The Determinants of Patent Applications Outcomes - Does Experience Matter?

Cédric Schneider

CEBR, Copenhagen Business School

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Cédric Schneider*
CEBR, Copenhagen Business School
and University of Southern Denmark

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Abstract

The aim of this paper is to study the determinants of the outcomes of patent applications (withdrawal, refusal or grant). The application process at the European Patent Office is modelled in three stages, using a Trivariate Probit model with double selectivity correction in order to test whether the applicants' patenting history has an effect on the outcome of the current application. I investigate the behavior of the applicant after the patent office has established the "state of the art", a precondition to an invention being patentable. The main results are (i) firms with large patents portfolios act following a "trial and error" strategy, by applying for large numbers of patents and thereafter waiting for the patent office's final decision when the expected probability of grant is high, (ii) the technological importance of a patent is a crucial determinant of a successful application grant, (iii) a withdrawal is to be regarded as an expected refusal, since applicants tend to withdraw their applications when there is evidence that the inventions cannot be considered to be novel or to involve an inventive step.

Keywords: patents, intellectual property rights

JEL: O31, O32, O34

* **Address**: Centre for Economic and Business Research, Copenhagen Business School, Porcelaenshaven 24b, DK 2000 Frederiksberg, Denmark; email: csc@cebr.dk

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1 Introduction

Firms' patenting activity is of great interest to economists and policy makers, as patent counts are a measure of innovation, admittedly in an imperfect way. The interest of research into strategic management has also dramatically increased as patent activity becomes an important ingredient of a firm's competitive strategy. A surge in patenting took place in the mid 1980s in the three main patent offices, the U.S. Patent and Trademark Office (USPTO), the European Patent Office (EPO) and the Japanese Patent Office (JPO). This worldwide growth in patent applications has been described e.g. in OECD (2004).

Within the EPO procedure, the patent office establishes the state of the art by issuing a search report that contains a list of prior art. The applicants then have the possibility to withdraw their applications if they consider that the search report is negative, i.e. if it contains evidence that the claimed invention is not novel or does not involve an inventive step, or to maintain it if their expected probability of getting a grant is high. Substantial examination follows if the application is maintained. The EPO procedure differs from the USPTO and the JPO, in which the search and substantive examination are undertaken in one phase.

The aim of this paper is to study the determinants of the outcomes of patent applications (grant, refusal or withdrawal). The main hypothesis tested is that the applicant's patenting history has an effect on the outcome of the current application. This paper also tests the behavior of the applicant after the state of the art is established by the patent office.

Van Dijk and Duysters (1998) found that basic research, which explores more novel and unknown paths, meets the patentability requirement more often, whereas Guellec and Van Pottelsberghe (2000, 2002) show that the characteristics that increase the probability of a grant at the EPO are: international applications through the Patent Cooperation Treaty (PCT), research cooperation between domestic researcher, research cooperation with foreign researchers and the designation of a limited number of countries in the application.

This paper differs from the before mentioned existing studies in several aspects: (i) The literature so far focused on patent applications and patent grants only. While more than half of all patent applications indeed receive a grant, a large number of all patent applications are withdrawn by the applicants and only a few of them are refused a grant by the EPO (see Harhoff and Wagner, 2006). I explicitly model the possibility that firms can withdraw their patents. (ii) The outcomes of the patent procedure is modeled by taking into account the sequential aspect of the applicant's and patent office's decisions within an econometric framework using a Trivariate Probit Model with double selection.

(iii) Firm heterogeneity and patent citation measures are taken into account by using a database linking patents, citations and firms data, where earlier work only studied the effect of patent-based variables.

The main results are (i) firms having large patent portfolios follow a "trial and error" strategy by applying for huge numbers of patents and thereafter waiting for the EPO's final decision when the expected probability of grant is high; (ii) the "importance" of a patent, as measured by the number of forward citations is a crucial determinant of a successful application; (iii) applicants tend to withdraw their applications when the result of the preliminary search report issued by the patent office is negative. In that sense, a withdrawal is generally an expected refusal, (v) the grant/refusal decision made by the patent office is more difficult to predict than with a "one-step" model that compares the probability of grant to all other outcomes.

Section 2 briefly summarizes the application process at the EPO. Section 3 presents the economic background; the data are presented in Section 4, while Section 5 describes the variables used and Section 6 provides summary statistics. The empirical model and the results are presented in Section 7, which is followed by concluding remarks.

