Patenting Activity in Denmark[¶]

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Abstract

This paper describes the patterns of patent applications by Danish firms at the European Patent Office between 1978 and 2003. Our data shows that both the number of patent applications and the number of patent grants have considerably increased but with a widening gap between the number of patent applications and patent grants. Most patents are filed in the technology area "Electronics", closely followed by "Mechanics" and "Chemicals". There is a pronounced increase in the share of patent applications in "Electronics" as well as in "Drugs and Health". We also find evidence for an increased internationalization of research. The Greater Copenhagen Area is by far the most patent–intensive region in Denmark but has slightly lost in relative importance in recent years.

Our data also provides some indication for an increase in the economic value of Danish patents over time.

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1 Introduction

Firms' patenting activity is of great interest to economists and policy makers alike. The reason for this is that patents are measures of one of the crucial inputs to economic growth: innovation. A high technological standard is particularly important for a country like Denmark that lacks natural resources and whose fate hence crucially hinges upon knowledge capital as discussed in detail by Hougaard Jensen et al. (2003).

The patent system was introduced in order to set incentives for Research and Development (R&D). If an invention receives patent protection, the inventor obtains a temporary monopoly, for up to 20 years, on the use of her invention. The incentives to innovate provided by the patent system come, however, at a cost since the monopoly right leads to a deadweight loss. This trade–off has generated a lively debate about how the patent system should work; Gallini and Scotchmer (2005) as well as Encaoua et al. (2003) provide surveys.

Due to the long history of patent systems and the slowly changing institutional settings, patents are increasingly often used to compare the technological abilities of firms, regions and countries over time and across space (Griliches, 1990). This will be our perspective on patents in this paper.

The patenting activity of firms has been an active field of research interna-

tionally, but empirical research for Denmark is relatively meager. This paper describes a newly created patent data base that has been established by the Centre for Economic and Business Research (CEBR) labelled the "CEBR patent data base" with the support of the Danish Patent and Trademark Office (DKPTO) and funding from the Danish Research Council (Statens Samfundsvidenskabelige Forskningsråd). DKPTO supplied information on all patents that were applied for at the European Patent Office (EPO) with at least one applicant residing in Denmark at the time of application. The data cover the period Jan. 1, 1978 (when the European Patent Convention (EPC) came to existence) to Nov. 23, 2003 (when the data transfer between DKPTO and CEBR took place).

This paper gives a brief overview of the data by describing macro–level trends in the patenting behavior of Danish firms. We do not provide detailed discussions of our empirical findings but selectively highlight explanations, thereby barely scratching the surface of possible data interpretations. Many issues clearly warrant further analysis, and we are convinced that future research — by us and by other researchers that will use the data base — will deliver more details. The main goal of this paper hence is to draw the "big picture" on patenting activity in Denmark, to introduce the CEBR patent data base and to induce further analyzes on the topic.

Our main findings are as follows:

1. Both the number of patent applications and the number of patent grants have increased since 1978. There seems to be, however, an increasing gap between the number of patent applications and the number of patent grants.

2. Most Danish patents are filed in the technology area "Electronics", closely followed by "Mechanics" and "Chemicals".[1] There is a pronounced surge in the share of patent applications in "Electronics" and "Drugs and Health" while the share of applications in "Mechanics" has decreased substantially.

3. The mean number of applicants per patent is almost unchanged but the mean number of inventors per patent has increased. We also observe an increase in the relative number of foreign inventors to domestic inventors.

4. Danish patent applicants increasingly often directly turn to the EPO instead of proceeding to the DKPTO first. Priority applications to the US Patent and Trademark Office (USPTO) also increased in recent years.

5. The Greater Copenhagen Area is by far the most patent–intensive region

[1]The Appendix provides an overview of our technology classification. We follow a concordance by Lanjouw and Schankerman (2001).

in Denmark but has lost in relative importance in recent years.

6. Three indicators for the economic value of Danish patents — "family size", patent application renewals, and the number of claims — suggest an increase in patent value while our value indicator based on patent opposition indicates little change in patent value.

The CEBR patent data base is not the first attempt to construct a Danish patent data base. There exist at least two previous data bases that both cover the period until 1996: the "DKPTO98" data base and a data base constructed by the "Innovation, Knowledge and Dynamics" group at Aalborg University. These data bases are documented in Østergaard Nielsen (1998) as well as Pedersen and Præst (1997), respectively. Østergaard Nielsen and his coauthors have analyzed the patenting behavior of Danish firms in various publications, both in a national and in an international context (Østergaard Nielsen, 1999; Strøjer Madsen et al., 2000a,b). These publications contain some of the descriptive statistics that we also report such as the number of patent applications and grants. Since the CEBR patent data base contains much more information than "DKPTO98", our paper provides, however, a multitude of new information, in particular on the the internationalization of patenting activity, the economic value of Danish patents and the regional distribution of patent applicants and inventors in Denmark.[2] We hence con-

[2]A major advantage of the "DKPTO98" data base is that the patent data is linked

tribute to the ongoing public debate on innovation in Denmark and the competitiveness of the Danish economy.

Our paper is organized as follows: Section 2 provides some necessary technical details on the construction of our data and on the definitions that we use in this paper. Section 3 discusses trends in patenting activity across different technology areas. Section 4 analyzes trends in the composition of patent applicants and inventors. Section 5 deals with differences in patenting activity across the geographical regions of Denmark. Section 6 is concerned with "patent value correlates". These are indicators for the economic value of patents such as the number of EPC member states for which the patent applications are valid, the likelihood that patents are opposed, the number of citations received and the number of times patent applications are renewed.

2 Technical issues

There are a few technical details with regard to what we define a "Danish" patent is, the choice of application dates and the issue of patents as lagging indicators that are important to our further analysis. We briefly comment on

to firm–level information on R&D expenditures, something that we do not yet have at our disposal. Strøjer Madsen et al. (2000a) use this information to estimate the relation between aggregate R&D expenses as input and patent applications or grants as output.

them below. Kaiser and Schneider (2004) provide details on how the patent data base was constructed and what variables it contains.

