Chapter 5

Driving forces of patent applications at the European Patent Office: a sectoral approach

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Modules: C, E
Software used: Eviews

1 Introduction

Patent filings are one of the most important output indicators for the analysis of technological progress. Many studies have analysed the interdependencies between patent applications and the expenditures for research and development (R&D) (Janz et al. 2001, Kortum and Lerner 1999), foreign trade flows (Fagerberg 1988, Greenhalgh 1990, Wakelin 1997) or production (Jungmittag et al. 1999). However, these studies used – in most cases – a product-based approach or the objects of the analyses have been complete countries, because an adequate concordance between technological output and economic sectors (or branches) is not yet available.

Whereas the scope of the above mentioned studies is usually the analysis of economic performance, the aim of this project is to investigate the dependency of patent filings on other economic factors. So the main interest is to uncover and quantify these dependencies. This is done by the following macro approach which is complemented by the micro level analysis reported in Chap. 8.

The consideration of micro-level data alone does not take into account the economic and technological framework of sectors or national economies, which can be assumed to have a certain impact on patent filings. Furthermore, it is much easier to obtain information on sectors than on individual firms, so that it becomes more efficient to get sophisticated forecasts in the future. Most official statistics are provided on the basis of branches and/or national economies, so one solution to this problem is to shift to a higher grade of aggregation and to analyse sectors or national economies. This was done by using a concordance between economic and technological fields.

Time series of the relevant data from 1987 to the present are provided. These data are used to estimate time series models. Due to the restricted length of the time series and the assumption that patent filing depends both on sector characteristics and national idiosyncrasies, the time series are pooled both over sectors, respectively countries, separately and together. The models imply the number of patents as the dependent variable and independent variables like R&D expenditures (source: OECD ANBERD). However, Kortum and Lerner (1999) have observed a change in the patent-R&D relationship in the US, and Janz et al. (2001) have shown, based on German company data, that the relationship between R&D and patenting has become looser. Therefore, other explanatory variables have to be included in the regression analysis. Besides internal sources of information like R&D employees, companies rely in their innovation processes also on externally available knowledge. For science-based industries, publications of the scientific community are important. However, these links are very loose and currently no concordance exists between science classifications and industrial sectors. Therefore, we will rely primarily on the publicly available pool of technological know-how embedded and codified in technical rules and standards. Based on a pooled time series analysis, Blind and Grupp (2000) found a positive relationship between the stock of standards and the output of patent applications. This approach may be extended to other countries.

The growing international interdependencies of companies increase their interfaces with other companies which may also increase the likelihood of patent-related conflicts. An indicator for this networking phenomenon may be the development of relative export flows of sectors (source: OECD STAN). For comparison, we also analyse the influence of economic activity in general measured by the development of value added. Other influential factors to be included may be market structures of sectors like the concentration ratios or the average company size, although data will not be available for all European countries. Nevertheless, all these additional explanatory variables should improve the quality of forecasts of future patent applications at the EPO.

2 Using a concordance between patents and economic factors[1]

There have been a number of attempts in the past to establish a link between technological and economic indicators. However these concordances have not found satisfactory solutions to the following four problems: (1) international comparability, (2) level of disaggregation (3) strong empirical basis, (4) easy applicability to specific problems. Furthermore, since some of these were established, industrial structures have changed, necessitating a change in the nomenclatures.

The earliest attempt at linking technology and industry classifications were done by classifying the patent applications of four countries by NACE classes. This was based on rather an intuitive approach, and was not really based on a systematic analysis that could lead to a well-defined concordance table.

Later, Evenson and Puttnam (1988) use data from the Canadian Patent Office, where patent examiners simultaneously assigned IPC codes, together with an industry of manufacture and sector of use, to each of 300 000 patents granted between 1972 and 1995. On the basis of these data, they established a cross-tabulation between 8 IPC sections and 25 industries, called the Yale-Canada patent flow concordance. The two main problems with this approach which limit its value in terms of practical applications are: (a) it is based on Canadian SIC, which needs to be translated to either ISIC Rev 3 or NACE; and (b) it is not very detailed in terms of IPC codes. An additional difficulty is that the relationship between sectors and technologies has distinctly changed during the period 1972 to 1995.

Verspagen et al. (1994) suggested a concordance scheme between four-digit level IPC subclasses and 22 (2 and 3 digit) industrial classes based on ISIC (rev. 2), the so-called MERIT Concordance. The linkage was established by an intellectual approach, and was based on a similar concordance of Statistics Finland. In this approach, many of the 625 IPC subclasses are linked with different weights to different sectors, so that it is quite time-consuming to calculate statistics for specific sectors.

In the 1980s, the USPTO established a detailed concordance between subclasses of the USPC and 41 unique classes of the US Standard Industrial classification, and this is used to produce regular statistics of US patents by SIC sectors. This is simply done on the basis of examining the definition of each USPC class (and sometimes subclass) and assigning them to one or more of the 41 industrial classes. For our purposes, this

1 The following parts follow closely Schmoch et al. (2003).

concordance has some of the problems already identified above. It is based on the USPC and not the IPC, limiting its applicability to EPO data. Further the industrial classification used is the US-SIC, which needs to be translated into ISIC for practical use.

Greif and Potkowik (1990) computed statistics of patents by industrial sectors, based on an old German national statistical classification scheme (Wirtschaftszweige, WZ79) which is not compatible with the present NACE or ISIC codes. They assigned WZ codes to a sample of 280 applicants in 1983 at the German Patent Office and analysed their patent activities in terms of IPC codes. Again the validity for present purposes is quite limited.