2 Application process, outcomes and cost of patenting at the EPO

I first describe the application procedure at the EPO and then the associated costs.

2.1 The patent application process

The EPO was founded in 1978 as the result of the European Patent Convention (EPC). Within this framework, a single and centralized application is made, designating the signatory states of the EPC in which protection is sought for. The EPO system allows the applicants to choose the jurisdictions, among the contracting states of the EPC, in which protection is sought for. Thus, a patent provides the applicant with protection in all the designated states. If patent protection is sought for in more than three EPC countries, an EPO patent application is less costly than direct applications in each national patent office. Applicants may, however, apply for a patent at the EPO for an invention that had previously been applied for at a national patent office, within twelve months after the first application (priority application).

Figure 1: Examination of patent applications at the EPO

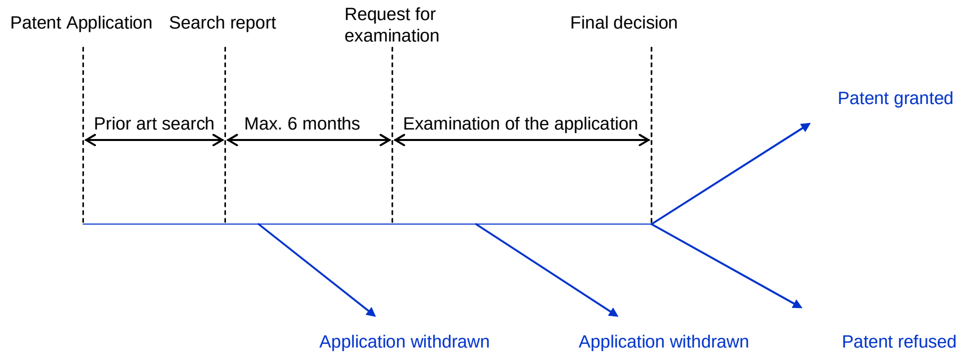

Figure 1 provides a simple presentation of the application process at the EPO. The application is published 18 months after the date at which the European or national priority application was filed. A search report describing the state of art is published either with the application or later on. It contains references to prior patents or scientific publications, classified in different categories according to their relevance for the final decision. After the search report is published, applicants have six months to decide whether or not to pursue their application by requesting substantive examination. If no request for examination is filed within the six months, the application is *deemed to be withdrawn*. If the renewal fee or any other fee were not paid in due time, the application is also *deemed to be withdrawn*. The *withdrawal* of the application can also be explicit, under the form of written correspondence between the applicant and the patent office, at any time before or during the examination process. A *withdrawal* typically takes place when the search report issued by the patent office contains evidence that the claimed invention is not novel, or does not involve an inventive step, in the sense that the applicant expects the patent not to be granted.

If examination was requested by the applicant, the application is examined by the patent office according to three criteria: novelty, inventive step and industrial applicability. The application then may end up with a *grant* or a *refusal to grant*. A request for examination does, however, not necessarily lead to a final *grant/refusal* decision by the EPO, in the sense that the applicants still have the possibility to withdraw their application after having requested examination[1]. Under examination, applicants receive additional information on the patentability of the invention and can then choose whether to withdraw the application, or to wait until the EPO's final decision.

According to the EPC, if a European patent is granted, competence is transferred to the designated contracting states, where it affords the same level of legal protection as a national patent and is valid for 20 years from the date of filing, if it is consecutively

[1] I thank Stefan Wagner for pointing this fact out.

renewed.

If the applicants seek patent protection in several countries, they have the possibility to fill an application under the Patent Cooperation Treaty (PCT, effective since the early 1980s), to be filed at the World Intellectual Property Organization (WIPO). Since a large share of applications in this study are filed under the PCT, it is worth describing the procedure briefly. A PCT application is an international agreement for filing patent applications having effect in all designated countries. Although the PCT system does not provide for the grant of an international patent, the system does simplify the process of filing patent applications. Under the PCT, an inventor can file a single international patent application in one language, with one patent office in order to simultaneously seek protection for an invention in up to 183 countries. Such a procedure gives the applicant more time to decide whether to apply for the patent or not and in which of the 183 PCT member countries. Our database contains PCT applications in which the applicants have designated the EPO, so called "Euro-PCT" applications.