2.1 "Danish" patents

We define a patent as being "Danish" if (i) at least one applicant resides in Denmark and (ii) if at least one of the patent inventors resides in Denmark. Our initial 12,109 unique patent applications obey to selection criterion (i) by construction. Selection criterion (ii) does not hold, however, for a total of 802 patents (6.7 percent). We regard these patents as non–Danish and discard them in our empirical analysis. Section 4.2.1 provides further evidence on the internalization of research.

2.2 Time stamps

It is important for a descriptive macroeconomic analysis as the one we perform in this paper to accurately locate in time ("time stamp") the invention underlying the patent application. Our data provides two different patent application dates, the "priority date" — the date at which the patent applicant first sought patent protection either at some national patent office or the EPO— and the "application date" — the date at which the patent applicant sought patent protection at the EPO. The two dates only coincide if

the patent application directly went to the EPO without a prior application to a national patent office. Most of our analyzes use the priority date as the relevant time stamp since this date is closest to the invention date. This is consistent with the existing literature. Any analysis of patent counts is of course not invariant with respect to the time stamp (Dernis et al., 2001).

2.3 The "lagging indicator" issue

It is obvious but nonetheless important to note that patents are "lagging indicators" (Griliches 1990) in the sense that a considerable amount of time elapses before a patent application shows up in the patent statistics. A patent application at EPO is published 18 months later, and additional time may pass until the patent can eventually be found in the EPO patent data base due to administrative delay. Further delay can arise when patent applicants choose to seek patent protection at a national authority first. The applicants will then typically wait for one year before they apply to the EPO. This is because the right to patent the same invention at the EPO expires one year after the first national application (i.e. one year after the priority date). After that period, the same invention can neither be patented at the EPO nor at any other patent office. Patent applicants tend to wait as long as possible before proceeding with the costly EPO application, because they hope to

gain additional information, for example with respect to commercialization or the probable success of their application.[3]

There is also a significant time lag between patent application and grant. The average duration between patent application and patent grant was 4.7 years (the median is 4.7 years as well) for patents filed at the EPO in 1996, the last year for which we believe to have fairly complete information on patent grants.[4] Subsection 3.2 discusses the delay between application and grant in further detail.

Our data is generated from a data transfer that took place at the end of November 2003. The most recent priority date is December 20, 2002; the latest EPO patent application date is May 15, 2003.

3 Patent applications and patent grants

Figure 1 shows that the number of Danish patent applications and the number of patent grants have steadily increased since 1978, presumably partially

[3]According to Harhoff and Reitzig (2004), the total cost of a patent application is 29,800 Euro, of which only a small fraction are application fees and the larger parts are professional representation before EPO and translation into the languages of the designated states.

[4]The delay between the application and grant may be even larger if the priority application was a Patent Cooperation Treaty application.

due to an increased use of the patent system for business strategic reasons.

Figure 1 also visualizes the "lagging indicator" property of patents. The sudden interruption of the steep increase in the number of patent applications after 2000 and the marked drop in patent grants after 1996 are just artifacts of the lagging indicator property discussed above.

Figure 1 points towards an increasing gap between patent applications and patent grants which seems to be especially true since 1988. There are different potential explanations for this phenomenon. These explanations range from shifts in the technological composition of the patent applications, as highlighted in the next section, to administrative overload at the EPO due to the success of the EPO system.

If Figure 1 is compared to results for other European countries as in OECD (2003), it is found that the increase in the number of applications is much higher in Denmark than in the rest of Europe. According to OECD (2003), the total number of patent applications to the EPO doubled over the period 1985 to 1999, whereas in Denmark there were four times more applications over the same period. Unfortunately, data for patent grants are not available at the European level so we cannot compare patent grant figures.

Insert Figure 1 about here!

Figure 2 shows that the probability of patent grants indeed decreased substantially between 1989 and 1996.

Insert Figure 2 about here!

Before we provide more details on the widening time lag between application and grant, we look more closely at the technological composition of patenting activity in Denmark. In order to take into account the lagging indicator issue, all absolute numbers that relate to patent grants therefore end in 1996, even though we probably still miss out particularly "late" patent grants. All absolute numbers that relate to patent applications end in 2000. Relative numbers are displayed up and until 2003 — thereby assuming that there are no significant differences between "late" patent grants and "early" patent grants as well as applications.

A second issue worth mentioning is that even though the application growth rate is high, Denmark does not belong to the leading patenting countries. With around 904 applications in 1999, it is of course far behind larger European countries like Germany with around 20,000 applications in 1999 (OECD 2003). Denmark lags, however, also behind some countries of similar size like Switzerland (2,500 applications in 1999), Sweden (2,000 applications in 1999) and Belgium (1,300 applications in 1999). These differences can have many sources: R&D efforts, firm size, export activity, or industry structure.

3.1 Technology areas

3.1.1 Patent applications by technology fields

The International Patent Classification (IPC) system indicates the type of technology embodied in an invention. It provides a breakdown of technologies into about 60,000 subgroups. In our data we find a total of 8,860 unique IPC numbers at the "subgroup" level, the lowest level in the IPC system, and 118 unique IPC numbers at the "class" level, the second–highest level.[5] Even the "class" level distinguishes between too many technology classes to be interpretable in a meaningful way. We therefore follow a concordance by Lanjouw and Schankerman (2001) and classify the IPC codes into five main technology areas: "Drugs and Health", "Chemicals", "Electronics", "Mechanical" and "Other".

Most patents have more than one IPC number. The average number of technology classes is 2.1, the median is two, the standard deviation is 1.25 and the maximum is six. Consistent with existing empirical studies we consider the first IPC class listed in the patent application (the "main" IPC class) as the relevant indicator for technology class.

[5]The IPC system considers five different levels of technology classes, "section" (the first letter), "class" (the following two numbers), "subclass" (the following letter), "main group" (the following two numbers) and "subgroup" (the following two to six numbers).

Figure 3 displays the number of patent applications in each of the five technology classes. It shows that "Electronics" took off in the mid–90s. There is a stable growth in "Mechanical" and "Chemicals". "Mechanical" used to be the most patent–relevant technology field but is now overtaken by "Electronics", closely followed by "Chemicals".