The most recent attempt at defining a concordance between IPC and ISIC codes is by Johnson (2002). As with the earlier work of Evenson and Putnam (1988, see above), this is based on data from the Canadian Patent Office. For 625 IPC subclasses, Johnson defines probabilities of linkages to about 115 different sectors of manufacture and use. However, this interesting method has several limitations. Firstly, the linkage between IPC codes and sectors is defined by examiners of the Canadian Intellectual Property Office, and is not based on the official industrial class of the company to whom the patent is assigned. This is likely to result in a technology bias. Secondly, the Canadian Office stopped assigning sector codes to patents in the grant year 1995, equivalent to about 1991 in terms of first application (priority). Thus, the concordance is quite old, and there is a high probability that the relationship between technology and sectors has changed since then. Thirdly, the sectors are defined in terms of Canadian SIC codes, and have to be translated into ISIC codes, implying certain inaccuracies due to translation. Fourthly, the concordance is based on the determination of 70 000 probabilities of linkage between IPC and ISIC codes. Therefore it can only be handled with the support of a complex software package, consisting of three separate modules. Moreover as input, the user has to provide search results for all IPC subclasses which requires the access to a comprehensive large-scale patent database. Notwithstanding these limitations, the Johnson concordance represents the most advanced suggestion for linking technologies to industrial sectors. However, its adequacy was never tested by a comparison to economic data.

In our analysis, we rely on a concordance developed by Schmoch et al. (2003), which allowed us to produce time series of European and PCT applications for twelve countries (see Table 5.1).

Table 5.1. List of countries

Abbreviation	Country
BEL	Belgium
DNK	Denmark
FIN	Finland
FRA	France
DEU	Germany
ITA	Italy
JPN	Japan
NLD	Netherlands
ESP	Spain
SWE	Sweden
GBR	United Kingdom
USA	United States of America

This approach of Schmoch et al. starts with the selection of industrial sectors at the 2-digit level of NACE or ISIC, with a finer breakdown of the quantitatively important sectors within chemicals, machinery, and electrical equipment, leading to 44 sectors of manufacture. This level of disaggregation is finer than most statistics on economic data, e.g. foreign trade, value added, or R&D expenditure, as provided by OECD, Eurostat or other authorities. It was chosen to be able to show the main differences between the sub-sectors in chemicals, machinery, and electrical equipment industries. Thus a higher level of aggregation to 23 sectors (see Table 5.2) can be achieved by a simple combination (addition) of sub-sectors. We use only 23 sectors due to restrictions in the availability of international comparable economic data on the level of 44 sectors. Moreover it is possible to transfer the NACE-defined fields directly into ISIC-based sectors.

Industrial sectors are defined by the manufacturing characteristic of products, so that it is possible to associate them to technologies. On this basis, technical experts of Fraunhofer ISI associated each of the 625 subclasses of the IPC to one of the 44 industrial categories mentioned above. The IPC subclasses were linked to one field only, even if multiple linkages to other fields were obvious, by applying the principle of main focus.

Table 5.2. List of 23 sectors

Abbreviation	Sector
FOOD	Food products and beverages
TOB	Tobacco products
TEXT	Textiles
WEAR	Wearing apparel, dressing and dyeing of fur
LEA	Leather, leather products and footwear
WOOD	Wood and products of wood and cork
PAP	Paper and paper products
PRIN	Publishing, printing and reproduction of recorded media
PETR	Coke, refined petroleum products and nuclear fuel
CHEM	Chemicals excluding pharmaceuticals
PHAR	Pharmaceuticals
RUB	Rubber and plastics products
NONM	Other non-metallic mineral products
BASM	Base metals
FABM	Fabricated metal products, except machinery and equipment
MACH	Machinery and equipment, n.e.c.
OFF	Office, accounting and computing machinery
ELEC	Electrical machinery and apparatus, n.e.c.
RDTV	Radio, television and communication equipment
MED	Medical, precision and optical instruments, watches and clocks
MOT	Motor vehicles, trailers and semi-trailers
OTRA	Other transport equipment
FURN	Manufacturing n.e.c.

For associating technologies and industries for single companies, an off-line database of Observatoire des Sciences at des Techniques, Paris (OST) was employed, which contains all the data on European and PCT applications without double counting. The information for each patent includes IPC codes, inventors, and applicants with geographical information. This was supplemented by data from Dun & Bradstreet (D&B)[2] which assisted in classifying each applicant by industry. In the D&B database, the industrial activities of firms are described using the US SIC classification, so that they had to be transferred to NACE codes for the purpose of the current project. Although there is no exact correspondence between SIC and NACE codes, it is possible to establish a good association between the classifications at a high level of aggregation (such as the 44 classes mentioned above).

[2] See http://www.dnb.com.

Some companies had more than one sector classification in the D&B database. For this purpose, the patents of these companies were split up and fractionally linked to several sectors in order to reduce the heterogeneity between sectors and technologies. The analysis showed that this approach did not reduce, but rather increased the heterogeneity. The reason for this effect is that the correct assignment of singular patents to a sector is not known, but only the overall of the companies' activities in different sectors and technologies. Eventually, each company was attributed to one sector classification.