Chapter I of the PCT procedure consists of sending the application to an International Searching Authority (ISA), which is a national or regional patent agency, for carrying out the search on the state of the art. The EPO is responsible for more than half of the searches. Once the report is provided by the ISA, the applicant has three possibilities:

(1) transfer the application to national or regional patent offices among those designated in his application,

(2) elect an International Preliminary Examination,

(3) withdraw the application.

Chapter II of the PCT procedure comes into play once the international preliminary examination is chosen by the applicants. If the Euro-PCT application is transferred to the EPO, the outcome of the preliminary search report is taken into account.

As indicated by Harhoff and Wagner (2005), PCT filings can be advantageous for the following reasons:

(1) they allow the expansion of patent protection to a large number of countries without incurring the full costs and complexity of national application paths,

(2) applicants will receive an international search report within a relatively short time period, informing them about prior art that may be relevant for the own application's likelihood of being granted,

(3) PCT filings allow applicants to delay decisions about the countries for which they want to designate the application for up to 30 months after the priority date, which is helpful if the applicant ignores the value of the invention.

2.2 The cost of patent applications

The cost an applicant has to incur throughout the whole patenting procedure is an important factor for the applicant's decision to maintain or terminate the application. The applicant is going to maintain the application in the process as long as the prospects for future profits are greater than the cost of the application. Thus it is worth mentioning the main components of the cost of a patent application at the EPO. However, given the variety of situations an applicant can be faced to and the complexity of the procedure, this cost can hardly be summarized with a single figure. In this subsection, I give a brief overview of the fees an applicant will have to pay at the different stages of the application procedure.

The nature of the fees and costs can be divided into three categories:

- **Pre-filing costs** comprise all the elements related to the drafting of the first application.
- **Procedural fees** have to be paid once the application has been filed at the EPO. These costs are summarized in Table 1 and do not include the administrative costs an applicant can be asked to pay.

Table 1: Procedural fees

Nature of fee		*Amount (€)*
Filing fee *		90.00
Search fee		690.00
Designation fee **		75.00
Renewal fee for the application	3rd year	380.00
	4th year	405.00
	5th year	430.00
	6th year	715.00
	7th year	740.00
	8th year	765.00
	9th year	970.00
	>10th year	1,020.00
Examination fee		1,430.00
Grant fee ***		715.00

* if filed online, € 160.00 otherwise
** per contracting designated state, up to seven countries
*** incl. printing up to 35 pages, €10.00 per additional page
source: "Schedule of fees and costs", supplement to official Journal OJ EPO 2/2005

- Notice that this schedule only applies to "Euro-direct" applications. If the application has been applied through the PCT route, additional fees have to be paid. For example, the fee for the preliminary examination of an international application is

€ 1,530. The same applies if the patent was applied for at a national patent office prior to the EPO application. The applicant also has the possibility to request the services of a patent attorney or a legal representative for guidance throughout the procedure which leads to additional expenses.

- **Post-grant costs** are probably the most expensive part of the procedure. Once a patent is granted by the EPO, the applicants have to translate the document in each official language of each designated state. Van Pottelsberghe and François (2006) estimate this cost at about € 1,700 per language. In addition, the patent has to be enforce and maintained in each jurisdiction by paying the renewal fees in each of them.

Van Pottelsberghe and François (2006) estimate that the procedural and translation cost of the "average" patent that designates three countries (the UK, Germany and France) is € 8,070. The same patent that designates 13 countries will cost about € 20,175. These figures can be compared to the cost of application (excluding renewal fees) at the USPTO (€ 1,856) and at the JPO (€ 1,541).

It is difficult to quantify the cost of application at the EPO with accuracy. Thus, in the analysis, I will use indirect measures such as the number of designated states, PCT applications, number of claims or if a patent attorney acted as a legal representative.

3 Theoretical background

The usual way to model patenting behavior in economic theory is to consider two or more firms "racing" for an invention. The winner of the race will then patent the invention, that is assumed to be granted with probability one.

However, the outcome of a patent application is essentially the result of a strategic interaction between the patent office and the applicant. Régibeau and Rockett (2003) assume that the applicant maximizes its private profit, while the patent office maximizes a social welfare function. In their model, the decision made by the patent office is imperfect, in the sense that there is a probability of erroneous judgement, i.e., that the patent office confers patent protection to a invention that is not novel or that the patent office rejects an application that meets the patentability requirements. The probability of error is a negative function of time, as longer examination periods enable more thorough reviews, lowering the probability of error that will enter the firm's profit function.