It is somewhat surprising given the occurrence and importance of the "Medicon Valley" cluster in the Øresund region (Greater Copenhagen and southern Sweden) that "Drugs & Health" ranks only fourth in the statistics. This might be due to the fact that the distinction between "Drugs and Health" and "Chemicals" is not clear–cut.[6]

Insert Figure 3 about here!

Additional evidence on technology trends is provided by Figure 4 which sets the patent counts in Figure 3 in relation to the total number of patents in a given year. Figure 4 shows that the relative importance of "Mechanical" has decreased drastically whereas "Drugs and Health", "Chemicals" and "Electronics" experienced a substantial increase in relative importance. Interestingly, the relative importance of all technology fields is converging. The same type of convergence has been observed in US patent data (Hall et

[6]For example, 69.1 percent of the patent applications by Novo Nordisk A/S, the world market leader in insulin production, are allocated to technology class "Chemicals" and only 23.6 percent are in "Drugs and Health".

al. 2001). The causes of this convergence remain inconclusive, both in the present paper and in Hall et al. (2001). At the level of these highly aggregated technology classes, there is no clear picture with regard to Denmark's technological specialization.

Given the high joint importance of "Health and Drugs" and "Chemicals" it is not surprising that Denmark's most actively patenting firms come precisely from those industries. Denmark's leading EPO patentee is Nordisk Gentofte A/S (now Novo Nordisk A/S) that applied for a total of 1,452 EPO patents between 1978 and 2003. The other top ten members are Novozymes A/S (523),[7] Danfoss A/S (282), Haldor Topsøe A/S (214), Rockwool International A/S (198), V. Kann Rasmussen Industri A/S (now Velux A/S, 195), Coloplast A/S (154), H. Lundbeck A/S (143), Grindsted Products A/S (now Danisco A/S, 143) and FLSmidth A/S (137). The most actively patenting public or semi–public research institutions are Slagteriernes Forskningsinstitut (owned by the Association of Danish Pig Producers) with 66 patent applications and Risø National Laboratory with 57 applications.[8]

[7]Novozymes A/S emerged from a demerger from Novo Nordisk A/S in November 2000.

[8]The top ten patent applicants for *application* year 2003 are Nordisk Gentofte A/S (13 patent applications), Novozymes A/S (8), Danfoss A/S (7), Haldor Topsøe A/S (7), H. Lundbeck A/S (6), Coloplast A/S (6), Nuevolution A/S (6), V. Kann Rasmussen Industri A/S (6), Risø National Laboratory (5) and Oticon A/S (5). The top ten firms for the *priority* year 2003 are Nordisk Gentofte A/S (13), Aasted–Mikroverk APS (9), V. Kann

Insert Figure 4 about here!

3.2 Time lag between application and granting

Figure 5 shows that the lag between a patent application and a patent grant has increased substantially between 1978 and 1996. This observation is in striking contrast to findings for the US by Hall et al. (2001) who document that the lags between applications and grants have shortened significantly in the period 1970 to 1992 even though the number of examined patents doubled in the period. In addition, the mean patent granting lag was quite low in the US (1.7 years in 1996 compared to 4.7 years for the Danish EPO patents).

Insert Figure 5 about here!

A further analysis of our patent data shows that there is little heterogeneity in patent granting lags between the five different technology classes. Granting lags are slightly larger in the more "modern" technology area "Drugs and Health" where EPO patent examiners might have less experience compared to the more "traditional" area "Mechanicals".

Rasmussen Industri A/S (8), Haldor Topsøe A/S (8), Novozymes A/S (8), Danfoss A/S (7), Coloplast A/S (6), Nuevolution A/S (6), H. Lundbeck A/S (6) and Risø National Laboratory (5).

3.3 Priority countries

Figure 6 shows that a broad majority of patent applications have a Danish priority (i.e. the applicant first applied to DKPTO before applying to EPO). The share of patent applications with a Danish priority has, however, been decreasing since 1984, mainly to the benefit of direct applications to the EPO. Priority applications at the USPTO have increased quite substantially since 1994. The importance of other priority countries such as Germany, Great Britain and the Nordic countries (Finland, Iceland, Norway and Sweden) has remained fairly stable.

Insert Figure 6 about here!

4 Patent applicants and patent inventors

In this section we look at changes in the composition of patent applicants and inventors in the 24 years of our data. We also examine additional indicators of internalization of patenting activity.

4.1 Patent applicants and inventors

Our prior belief was that the number of applicants per patent increased since 1978 because the complexity of inventions is said to have increased so that

firms are forced to pool their resources to create inventions, as already predicted by Galbraith in 1952. An increase in the number of patent applicants is, however, clearly not what Figure 7 shows. The figure displays the mean number of patent applicants. There is a period of a very slight increase in the number of patent applicants between 1978 and 1986 and a period of very slight decrease thereafter with the overall impression that there is no time trend at all.

Insert Figure 7 about here!

However, some evidence of increased complexity of inventive processes can be found when looking at the mean number of inventors per patent, which has increased considerably. This is shown in Figure 8 that displays both the (unconditional) mean number of inventors per patent and the number of inventors per patent conditional on the presence of more than one inventor. Both numbers have been rising steadily since 1978, which shows that innovation is increasingly often the product of larger research groups. Another possible explanation is that patentable inventions are increasingly often made by large firms with large R&D departments where larger research teams are more likely than in small firms. This issue will be studied in more detail in further research.

Insert Figure 8 about here!

4.2 International co–patenting

4.2.1 Joint patent applications

International co–patenting — joint patent application by at least one domestic and one (or more) foreign applicant(s) — is a quite common phenomenon among small countries such as Luxembourg, Belgium and Iceland (OECD, 2003). It is argued that frequent international co–patenting is due to the relatively limited pool of researchers in small countries, which causes inventors to look abroad to find collaborators.

Figure 9, which displays both the mean ratio of foreign to domestic applicants per patent and the share of patent applications with at least one foreign applicant, shows that the share of patents with at least one foreign applicant has remained fairly stable since 1988, while the ratio of foreign to domestic applicants decreased substantially since 1995 (after being quite unstable between 1978 and 1985, an issue that is due to a relatively low number of patent applications in that period). The data is, however, very volatile so that we do not want to draw sharp conclusions here. We cannot yet explain the spike in the ratio of foreign to domestic assignees (and also in the ratio of domestic to foreign inventors in Figure 9 in 1984. Our suspicion is that those spikes are related to one large family of similar inventions that were co–invented by an international partner.