If the industrial sectors and the associated technology areas were in exact agreement, only the diagonal elements of a cross-tabulation in a matrix of 44 technological fields and 44 industrial fields would be filled. In the case of complete equivalence between technologies and industries, all applications should appear as diagonal elements. However the results of the empirical analysis show that this is not the case, as there is a substantial number of patents in the non-diagonal fields, because the linkage of an IPC code to a sector is "wrongly" assigned, i.e. the IPC code refers to a product range that is not covered by the industrial sector, the technology field can not be linked to one sector in an unambiguous way, but it is linked to several sectors, or the firms in a sector are active in several technologies, partly because they are large multi-product firms, and partly because the products they produce are multi-technology.

The correspondence has a sound empirical basis, as it does not entirely rely on expert assessment in a technological perspective, but on the patent activities of industrial sectors, determined by a very large sample of more than 3 000 enterprises. Moreover, the application of the concordance to specific examples requires a limited amount of work. Database searches have to be performed for only 44 technological fields, defined by a set of IPC subclasses, whereof the results can be transformed into industrial sectors using a 44x44 concordance matrix. Therefore the searches do not require in-house databases, but can be realised by online databases as well. The transformation does not need special software developments and can be done by standard calculation programs.

The suggested concordance can be used for international comparisons, as it refers to international classifications, namely NACE and ISIC for industrial sectors and IPC for patents. With 44 sector fields, the concordance has a reasonable level of disaggregation. A further differentiation would not be useful, as the economic data for international comparisons are not available in a finer breakdown, and the technical interconnections between the sub-sectors would become too strong. Higher aggregation levels can be achieved by a mere combination of sub-sectors.

A specific advantage of the correspondence is the possibility of analysing industrial structures, for instance, by making comparisons across countries, looking for changes over time, or examining differences between large and small enterprises. For such purposes, the technical definitions are kept invariant, whereas different data sets are used for the empirical construction of structural matrices.

The empirical analyses show that a simple, straightforward definition of industrial sectors by technologies would not be appropriate. The two main reasons are that there is often a strong technological interconnection between different sectors, and secondly that large firms produce a broad spectrum of technologies. This result is primarily reflected in the sometimes low importance of the diagonal elements in the concordance matrix, frequently below 20 per cent. This means that in many cases, other sectors contribute more to patents of a specific field than the related *core* sector itself.

The comparison of distribution of the technical fields and industrial classes for different countries, based on country-specific transfer matrices, show a good correlation in many cases. However, there is a relevant number of technical fields with considerable differences. These cases primarily refer to fields with low absolute numbers of patents and firms and to less technology-intensive fields.

These differences between sectors and countries may be, to a certain extent, due to inaccuracies of the association of technological and industrial fields or of the problem to directly link the technological activities of a firm to secondary industrial classifications. Major reasons are, however, the structural differences between the technological activities of industrial sectors in the different countries. The country comparisons in this report exclusively refer to large countries. The structural differences will become even larger if smaller countries are considered, where the technological activities of a specific sector are often dominated by a few firms. Therefore, the comparison of countries has to be handled with care, at least with regard to specific sectors. The concordance matrix developed in this project represents an international average structure.

In summary, the concordance allowed us to calculate the annual number of patent applications in the period from 1985 to 2001 for the 23 sectors in Table 5.2 from the 12 counties listed in Table 5.1. This was the preliminary step for the econometric calculations of the following sections.

3 Empirical results

Time series analyses are a necessary element for predicting the future development of patent applications. The objective of this working step is the identification of determinants for the development of patent applications on an aggregated level. In order to make use of industry indicators, we rely on a new concordance between technology fields classified by IPC codes and industry sectors grouped according the NACE on a two digit level (Schmoch et al. 2003). Before we discuss the selection of adequate industry indicators, we briefly elaborate a second motivation. Since we are able to compare both the results of country and sector analyses, we gain additional insights for the question, whether we still observe country differences by performing analyses on a sectoral level. If we do not find any country influences, this will have strong impacts on the sampling of companies, because then it would be adequate not to consider country quotas any more.

Regarding the indicators, we have selected the following variables. First and most important are the private R&D expenditures. We use the data from the OECD ANBERD database (edition 2003). The values are in PPP US$. The R&D expenditures are the traditional input indicator of the R&D process and it should correlate with its output, the applications of patents. However, there is a recent debate going on, as to whether in the 1990s the development of patent applications is not any more so closely linked to the trends in R&D (Blind et al. 2003a).

Another argument is that the productivity of the R&D process has risen, due to a larger knowledge pool that researchers can rely on. Although it is rather difficult to assess the pool of knowledge relevant for R&D processes, we use as indicator the stock of technical standards as a kind of codified knowledge available to every company (Blind 2004). The hypothesis is consequently that the number of patent applications should correlate positively with an extension of the stock of technical standards. We use the database PERINORM (edition 2003)[3] for constructing data on the stocks of standards for the countries most active in standardisation, like Germany, France, UK and the Netherlands. For all other European countries, the stock of European standards is relevant, because they have reduced national standardisation activities significantly. For Japan and the US, we have no access to adequate time series.

Whereas both the R&D expenditures and the stock of standards are indicators closely connected to the production of new technological knowledge, we use two further indicators. A third general indicator of economic

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[3] See http://www.perinorm.com/pol/accueil.php.

activity with a possible influence on patent activities, the development of value added, is checked for its influence. We use the data available in the OECD STAN database (edition 2003). These values are recorded in Euros. Finally, the demand for patents representing the intensity of competition is important for explaining the development of patent applications. However, there are no direct indicators measuring the intensity of competition. One can think about the use of concentration indices, like Herfindahl-index or Gini coefficients, but they are not available on an OECD base. One feasible alternative is the trends of export volumes, which is especially relevant for the applications at the EPO, because companies active in foreign markets have a high inclination to apply for patents there. The export data are also taken from the OECD STAN database (edition 2003).