To explain early or late withdrawals, one could think that the distance between the actual quality of the invention and the quality standard set by the patent office enters the erroneous judgement function. The higher this distance is, the easier it is for the patent office to demonstrate lack of novelty or inventive step. The actual quality of the application is however observed with some noise by the patent office, which might be influenced by its capability to perform efficient searches and examinations or the willingness of the applicant to hide the true potential of the application. In some cases, unexperienced applicants might even be unaware of the quality of their own inventions, compared to the quality standard of the patent office.

In that event, applicants might withdraw their applications because the search report demonstrates that conflicting prior art exists. These early withdrawals take place when the quality of the invention is low compared to the patent office's standard.

If the lack of novelty is more difficult to demonstrate, possibly because the applicant tries to hide the true quality of the application, substantial examination will be requested, where the firm gets additional information on the patentability of the invention and updates the expected probability of grant. In this scenario, the application will be maintained as long as the probability of erroneous judgment enables positive private profits.

4 Data sources

In Section 5 I make several hypotheses regarding the effects of a set of variables on refusals, withdrawals and grants, that I derive from the existing literature. The hypotheses are easier to expose if I first describe the dataset at my disposal.

The data was compiled from four main sources:

1. The **CEBR patent database** contains all the patents applied for by at least one Danish firm at the EPO since the creation of the EPO in 1978 up to 2003. The initial database contains 12,109 patent applications. A major advantage of this database is that a unique firm identifier has been attached to the patent assignees, the so-called "CVR" number (central firm registry number) to find exact matches between the firm names and addresses in the patent data and the firm name and addresses in the financial data (the KOB data, see below).

   We identify a total of 2,822 unique Danish non-person patent applicants, a total of 1,152 Danish private applicants (see below for the definition of "private applicants") and a total of 591 foreign (co-) applicants. Both the Danish private applicants and the foreign applicants have been assigned unique identification numbers. We therefore have the entire population of patents applied for by Danish firms at the EPO, with an exact match with the firm-level data. More details on the database and how it was constructed can be found in Kaiser and Schneider (2005).

2. The **EPO/OECD citations database** contains information on citations made in the patent applications, as well as information on the citations received by all EPO patents applied before October 2004. More information on the citation database can be found in Webb et al. (2005)

3. The **KOB data** provides us with firm level data. KOB A/S is a private firm that has specialized in collecting and processing data on Danish businesses. Our dataset is an image of the data that can be found on http://www.kob.dk/. This dataset is described in detail in Bennedsen et al. (2006)

4. Finally, the **number of claims** has been searched manually for each patent application via http://ep.espacenet.com/

In order to include the number of forward citations (the number of citations received from subsequent patents) within five years after the patent application and allow for ample examination time, I restrict the dataset to patents that were applied for before January 1st 1998.

5 Variables

The dependant variables and explanatory variables are described in turn.

5.1 Dependent variables

All dependent variables are binary. The purpose is to explain both the decision to withdraw an application, after search report and during examination, or to maintain it, and the subsequent decision made by the patent office to grant the patent or not. The application procedure outlined in Section 2 shows that withdrawals can take place before or during the substantial examination phase. These decisions might be driven by different factors, thus they are going to be analyzed in different equations.

My empirical model considers three dependent variables of which the final decision by the EPO is observed if the application has not been withdrawn during examination, which in turn is conditional upon a request for examination after the search report has been received by the applicant.

Request for Examination/withdrawal after search report. This variables takes the value 1 if the applicants have requested for examination and 0 if the application was withdrawn before examination.

Final decision/withdrawal during examination. For each patent application, we know whether the applicant decided to maintain it until the EPO makes a final decision, or to withdraw it. The variable takes the value 1 if the application is maintained and 0 if it is withdrawn during examination.

Decision of the EPO. If the applicant indeed decided to maintain the application, we observe the decision by the EPO to grant (= 1) or to refuse (= 0) the patent.

5.2 Explanatory variables and hypotheses

This section introduces the explanatory variables used in the multivariate analysis, as well as a set of hypotheses on the expected effects of experience, citations, patent characteristics, application ways and legal structure of the applicant.