International co–patenting is lower in Denmark than in other countries of the same size as documented by OECD (2003). If the share of patents with at least one foreign inventor is interpreted as an indicator of internationalization as in Guellec and van Pottelsberghe (2002) and OECD (2003), then Denmark belongs to one of the least internationalized countries in the OECD. Only large OECD countries such as Japan, the US and Germany have a lower degree of international co-patenting.

Denmark's most important partner in research according to our EPO data is the US. 28.1 percent of all international patent applications with priority years 1990 to 2003 are filed with an US partner. Switzerland is the second most important co–patenter (23.6 percent of the international co–patents), probably due to the importance of pharmaceutical and chemical firms both in Denmark and Switzerland. The third largest partner is Germany with a share of 12.9 percent followed by Sweden with 8.4 percent.

Insert Figure 9 about here!

4.2.2 International joint inventor teams

While the number of international co–applications has not increased in recent years, there is an upward trend in international co–inventions as displayed in Figure 10. There is a slight but stable increase in both the share of patents with at least one foreign inventor and in the mean ratio of foreign to domestic

inventors. These facts together indicate that Danish firms increasingly often ship research activities abroad.

The majority of foreign inventors (30.5 percent of all foreign inventors) between priority years 1990 and 2003 were based in the US, followed by Sweden (13.7 percent), Germany (13.2 percent) and the United Kingdom (7.8 percent).

Insert Figure 10 about here!

5 Regional differences in patenting activity

There are pronounced differences in patenting activity across Danish counties (or "Amt" as counties are called in Danish). As shown in Table 1, by far the most patent active region — both measured by the share of patent applications (upper panel) and the share of inventors (lower panel) is Greater Copenhagen (where we combined five counties: Københavns Amt, Københavns Kommune, Frederiksberg Kommune, Frederiksborg Amt and Roskilde Amt).

The dominance of Greater Copenhagen in patent counts decreased quite substantially between 1996 and 2003 compared to the period 1990 to 1995. There is a decrease in the inventor share by 6.3 percent and a decrease in the applicant share by 10.6 percent. Benefitting regions were all other

geographical areas, but in particular Århus Amt (plus 2.6 percentage points in patent application share), Viborg Amt and Nordjyllands Amt (both plus 1.1 percentage points).

Insert Table 1 about here!

6 Patent value correlates

This section deals with patent characteristics that are considered as "value correlates" in the literature (see Gambardella et al. 2005 for a recent exhaustive survey). It is well documented that the value distribution of patents is heavily skewed in the sense that there are very few patents that are economically valuable while by far most patents have no economic value at all (Harhoff et al., 1999; Harhoff et al., 2003; Lanjouw et al., 1998). This implies that a surge in patenting activity does not necessarily imply a surge in the economic value of research activities (and vice versa).

We consider four patent value correlates: (i) "family size", (ii) patent opposition, (iii) patent renewal and (iv) the number of patent "claims". We describe our measures in turn below.

A fifth measure of patent value is the number of citations a patent receives ("forward citations") with the underlying idea being that *technologically* valuable patents receive more citations than economically less valuable

patents. At the same time it is assumed that technologically more valuable patents are also economically valuable. The main practical difficulty here is, however, that forward citations occur with considerable time lags. This implies that younger patents receive fewer citations not because they are less valuable but because the time window in which they could potentially have been cited is narrower. We therefore do not analyze the citations data in detail. Our patent citations analysis shows that the mean number of forward citations considerably increased between priority years 1978 and 1988 and continuously decreased thereafter — which primarily is an artefact that is due to the forward citations being particularly lagging indicators.[9]

6.1 Family size

"Family size" means the number of EPC member countries for which patent protection is sought for.[10] An application at the EPO needs to contain a list of such "designated states". Patent applicants may include up to three designated states without paying fees in addition to the basic application fee. Each additional designated state costs 75 Euros (EPC Art. 2 No. 3a)

[9]We thank Colin Webb, Hélène Dernis (both OECD), Dietmar Harhoff and Karin Hoisl (both Ludwig–Maximilians University Munich) for kind data provision.

[10]Our measure of patent family size provides a lower bound since patent applicants may also seek patent protection outside the EPC area.

plus the cost of translating the patent application into the languages of the additional designated states.

Two observations suggest that patents with a large family size are generally high–value patents. First, family size tends to be highly positively correlated with the number of times that the renewal fees are paid to maintain the patent (Lanjouw et al., 1998). Moreover, a patent applicant will only pay for additional designated states if she expects the returns from patent protection to be sufficiently large (Dernis et al., 2001).

Figure 11 displays the mean ratio of designated states to the total number of possible designated states (the number of EPC member states).[11] The figure shows that the mean ratio of designed states has been steadily increasing. The drops in 1985 and 1992 are presumably related to relatively "unimportant" countries joining the EPC (Monaco in 1991, Portugal and Ireland in 1992). Likewise for the decrease in and after 2001 when former East Bloc countries joined the EPC.

Apart from those merely institutional slowdowns, Figure 11 shows an

[11]The original contracting states were Belgium, the Federal Republic of Germany, France, Luxemburg, the Netherlands, Switzerland and the United Kingdom. The following countries joined later: Italy and Sweden (1978), Austria (1979), Liechtenstein (1980), Greece and Spain (1986), Denmark (1991), Monaco (1991), Ireland and Portugal (1992), Finland (1996), Cyprus (1998), Turkey (2000), Bulgaria, Czech Republic, Estonia, Slovakia and Slovenia (2002), Hungary and Romania (2003), Poland (2004).

upward trend in the relative number of designated states, which suggests that the value of Danish patents has increased over time.

Insert Figure 11 about here!