The time series cover at maximum the period from 1987 until 2001, because the data for the R&D expenditures in the OECD database ANBERD start in the year 1987. In general, we use the logarithms of the data, because then the coefficients are elasticities, which represent the change in percentages of the dependent variable after a percentage change of the independent variable.

3.1 The total model

Based on the data of 23 sectors in the twelve countries, we perform in a first step analyses of a so called "total model", which includes a maximum 276 time series. This "total model" assumes identical relations between countries and sectors. Since these are rather unrealistic assumptions, these analyses represent just a preliminary step of the whole time series analysis. We use the following equations for determining the explanatory power of the four indicator variables R&D expenditure (RD), stock of standards (STD), value added (VALA) and exports (EXP).

$$pat_{ict} = C_{ic} + a_1.RD_{ic;t-n} + g_{ic}.TREND_{ic} + e_{ict} \quad (1)$$

$$pat_{ict} = C_{ic} + a_1.STD_{ic;t-n} + g_{ic}.TREND_{ic} + e_{ict} \quad (2)$$

$$pat_{ict} = C_{ic} + a_1.VALA_{ic;t-n} + g_{ic}.TREND_{ic} + e_{ict} \quad (3)$$

$$pat_{ict} = C_{ic} + a_1.EXP_{ic;t-n} + g_{ic}.TREND_{ic} + e_{ict} \quad (4)$$

Where i = sector; c = country; t = time; n = time-lag; $e_{ict} = \rho_{eict}$-1+u_{ict} with u_{ict} = error term and ρ_{eict} = autocorrelation coefficient of first order. In general, we assume first order autocorrelation in all regressions.

Table 5.3 summarises the results of the four models. In general, the regressions are very significant and have very high R^2 values due to the inclusion of the autocorrelation term.

We find, for all indicator variables, a significant negative coefficient except for the stocks of standards. Since these results are surprising, we do not interpret those further, but proceed immediately with the analyses based on country data.

Table 5.3. Signs of coefficients of the country models

	R&D	Standards	Value Added	Exports
Total model	-(-4)***	+(-5)***	-(-6)**	-(-5)***

Sign: + or -; Lags: number of years in brackets; * = significance at the 10%-level; ** = significance at the 5% level; *** = significance at the 1%-level.
In the case of Japan we use the differences D instead of the logarithms. Data sources: OST patent database; OECD ANBERD; OECD STAN; PERINORM.

3.2 The country models

After presenting and discussing the results of the total model, as based on the time series of all industries in all countries, we analyse the relationship between the various indicators and the patent applications differentiated by country. In Fig. 5.1 the total patent applications of the twelve countries are displayed. We find in all countries a strong increase in the applications in the time period of 1987 to 2001, especially since the middle of the 1990s. The highest level of growth is Spain with almost a 10 fold increase over the period.

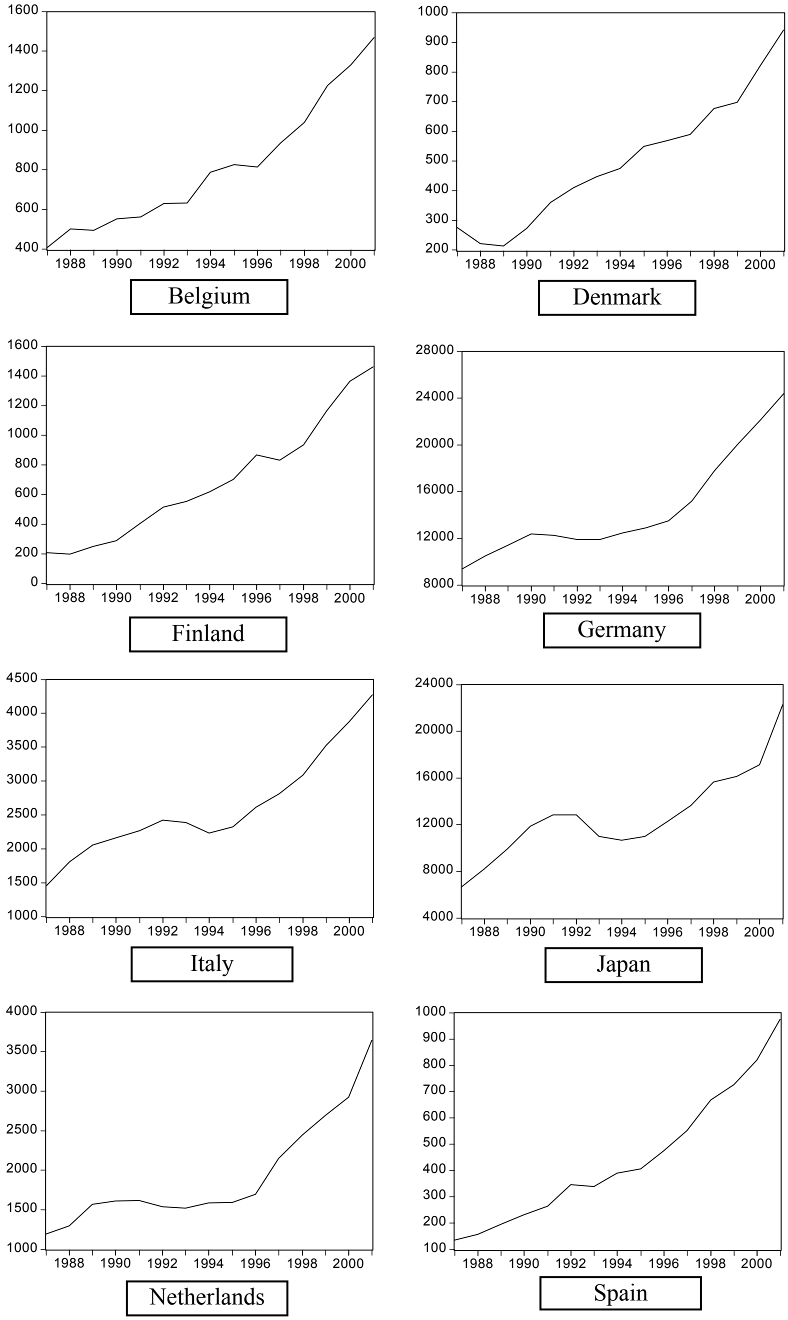
The objective of this step in the analysis is to find out whether there are differences between countries regarding the explanatory power of the four indicator variables. We use the following equations for determining the explanatory power of the four indicator variables: R&D expenditure, stock of standards, value added and exports, with variable definitions as in Eqs. 1 to 4 above. We compute regressions for each of the four models for all of the twelve countries based on the time series of the 23 sectors i.