5.2.1 Experience variable

A main explanatory variable is:

Patent applications stock*.* The effect of this (lagged) stock variable with declining balance depreciation will be tested. The variable is constructed using the perpetual inventory method and is defined as:

$$A_{it} = (1 - \delta)A_{it-1} + N_{it} \quad (1)$$

Where A_{it} is the stock of applications of firm i at time t, N_{it} is the number of patents applied by firm i at time t and δ is the depreciation rate of the patent stock from year $t-1$ to year t. As noted by Czarnitzki et al. (2005), the use of a depreciation rate is justified by the fact that knowledge tends to decay or become obsolescent over time, losing economic value due to advances in technology. We will make the usual assumption that $\delta = 15\%$, see for example Hall (1990). In case of multiple applicants, the sum of the stock of the collaborating firms is taken.

H1: Experienced firms are more likely to maintain their applications and to have them granted.

Preliminary hypothesis can be made to explain the (hypothetical) importance of applicants' experience:

- They have intrinsically a higher capability to generate patentable ideas.

- They have learned how to draft the documents well, if only due to a greater familiarity with the application procedure, which increases the chances of future success.

- They have created informal networks at the patent office and are receiving special treatments.

- They know the relevant prior art in the area they are active in.

5.2.2 Citation measures

The analysis includes both citations made by the application and citations received.

Number of citations made (backward citations). The search report issued by the EPO lists all the documents regarding prior art that are relevant for the examiner's decision on patentability. Harhoff et al. (2005) describe in detail how to use citations assigned to EPO patents.

For our purpose, an interesting feature of the search report made by the EPO is that the patent references are classified in different categories according to their relevance. In addition to the total number of backward patent citations, I will use:

- The number of "type X" citations which indicate that the claimed invention cannot be considered to be novel or cannot be considered to involve an inventive step when the referenced document is taken alone.
- The number of "type Y" citations, indicating that the claimed invention cannot be considered to involve an inventive step when the referenced document is combined with one or more other documents of the same category, such a combination being obvious to a person skilled in the art.
- The number of "type D" citations, referring to patent references already mentioned in the description of the patent application and approved by the examiner.

H2: Conflicting prior art leads applicants to withdraw their applications and the EPO to refuse the grant.

It is obvious that a high number of type X and type Y citations reflects a negative search report, since they imply that the invention is not novel, which is expected to lead the applicant to withdraw the application or the patent office to refuse the grant.

H3: Applicants mastering the state of the art are less likely to withdraw their applications.

Type D citations are references already mentioned by the applicant when the application was submitted. This type of citations could reflect the fact that the applicant has a good command of prior art. The probability to maintain the application up to the final decision is expected to increase with the number of type D citations.

Reference to the Non-Patent Literature (NPL), might also be a relevant variable to include in the regression. However, this data is only available for patents applied for after 1990. Therefore they will not be used in the analysis.

Number of citations received (forward citations). Trajtenberg (1990) showed that the number of citations received from subsequent patents is highly correlated with the social value of the underlying invention. Since then, this indicator has also become one of the most validated measure of the private value of the patent rights, see e.g. Harhoff et al. (1999) or Hall et al. (2005). Thus, the number of citations the patents receive from other EPO patents within five years after the publication date will be included. The number of forward citations also indicates that the patent has contributed to the state of the art, since it measures the "importance" of the patent. The effect of the number of forward citations is expected to be positive both on the probability to maintain the application and on the probability to obtain the grant.

H4: Valuable or technologically important patents are more likely to be granted and less likely to be withdrawn.

A high number of forward citations indicates that a patent is valuable and technologically important. This should lead applicants to maintain their applications and the EPO to grant the patent. This of course, requires that both the applicant and the patent office are aware of the potential value of the patent at the time the patent is applied for and examined.

5.2.3 Patent characteristics:

Number of IPC assignments. During the examination period, a patent is assigned to a number of codes from the International Patent Classification (IPC) system, according to its applicability for different technology areas. Lerner (1994) interprets the number of (IPC) assignments of a patent as the "scope" of this patent, whereas other authors prefer to take it as a measure of the complexity of the invention (Harhoff and Wagner, 2005).

Number of claims. In the same way as the number of IPC assignments, the number of claims, which delimit the boundaries of a patent by describing precise features of the invention, can be interpreted as the "scope" or "breadth" of a patent as well as an indicator of complexity, see Harhoff and Reitzig (2004) or Lanjouw and Schankerman (2004). According to EPO rules, a claims fee is payable for the eleventh and each subsequent claim. Although this fee is marginal[2], applicants seem to be sensitive to this rule, as more than 60% of the patents in our sample contain ten claims or less (see Appendix B). Therefore, I include a dummy variable for applications containing more than ten claims.