6.2 Patent opposition

Patent opposition is a value indicator since patent opposition is costly. Only patents that are economically valuable will thus be subject to opposition. Harhoff and Reitzig (2004), who provide an excellent overview over the European Patent System and institutional features of the opposition system, report that the official fee for filing an opposition is 613 Euros. Filing an appeal against the outcome of opposition costs 1,022 Euros. The total costs to an opponent or to the patent holder are much higher, however. Estimates by patent attorneys, as cited by Harhoff and Reitzig (2004), range between 15,000 Euros and 25,000 Euros for an opposition case for each opposing party.

We find multiple opposition against the same patent in our data. We have therefore made patent opposition "unique" (unless indicated otherwise) to avoid double counts by considering only the earliest opposition to a patent. We also discard all patent applications beyond priority year 1996 since this is the last year for which we believe to have fairly complete information on patent grants and since central patent opposition at the EPO is only possible

up to nine months after the granting date.[12]

Figure 12 provides three different measures of patent opposition: the percentage share of opposed patents, the mean number of patent opposers per opposition (an indicator of how forceful patent opposition is) and the mean number of oppositions per patent. While the mean number of oppostions per patent has remained fairly stable since 1978, there are quite considerable fluctuations in the share of opposed patents with a peak in 1985 and a through in 1987. There is a downward trend in the share of opposed patents between 1988 and 1996. At the same time, however, the number of opposers per opposition has increased. This last observation could indicate that the opposed patents are more valuable. It may also, however, be a consequence of the increased average family size, which implies that more competitors and other potential opposers are affected by the patent. Nevertheless, the main conclusion is that there is no strong evidence of Danish patents having become more valuable over the period considered when looking at patent opposition.

Insert Figure 12 about here!

[12]After expiration of the nine months period, opposition may be filed at the national patent offices since an EPO patent grant falls into a bundle of national patents. However, central opposition at EPO is the most convenient and most cost effective way of opposing so few patents are challenged after the nine months period.

6.3 Patent renewal

An often used measure for patent value is the payment of patent renewal fees. Applicants to EPO may have to pay two different types of renewal fees (i) renewal fees prior to the patent grant and (ii) renewal fees post to the patent grant. The first type of renewal fee is due two years after the date of patent application. The application has thereafter to be renewed every other year until the patent is granted (or rejected). These payments go directly to EPO.[13] The second type of renewal fees are due once the patent has been granted. Since an EPO patent application falls into a bundle of national patents, countries in which the patent is valid may impose their own renewal fees after granting.[14] We do not observe the latter type of renewal fee in our data and hence do not analyze it.

Our renewal–related measure of patent value is the share of patent applications that were renewed at least once. We discard withdrawn, suspended and refused patent applications, e.g. we related patents that were at least

[13]The renewal fees prior to granting are 383 Euros for the third year after application, 409 Euros for the fourth 4th, 434 Euros for the fifth year, 715 Euros for the sixth year, 741 Euros for the seventh year, 766 Euros for the eight year, 971 Euros for the ninth year and 1,022 Euros for the tenth and each subsequent year, see EPC Art. 86(1).

[14]For example, the German Patent and Trademark Office charges between 70 Euros (for the third year after the patent grant) and 1,940 Euros (for the 20th year after patent grant).

renewed once to all patents that were either not renewed or were not granted patent protection. We obviously only consider patent applications if the examination took more than two years.[15] Figure 13 shows that the share of patent applications that were at least renewed once has increased between 1978 and 1996, the last year for which we believe to have fairly complete information on patent grants. If we interpret patent application renewal as patent value indicator, Figure 13 indicates an increase in the value of Danish patent applications over time.

Insert Figure 13 about here!

6.4 Patent claims

"Patent claims" are the parts of a patent that define the limits of patent protection. Patent claims are the legal basis for patent protection.[16] They delimit the patent rights so that broader claims mean broader patent pro-

[15]There are only 19 application where less than two years elapsed between application and grant.

[16]The OECD Compendium of Patent Statistics (OECD 2003) defines a patent "claim" as "the definition of the monopoly rights that the applicant is trying to obtain for the invention. The claims become the actual monopoly that is given when the patent is granted. A claim consists of a specification and one or more claims. Each claim defines a claimed invention by its periphery. A valid claim is one which reads on the invention described in the specification but does not read on any prior art."

tection and hence higher economic value and an increase in the likelihood of opposition.

Lanjouw and Schankerman (2004) use multiple indicators to construct a composite measure of the quality of patents, and show that forward citations and claims are the most informative indicators.

Figure 14 displays both the mean number and median number of claims per patent by priority year. The figure shows a steep and steady increase in the number of patent claims between priority years 1978 and 2002, indicating that the economic value of Danish patents has increased in that time period.

Insert Figure 14 about here!

7 Conclusions

This paper provides a macro–level overview of the patenting activity of Danish firms using the newly established CEBR patent data base that contains all patent applications at the European Patent Office that were filed by Danish firms.

Our main findings are that both the number of patent applications and the number of patents grants have increased since 1978 when the EPC was established. There is, however, an increasing gap between the number of patent applications and the number of patent grants. By the same token,

the probability of patent granting has been decreasing, in particular since 1989.

We also consider four measures for the economic value of patents, namely (i) "family size", (ii) patent opposition, (iii) patent renewal and (iv) the number of patent "claims". Except for patent opposition which does not follow any particular trend, these indicators somewhat suggest an increase in the economic value of Danish patents between 1978 and 2002.

Most patents are filed in the technology area "Electronics", closely followed by "Mechanics" and "Chemicals". "Drugs and Health‘" play a rather subordinate role. There has been a pronounced surge in the share of patent applications in "Electronics" and "Drugs and Health" while the share of applications in "Mechanics", until 1994 the by far most important technology field, has decreased substantially.

Contrary to our initial expectations there is relatively little change in the mean number of applicants per patent, which contrasts the view that research has become increasingly complex so that firms need co–patenters to produce a patentable invention. We do find, however, an increase in the mean number of inventors per patent. We also observe an increase in the relative number of foreign inventors to domestic inventors, suggesting an upward trend in the international cooperation in research. There is no evidence of increased internationalization as measured by the ratio of foreign to domestic patent

applicants in joint patent applications.

Danish patent applicants increasingly often directly turn to the European Patent Office instead of applying to the Danish Patent and Trademark Office first. Priority applications to the US Patent and Trademark Office also increased in recent years.