$$pat_{it} = C_i + a_1.RD_{i;t-n} + g_i.TREND_i + e_{it} \quad (5)$$

$$pat_{it} = C_i + a_1.STD_{i;t-n} + g_i.TREND_i + e_{it} \quad (6)$$

$$pat_{it} = C_i + a_1.VALA_{i;t-n} + g_i.TREND_i + e_{it} \quad (7)$$

$$pat_{it} = C_i + a_1.EXP_{i;t-n} + g_i.TREND_i + e_{it} \quad (8)$$


Belgium
Denmark
Finland
Germany
Italy
Japan
Netherlands
Spain

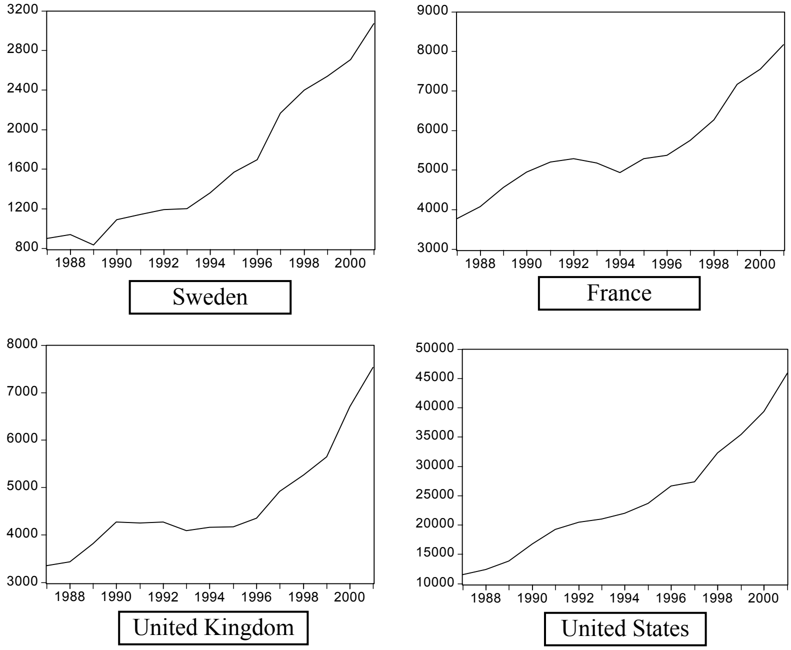


Fig. 5.1. Patent applications by country (Source: OST)

Due to the stable trends in most of the time series, the TREND variable with the basis in 1987 is significant in almost all estimations. The inclusion of the TREND variable is necessary, because the explanatory variables are also characterised by increasing values over time. Furthermore, there are no common deflators, either for R&D expenditures (Hingley 1997, p. 16), value added or for exports. There are also other factors determining patent applications which cannot be operationalised by indicator variables, like strategic patent motives. Consequently, the TREND variable catches all these factors and the exogenous variables are used to explain the deviations of the patent applications from the simple trend extrapolation. Although this approach reduces the likelihood that the exogenous indicator variable is significant, it increases the reliability of the indicator variables in the case of significant coefficients.

First of all, it has to be noted that we find no unique pattern for the explanatory power, either among countries or among the four indicator variables. We report the results of the lagged variable with the highest significance. The input indicator R&D is rather ambivalent. In one quarter of the countries, the coefficient of the R&D indicator is not significant. Only in three small countries, Belgium, Spain and Sweden, do we find the expected positive coefficients of the R&D expenditures. However, the coefficients of the R&D expenditure of the large countries Japan, Germany, France and Italy, and of the small R&D intensive country Finland, are significantly negative. In the industries of these countries, the phenomenon of a relaxed R&D-patenting relationship explained by an increased strategic patenting (cf. Blind et al. 2003a) is obviously more widespread. The sector related analysis promises additional insights because of the strong sector-bias of the R&D-patent relationship.

