 3.18 | 4.16 | 3.76 | 4.39 | 4.29 | 5.00 |
| 1994 | 3.64 | 3.67 | 3.64 | 4.10 | 4.21 | 4.36 |
| 1995 | 3.59 | 3.43 | 4.10 | 4.02 | 4.75 | 4.33 |
| 1996 | 3.26 | 4.54 | 3.33 | 3.92 | 4.25 | 4.00 |
| 1997 | 3.36 | 3.17 | 3.50 | 4.13 | 4.56 | 4.73 |
| 1998 | 3.82 | 3.94 | 3.51 | 4.61 | 4.57 | 3.85 |
| 1999 | 3.48 | 4.39 | 4.00 | 4.12 | 3.95 | 4.35 |
| 2000 | 3.82 | 4.86 | 4.93 | 4.19 | 4.28 | 5.17 |
| 2001 | 4.11 | 5.06 | 3.72 | 4.60 | 4.21 | 4.67 |
| 2002 | 3.96 | 4.62 | 3.77 | 4.16 | 4.42 | 4.10 |
| 2003 | 4.04 | 5.05 | 4.35 | 3.93 | 4.44 | 3.81 |
| 2004 | 3.95 | 4.91 | 4.77 | 4.15 | 4.62 | 5.37 |

Mean citations received

| | Electrical engineering | Instruments | Chemicals | Process engineering | Mechanical engineeri | Consumer goods and civil eng. |
|---|---|---|---|---|---|---|
| 1991 | | 10.60 | 4.14 | 3.77 | 2.28 | 0.83 |
| 1992 | 2.83 | 9.82 | 7.18 | 3.89 | 3.29 | 4.46 |
| 1993 | 2.18 | 5.42 | 7.10 | 2.90 | 2.37 | 3.11 |
| 1994 | 4.80 | 7.63 | 3.67 | 3.25 | 2.97 | 2.32 |
| 1995 | 5.04 | 2.82 | 7.66 | 3.34 | 2.42 | 2.78 |
| 1996 | 7.52 | 7.50 | 4.88 | 3.80 | 2.42 | 2.08 |
| 1997 | 5.97 | 6.13 | 5.90 | 3.31 | 2.03 | 3.03 |
| 1998 | 5.44 | 5.18 | 4.37 | 2.42 | 2.78 | 2.88 |
| 1999 | 5.67 | 4.32 | 6.51 | 3.16 | 2.44 | 1.87 |
| 2000 | 4.69 | 6.10 | 6.26 | 3.13 | 3.26 | 2.57 |
| 2001 | 6.08 | 9.06 | 5.40 | 2.74 | 1.49 | 1.25 |
| 2002 | 5.59 | 3.26 | 2.38 | 2.20 | 1.51 | 1.38 |
| 2003 | 5.08 | 1.97 | 3.47 | 1.48 | 1.03 | 1.02 |
| 2004 | 5.30 | 1.42 | 2.87 | 1.28 | 0.72 | 0.58 |

Notes: 1991 data on electrical engineering has been excluded due to small number of patents.

# APPENDIX 3. PATENTS BY GRANT YEAR AND 30 TECHNOLOGY FIELD




Notes: Telecommunications and thermal processes have different scales on the y-axis. See Appendix 1 for details for technology fields.

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