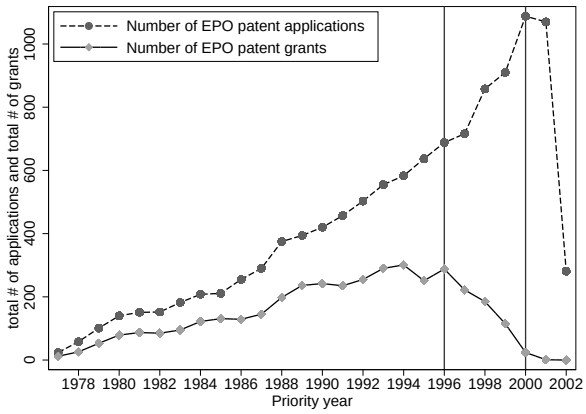
The Greater Copenhagen Area is by far the most patent–intensive region, both with respect to the number of applicants and with respect to the number of inventors. Its dominance quite substantially, however, between 1996 and 2003 compared to the period 1990 to 1995.

The present paper presented some descriptive statistics on macro–level trends on the patenting activity of Danish firms and individuals. Future research will take a deeper look at the internationalization of R&D, firms' strategic use of patents and the relationship between labor mobility and patenting.

Table 1: Distribution of patent inventors (upper panel) and patent applicants (lower panel)

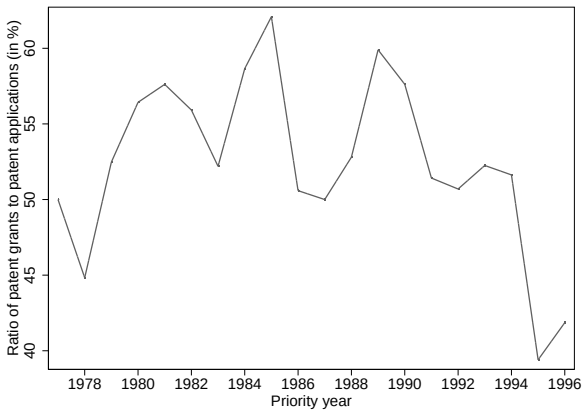
	1978-2003	1990–1995	1996–2003	Change
Distribution of patent inventors				
Vestsjællands Amt	0.7	0.7	1.0	0.3
Storstrøms Amt	0.5	0.4	0.7	0.4
Bornholms Amt	0.1	0.0	0.2	0.1
Fyns Amt	3.0	2.6	3.5	0.9
Sønderjyllands Amt	3.2	4.0	4.6	0.6
Ribe Amt	0.8	0.5	1.3	0.8
Vejle Amt	3.5	2.9	4.6	1.7
Ringkøbing Amt	1.5	1.1	2.0	0.9
Aarhus Amt	3.9	2.9	5.5	2.6
Viborg Amt	0.9	0.4	1.5	1.1
Nordjyllands Amt	2.4	2.4	3.6	1.1
Greater Copenhagen	79.5	82.1	71.5	-10.6
Total	100	100	100	
Distribution of patent applicants				
Vestsjællands Amt	0.6	0.4	0.7	0.4
Storstrøms Amt	0.3	0.2	0.4	0.3
Bornholms Amt	0.0		0.0	0.0
Fyns Amt	2.2	1.7	2.3	0.7
Sønderjyllands Amt	0.6	0.4	1.0	0.6
Ribe Amt	0.2	0.1	0.3	0.2
Vejle Amt	1.3	1.0	1.4	0.3
Ringkøbing Amt	0.6	0.4	0.7	0.3
Aarhus Amt	2.9	2.0	3.9	1.9
Viborg Amt	0.7	0.2	1.2	1.0
Nordjyllands Amt	0.8	0.5	1.1	0.7
Greater Copenhagen	89.8	93.2	87.0	-6.3
Total	100	100	100	

Figure 1: Danish patent applications and patents grants by year, absolute numbers



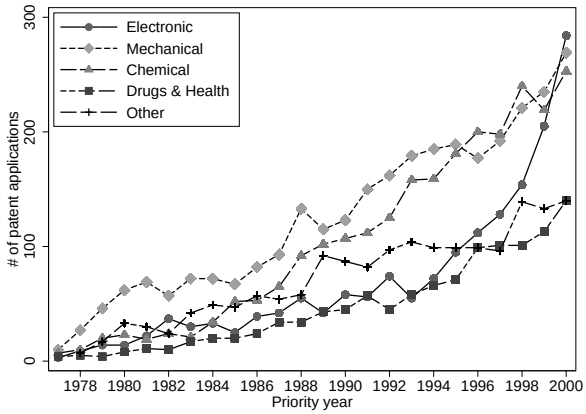
Note: the last year of complete recording of patent applications is 2000,the last year of fairly complete recording of patent grants is 1996.

Figure 2: Probability of patent granting by priority year (in percent)



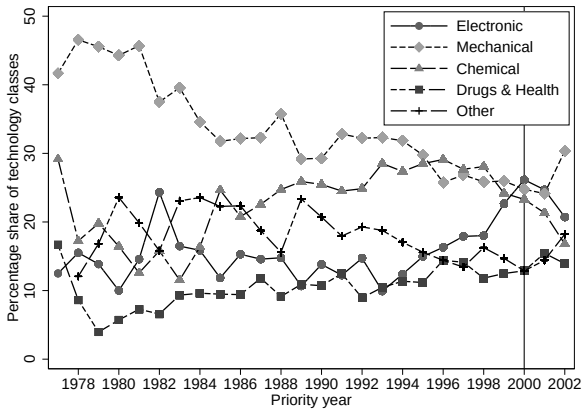
Note: the last year of complete patent application recording is 2000, the last year of fairly complete patent granting recording is 1996.

Figure 3: Patent applications by priority years and technology, absolute numbers



Note: the last year of complete recording is 2000; main IPC class considered only.