Although these results cannot be compared directly with those of Hingley (1997), due to our inclusion of the TREND variable, it has to be noted that he finds – as expected – mostly positive coefficients. This is no contradiction to our results, since our R&D expenditures explain the deviations from the linear trend of the variables. If we use another specification of the model above but omitting the TREND variable, then we find for six countries a significant positive impact and only for Germany a significant negative relationship. Regarding the length of the lags, Hingley (1997) finds on average just below three years for the data since 1980. This is comparable to the two years we find for the positive relationships. Regarding the specification without the TREND variable, we find time lags of either one or two years.

In contrast to the R&D expenditures, the stocks of standards are in most cases significant. However, again we find in half of the countries, like Belgium, Denmark, Italy, and the Netherlands, positive and in the other half, like Finland, France, Spain, Sweden, and UK, negative relationships. Although we use the stocks of European standards for the small countries, except the Netherlands, we find significant differences between Belgium, Denmark and Italy on the one hand and Finland, Spain and Sweden on the other hand. It has to be noted that, in the case of positive relationships the lags are mostly five years, whereas in the negative relationships we find mostly shorter lags between one to three years. The positive impacts obviously take longer to influence the patent applications than the negative influences do. Even more than in the case of the R&D expenditures, we expect more insights from the sectoral analyses because the economic impact of standards differs significantly between sectors.

The development of value added is, in the same way as the two other indicator variables, rather ambivalent. For six countries, Denmark, France, Italy, Sweden, UK and US, we find a positive impact on the development of the patent applications. For five countries, Belgium, Finland, Germany, Japan, and the Netherlands, we observe a negative relationship. The lags are evenly distributed between one and six years. Since country differences *per se* should not exist and can again only be explained by different sector distributions or developments, we have to focus once again on the sectoral analyses.

Finally, the export variable has to be discussed. In contrast to the other three indicator variables, for the majority of the countries we find a positive and mostly immediate relationship to the patent applications, including Denmark, France, Italy, Japan, the Netherlands, and Sweden. For the four countries, Finland, Spain, the UK and US we find negative links. In the specification of the model equations without the TREND variable, the export volumes have in ten countries a significant positive impact on the patent applications, with time lags of mostly one up to five years.

Although one could argue that some countries, like Japan or Germany but also Finland or the Netherlands, are very active in exporting goods and are therefore more active in applying for European patent protection, we fall back very quickly to a sectoral argument, because export activities are concentrated in some specific sectors where the competitive advantage is significant. Therefore, in same way as in the discussion of the three other indicator variables, we have to argue and analyse on a sectoral basis and ask whether, in sectors with globalised markets, the patent applications are pushed by the development of export volumes.

Table 5.4. Signs of coefficients of the country models

Coefficient	R&D	Standards	Value Added	Exports	Total
not significant	4	1	1	2	8
Positive	3	4	6	6	19
Negative	5	5	5	4	19

Data sources: OST patent database; OECD ANBERD; OECD STAN; PERINORM.

Table 5.5. Conformity of the signs of significant coefficients of the country models

	R&D	Standards	Value Added	Exports	
R&D		3	4	3	Same
Standards	3		3	6	signs
Value Added	3	5		6	
Exports	3	2	3		
	Different signs				

Data sources: OST patent database; OECD ANBERD; OECD STAN; PERINORM.

Table 5.6. Sign of coefficients, lag structure and degree of significance per country model

Countries	R&D	Standards	Value Added	Exports
Belgium	+(-2)***	+(-5)**	-(-1)*	+(-2)
Denmark	+(-4)	+(-6)**	+(-4)*	+(-3)***
Finland	-(-1)*	-(-3)*	-(-2)***	-(-4)**
France	-(-1)*	-(-1)***	+(-1)***	+(-1)***
Germany	-(-2)***	+(-5)	-(-6)***	+(-3)
Italy	-(-2)***	+(-5)**	+(-5)***	+(-4)**
Japan	-(-3)***(D)		-(-3)***(D)	+(-1)*** (D)
Netherlands	+(-2)	+(-5)**	-(-4)*	+(-1)***
Spain	+(-2)***	-(-2)*	+(-1)	-(-5)**
Sweden	+(-2)**	-(-6)*	+(-2)***	+(-1)**
United Kingdom	+(-1)	-(-1)***	+(-4)***	-(-1)***
United States	+(-4)		+(-3)***	-(-2)**

Sign: + or -; Lags: number of years in brackets; * = significance at the 10%-level; ** = significance at the 5% level; *** = significance at the 1%-level.
In the case of Japan we use the differences D instead of the logarithms. Data sources: OST patent database; OECD ANBERD; OECD STAN; PERINORM.

Finally, we briefly discuss the relationship between the different indicators in the same country. Again the signs of the indicators for each country do not correlate well, although we find a more positive correlation between the coefficients of the export and the value added respective standard equations. On the other hand, the coefficients of the development of the stock of standards and those of value added contradict each other in most cases. Again, we have to look whether we find on the sectoral level similar contradictions.