Figure 4: Share of technology classes in total number of applications by priority year and technology (in percent)

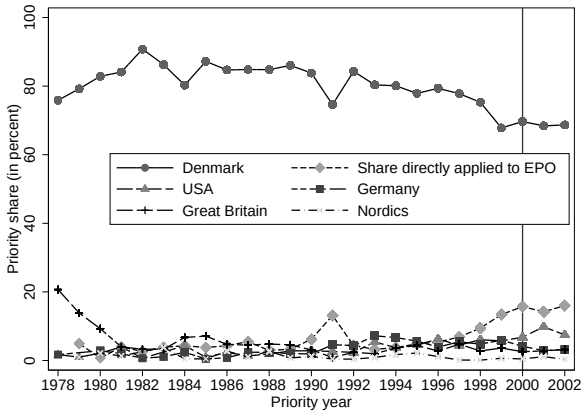


Note: the last year of complete recording is 2000; main IPC class considered only.

Figure 5: Mean lag between patent application and patent grant (in years)

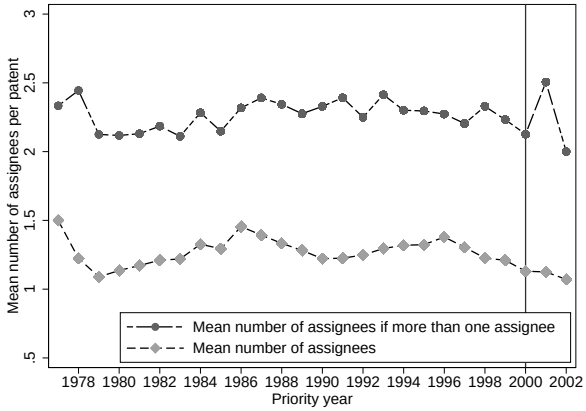
Note: the last year of complete recording of patent applications is 2000, the last year of fairly complete filing of patent grants is 1996.

Figure 6: Mean shares of patent priority countries by priority year



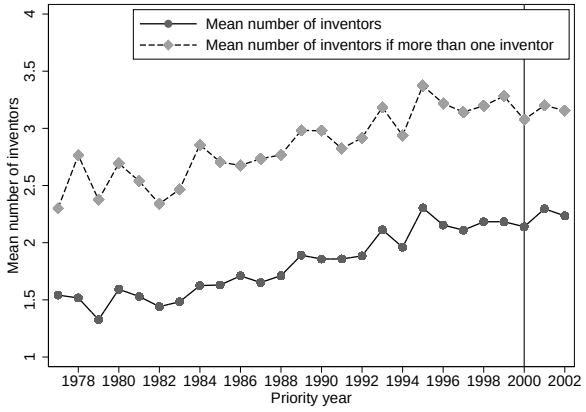
Note: the last year of complete recording is 2000.

Figure 7: Mean number of applicants per patent by priority year



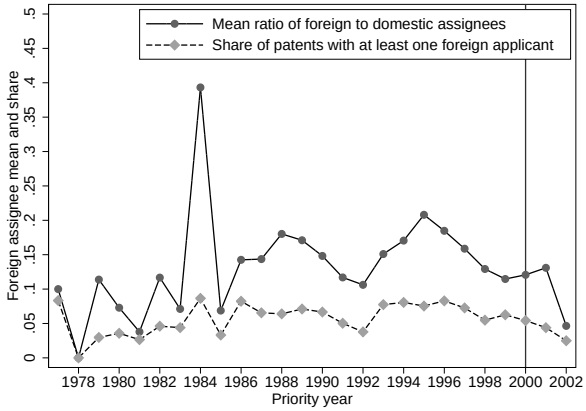
Note: the last year of complete recording is 2000.

Figure 8: Mean number of inventors per patent by priority year



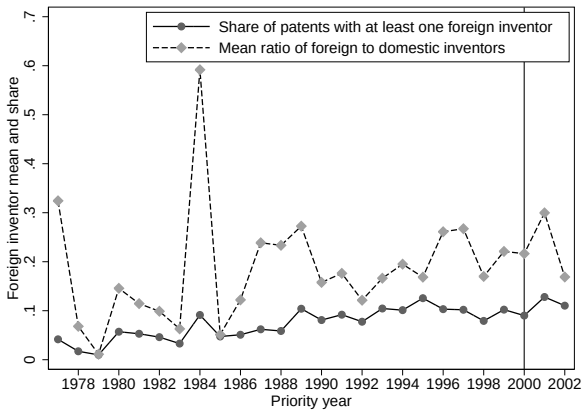
Note: the last year of complete recording is 2000.

Figure 9: Mean ratio of foreign to domestic patent applicants by priority year



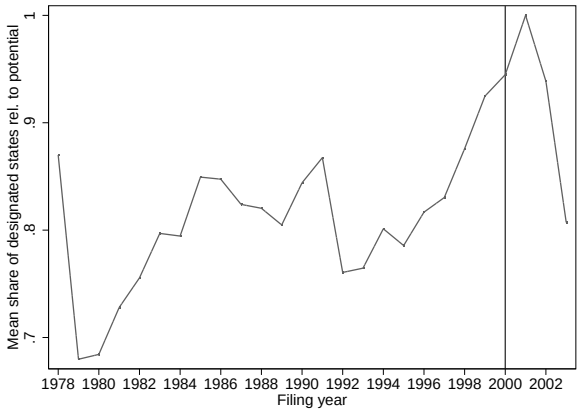
Note: the last year of complete recording is 2000.

Figure 10: Mean ratio of foreign to Danish patent inventors by priority year



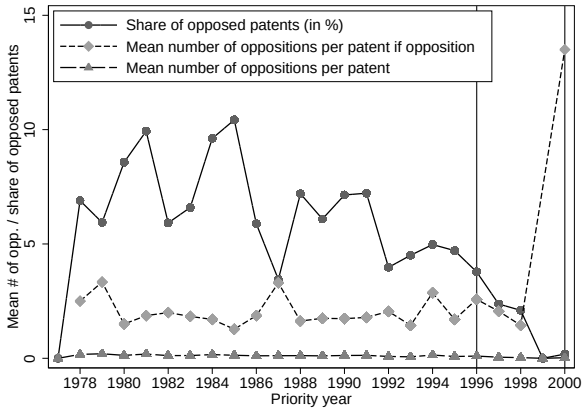
Note: the last year of complete recording is 2000.

Figure 11: Mean ratio of number of actual designated states to potential number of designated states by priority year



Note: the last year of complete recording is 2000.

Figure 12: Share of opposed patents in total number of patent applications by priority year

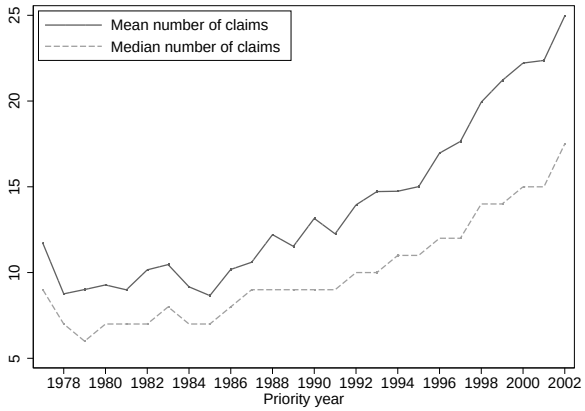


Note: the last year of complete recording is 2000.

Figure 13: Share of patent applications that were at least once renewed by priority year

Note: the last year of probably complete recording of patent grants is 1996.

Figure 14: Mean and median number of claims per patent application by priority year



Note: the last year of probably complete recording of patent applications is 1996.

Appendix: definition of technology areas

Our five main technology areas are defined according to the first letter and the following two digits of the patents' main IPC classification:
Drugs & Health:, A61, A01N
Chemicals: A62, B31, C01, C02, C03, C04, C05, C06, C07, C08, C09, C10, C11, C12 C13, C14, C15, C16, C17, C18, C19, C20, D
Electronic: G01, G02, G03, G04, G05, G06, G07, G08, G09, G10, G11, G13, G14 G15, G16, G17, G18, G19, G20, H
Mechanical: B2, B3, B31, B4, B5, B6, C2, C20, C30, E0, E1, E2, E3, E4, E5, E6, E7 E8, E9, F0, F1, F2, F3, F40
Other: A, A61, A01N, A62, B01, B02, B03, B04, B05, B06, B07, B08, B09, B10, B11 B13, B14, B15, B16, B17, B18, B19, B20, B81, B82, F41, F42, G12, G21

References

Gambardella, A., P. Giuri and M. Mariani (2005), "The value of European patents: evidence from a survey of European inventors", Sant'Anna School of Advanced Studies mimeo.

Dernis, H., D. Guellec, D. and B. van Pottelsberghe (2001), "Using patents counts for cross–country comparisons of technology output", *OECD STI Review*, 27, 129–146.

Encaoua, D., D. Guellec and C. Martínez (2003), "The economics of patents: from natural rights to policy instruments", mimeo., University Paris I Panthéon–Sorbonne.

Galbraith, J.K. (1952), *American capitalism: the concept of counterveiling power*. Houghton Mifflin, Boston, MA.

Gallini, N. and S. Scotchmer (2005), "Intellectual property: when is it the best incentive system?", in: Jaffe, A., J. Lerner and S. Stern (eds.), *Innovation Policy and the Economcy*, 5, MIT Press, Cambridge, MA.

Griliches, Z. (1990), "Patent statistics as economic indicators: a first survey", *Journal of Economic Literature*, 28, 1661–1707.

Guellec, D. and B. van Pottelsberghe (2002), "The internationalization of technology analysed with patent data", *Research Policy*, 30, 1253–1266.

Hall, B.H., A.B. Jaffe and M. Trajtenberg (2001), "The NBER patent citations data file: lessons, insights and methodological issues", NBER Working Paper 8498.

Harhoff, D. and M. Reitzig (2004), "Determinants of opposition against EPO patent grants — the case of biotechnology and pharmaceuticals", *International Journal of Industrial Organization*, 22, 443–480.

Harhoff, D., F. Narin, F.M. Scherer and K. Vopel (1999), "Citation frequency and the value of patented innovation", *Review of Economics and Statistics*, 81, 511–515.

Harhoff, D., F. Scherer and K. Vopel (2003) "Citations, family size, opposition and the value of patent rights", *Research Policy*, 32, 1343–1363.

Hougaard Jensen, S.E., U. Kaiser, N. Malchow–Møller, J.R. Skaksen and A. Sørensen (2003), *Denmark and the information society: Challenges for research and education Policy*, DJØF Publishing Copenhagen.

Kaiser, U. and C. Schneider (2004), "The CEBR matched patent/patent Applicant/employee data base: part 1 — patent data", mimeo. Centre for Economic and Business Research Discussion; available at: http://www.ulrichkaiser.com/papers/patentdesc.pdf.

Lanjouw, J.O., A. Pakes and J. Putnam (1998), "How to count patents and value intellectual property: The uses of patent renewal and application data", *The Journal of Industrial Economics*, XLVI, 405-433

Lanjouw, J.O. and M. Schankerman (2001), "Characteristics of patent litigation: a window on competition", *RAND Journal of Economics*, 32, 129–151.

Lanjouw J.O. and M. Schankerman (2004), "Patent Quality and Research Productivity: Measuring Innovation with Multiple Indicators", Economic Journal, 114, 441–465.

OECD (2003), *Compendium of patent statistics*, OECD, Paris.

Pedersen, K. A. and M. Præst (1997), "Dokumentation af Patent-database", mimeo. University of Aalborg; available at: *http://www.business.auc.dk/ike/ike-attach/epo_patent.pdf.*

Strøjer Madsen, E., A. Østergaard Nielsen and V. Smith (2000A), "Er danske virksomheder mindre innovative?", *Samfundsøkonomen*, Nr. 4 - 2000.

Strøjer Madsen, E., A. Østergaard Nielsen and V. Smith (2000B), "Patent– og FoU–aktivitet i Danmark", Rapport fra Analyseinstitut for Forskning 2000/5.

Østergaard Nielsen, A. (1998), "A selection model of patenting firms in Denmark", Århus School of Business discussion paper 98–5.

Østergaard Nielsen, A. (1999), " Patentaktivitet og FoU", Rapport fra Analyseinstitut for Forskning 1999/1.