3.3 The sector models

Since the analyses of the data based on the country models elucidated several puzzling results, we proceed with an analogous analysis of the 23 sectors, based on the data pooled over the twelve countries, i.e. we calculate 23 regressions for each sector based on the available data of the twelve countries c. We use again the four indicator variables in order to explain the development of the patent applications, with variable definitions as in Eqs. 1 to 4 above.

$$pat_{ct} = C_c + a_1.RD_{c;t-n} + g_c.TREND_c + e_{ct} \quad (9)$$

$$pat_{ct} = C_c + a_1.STD_{c;t-n} + g_c.TREND_c + e_{ct} \quad (10)$$

$$pat_{ct} = C_c + a_1.VALA_{c;t-n} + g_c.TREND_c + e_{ct} \quad (11)$$

$$pat_{ct} = C_c + a_1.EXP_{c;t-n} + g_c.TREND_c + e_{ct} \quad (12)$$

Tables 5.7 to 5.11 summarise the results of the 23 sectoral analyses. For information, we also computed a model for manufacturing as a total. At first glance, we see no general pattern regarding the signs of the coefficients of the four indicator variables. Although we will also interpret – if appropriate – the results on a sectoral basis, we have divided the sectors in two groups: low-technology and high-technology sectors. Based on Grupp et al. (2000), we define the petroleum, the chemical, the pharmaceutical, the machinery, the office machinery, the electro technology, the radio and television, the medical technology, the motor vehicle and the other transport sector as high-technology sectors. The remaining 13 sectors are defined instead as relatively low-technology sectors. This separation helps us to find more convincing patterns.

Regarding the R&D expenditures, we observe again a rather mixed picture both on the basis of all sectors and after the separation of low- and high-technology sectors, because in one third of the cases we find no significant results at all, in another third we find the expected positive relationship and in the last third a negative link. Even the differentiation into low- and high-technology sectors does not provide significantly more insights. However, the broad majority of high-technology sectors, with the exception of office machinery and medical technology, is obviously not characterised by a positive R&D-patent link, while in the low-technology sectors at least half of the sectors show the expected positive connection.[4] The lags range between one and five years, whereas in the case of negative relations lags of four and five years dominate.

4 If we use the model specification without the TREND variable, we find even less significant connections, but, especially in the low-technology sectors, we mostly find the expected positive relationship between R&D expenditures and patent applications.

Table 5.7. : Signs of coefficients of all sectoral models

	R&D	Standards	Value Added	Exports	Total
not significant	8	8	5	3	24
positive	7	10	7	11	35
negative	8	4	11	9	32

Data sources: OST patent database; OECD ANBERD; OECD STAN; PERI-NORM

Table 5.8. Signs of coefficients of the low-technology sectoral models

	R&D	Standards	Value Added	Exports
not significant	3	4	1	3
positive	5	5	1	3
negative	5	3	11	7

Data sources: OST patent database; OECD ANBERD; OECD STAN; PERI-NORM

Table 5.9. Signs of coefficients of the high-technology sectoral models

	R&D	Standards	Value Added	Exports
not significant	5	4	4	0
positive	2	5	6	8
negative	3	1	0	2

Data sources: OST patent database; OECD ANBERD; OECD STAN; PERI-NORM

Table 5.10. Conformity of the signs of significant coefficients of the sector models

	R&D	Standards	Value Added	Exports	
R&D		6	6	5	Same signs
Standards	4		7	7	
Value Added	6	4		13	
Exports	9	6	2		
	Different signs				

Data sources: OST patent database; OECD ANBERD; OECD STAN; PERI-NORM

The analysis of the influence of the stock of standards elucidates a clearer picture. Although for eight sectors no significant relationship can be detected, in more than double of the sectors a positive connection reveals. The separation into high- and low technology sectors makes the picture even more obvious. The development of the stocks of standards as indicator for the pool of codified technological knowledge has obviously a positive impact on the patent applications in the high-technology sectors, with the exception of office machinery. Among the low-technology sectors, we find three sectors with a negative relationship of the stock of standards to the number of patent applications: the food, the wood and the paper sector. In contrast, five sectors have a positive relation between the respective stocks of standards and the patent applications: the tobacco, the textile, the wearing and dressing, the non-metallic products, and the base metals sectors. The lags cover equally an interval between one and four years.

The results of the estimations of the patent applications based on the time series of the value added are in contrast to those based on the stock of standards. Firstly, in almost half of the sectors, we observe a negative relationship between the value added and the patent applications. Especially in all low-technology sectors except the base metals sector, we find a negative connection. How do we have to interpret this phenomenon? These low-technology sectors are often characterised by relative low growth rates or even by stagnation. On the other hand, the number of patents grows steadily at a rate that is often even apparently exponential. Consequently, we find a negative correlation. The economic activity in these sectors is more or less disconnected with the respective patent activities. In contrast, the dynamic development of high-technology sectors goes in line with the very strong increases in the patenting activities. Taking these observations together, one has to conclude that the development of the economic activity has no influence on the trends in patenting in the low-technology industries, whereas in the high-technology sectors at least a parallel development can be observed, but a direct causality cannot be assumed. Regarding the lags, we find in the case of positive coefficients mostly lags between one and three years. If we observe negative links the lags range between two and six years.

Finally, we have to discuss the results of the estimations with the export volumes as explanatory variable. Whereas we find for the all sectors together that there is no clear picture regarding the sign of the coefficient of the export variable, the separation into low- and high-technology sectors reveals an obvious pattern. In the low-technology sectors, the export volumes correlate negatively with the patent applications in the same way as the development of value added. Only in the food, the leather and the base metals industries do we find a positive correlation. In contrast to this result, all high-technology sectors are characterised by a strong positive influence of the export volumes on the patent applications, with the exception of the special cases of the petroleum sector due to the role of oil and of the other transport industries dominated by the large and heavily integrated aircraft industry. Besides the development of the economic activity in general, the export activities obviously have a strong influence on patent applications. If we consider the lag structures, lags of just one year dominate among the cases of positive correlations, whereas the lags are two to six years in case of negative links, which is similar to the pattern of the estimations based on value added.

Table 5.11. Sign of coefficients, lag structure and degree of significance per sector model[5]

Sectors	R&D	Standards	Value Added	Exports
FOOD	-(-4)**	-(-1)*	-(-3)***	+(-3)**
TOB	+(-3)**	+(-1)***	-(-3)*	-(-3)*
TEXT	+(-4)*	+(-4)**	-(-6)*	-(-5)
WEAR	+(-4)***	+(-1)**	-(-2)***	-(-3)*
LEA	+(-3)	+(-1)	-(-4)***	+(-1)**
WOOD	+(-2)**	-(-1)*	-(-2)	-(-3)*
PAP	-(-4)**	-(-2)**	-(-4)**	-(-2)**
PRIN	-(-4)**		-(-5)**	-(-4)
PETR	-(-5)***	+(-3)***	-(-1)	-(-2)**
CHEM	-(-4)	+(-2)*	+(-3)**	+(-4)**
PHAR	-(-3)	-(-1)	-(-3)	+(-6)***
RUB	-(-5)*	+(-4)	-(-5)**	+(-3)
NONM	+(-2)	+(-4)**	-(-5)**	-(-6)*
BASM	+(-2)	+(-2)***	+(-3)***	+(-3)***
FABM	-(-1)*	-(-4)	-(-4)*	-(-5)**
MACH	+(-1)	+(-2)***	+(-1)**	+(-3)***
OFF	+(-1)*	-(-3)**	+(-4)	+(-1)*
ELEC	-(-4)	-(-2)	+(-2)*	+(-1)*
RDTV	-(-4)**	+(-3)*	+(-1)***	+(-1)***
MED	+(-2)***	+(-1)***	+(-1)**	+(-1)**
MOT	-(-5)**	+(-3)	+(-1)**	+(-1)*
OTRA	-(-3)	+(-2)	+(-2)	-(-5)***
FURN	+(-5)**	+(-2)	-(-3)***	-(-4)**
Total manufacturing	+(-2)***	-(-3)**	+(-2)*	+(-1)**

Sectors defined in Table 5.2. Sign: + or -; Lags: number of years in brackets; * = significance at the 10%-level; ** = significance at the 5% level; *** = significance at the 1%-level. Data sources: OST patent database; OECD ANBERD; OECD STAN; PERINORM.

[5] Sign: + or -; Lags: number of years in brackets; * = significance at the 10%-level; ** = significance at the 5% level; *** = significance at the 1%-level.

In the same way as in the analysis of the country models, we finally discuss conformity or contradictions between the signs of the four indicator variables. Most obvious is the strong conformity of the coefficients of the models with value added and export volumes as explanatory variables, because of their strong correlation. For most other combinations we find both identical and different signs. However, it has to be noted that the coefficients of the R&D expenditures contradict each other in two thirds of the cases.

This pattern as well as the same analysis for the country models (in Sect. 3.2) reveals that there is no strong conformity between the direction of influence of the four indicator variables. We observe only a certain correspondence between the signs of the coefficients of value added and export due to their general correlation.

4 Conclusions

We have performed time series analysis based on both twelve country and 23 sector models to estimate the development of patent applications using four indicator variables. At first glance, it is very difficult to detect clear and interpretable patterns. However, the following general conclusions can be drawn based on our results.

The results of the country models are rather heterogeneous and it is difficult to find reasonable explanations for this. However, it has to be noted that the R&D expenditures have only for three countries the expected positive explanatory power for the development of the patent applications. The upsurge in patenting can obviously not be explained by the expansion of R&D expenditures. More powerful for the explanation of the international patent applications on the country basis is the development of the export volumes, because in half of the countries we find a significant positive relationship. In general, the patent activities of most countries we have analysed are biased by a few sectors, which calls for an analysis on a sectoral base.

However, the results of the sector-based analyses are at first glance also not very convincing and we find a similar ambivalence as among the results of the country models. The puzzles of the results can be partly resolved by separating the sectors into low- and high-technology sectors. Firstly, the positive R&D-patent relationship can still be observed in some of the low-technology sectors, whereas it is almost non-existent among the high-technology sectors. Secondly, the stocks of standards have obviously a strong positive influence on half of the high-technology sectors, whereas this is not so clear-cut for the low-technology sectors. Thirdly, value added, but even more the export volumes, have a significant influence on the patent applications. Although we find for most of the low-technology sectors with small or even negative growth rates a negative relationship to the mostly steadily growing patent applications, the picture for the high-technology sectors is a different one. Here, both the development of value added and of the export volumes have a strong and positive influence on the patent applications.

Finally, if we connect the results of the sectoral analyses with the country results, we have to conclude that some few dominating sectors are decisive for the results of the country models. For example, countries like Spain, that are still dominated by low-technology sectors, have a higher likelihood that the R&D expenditures will have a positive influence on their patent applications. On the other hand, the models for countries like Finland, that are dominated by one high-technology sector, will show no significant or even a negative relationship between R&D expenditures and patent applications.

Based on these general results, it seems that future research at the country level should take the sector distributions into account. Furthermore, the application of weighted least squares may be adequate both in the country and sector models in order to account for cross-equation heteroscedasticity. Finally, more comprehensive multivariate models should be developed, which requires further analysis of the interactions between the four indicator variables that have been studied here and others as well.