Both these variables can thus be interpreted in contradictory ways, as each additional claim and/or IPC assignments could either mirror a broad patent by increasing its scope

[2] The fee for the eleventh and each subsequent claim is 40,00 Euros

or breadth, or make the description of the invention more precise, narrow and specific, thus reducing the scope of the patent.

H5: The number of IPC assignments and a high number of claims positively influence the probability for an application to be granted.

Theses two variables have been found to be "time-zero" value indicators, since they reflect the price the applicant is willing to pay for a given patent at the time of the application. They can also be interpreted as the technical complexity and/or the scope of the patent.

5.2.4 Application ways

Number of designated states. The "Family size" is the number of jurisdictions in which patent protection is sought for. We do not, however, observe the entire patent family, thus I use the number of designated states member of the European Patent Convention (EPC)[3]. Harhoff et al. (2003) and Lanjouw et al. (1998) show that the family size is a patent value correlate.

H6: The higher the number of designated states, the higher the probability of grant and the lower the probability to withdraw the application.

The total number of designated states has been found to be a "time-zero" value correlate (like the number of IPC assignments and the number of claims, see above). This is very intuitive, since applicants have to pay an additional fee for each jurisdiction in which protection is sought for, thereby increasing the geographical scope of protection.

PCT application. A dummy variable indicates whether PCT Chapter I or II applications have been filed for the invention.

H7: Applications that went through the PCT procedure Chapter I only have a higher probability of early withdrawal, whereas applications that went through the whole PCT procedure (Chapter I and II) have a lower probability of withdrawal.

Guellec and Van Pottelsberghe (2002) give arguments for and against a positive role of PCT applications. The PCT procedure provides the applicants with a longer period to decide whether to apply for a patent or not, which enables them to assess the market potentials more thoroughly. The decision to transfer the applications to the EPO might therefore be an indicator of higher quality. On the other hand, the PCT procedure might

[3] The EPO memebers are Belgium, Federal Republic of Germany, France, Luxemburg, the Netherlands, Switzerland, United Kingdom (from Oct. 7, 1977), Sweden (joined May 1, 1978), Italy (Dec. 1, 1978), Austria (May 1, 1979), Lichtenstein (April 1, 1980), Greece and Spain (Oct. 1, 1986), Denmark (Jan. 1, 1990), Monaco (Dec. 1, 1991), Portugal (Jan. 1, 1992), Ireland (Aug. 1, 1992), Finland (March 1, 1996), Cyprus (April 1, 1998)

be a sign of inventions with unclear market potential. In their analysis, Guellec and Van Pottelsberghe (2000, 2002) find that applications that went trough the first part of the PCT application procedure only (PCT I for short) have a lower grant rate, which they interpret as an unclear market potential. They argue that applicants only want to benefit from the longer delay to decide in which jurisdictions to apply, whereas applicants going through the whole PCT procedure (PCT II) are more aware of the value of their inventions.

Number of applicants and number of inventors. These variables are included in order to measure the importance of collaborations in patent applications. The idea is to test whether collaboration is a source of higher technical quality, leading to a higher probability of grant. See Guellec and Van Pottelsberghe (2000, 2002).

H8: Collaborations between applicants and inventors lead to successful applications.

Joint patent ownership is assumed to be a sign of technical quality. The propensities to pursue and to grant should thus be positively influenced by the number of co-applicants and co-inventors.

Legal Representative. Any applicant at the EPO may be represented by:

- A professional representative on the list maintained to this purpose by the EPO (Art. 134(1) of the EPC).

- Legal practitioners (Art. 134(7) EPC)[4]

- Employees (Art. 133(3) EPC), typically from the IP department. The employee(s) must work for the applicant and not for an economically connected company.

We introduce a dummy variable indicating wether the applicant had any legal representation.

H9: Firms legally represented are less likely to withdraw their applications.

Although the effect of legal representation has not been investigated in the economic literature, it is expected to influence the probability to maintain an application, as legal representatives are familiar with the procedure.

5.2.5 Ownership structure

I introduce dummy variables which indicate the legal form of each firm involved in the applications, in order to check whether the firm structure has an impact on either stage

[4] A Legal practioner may act as representative if he/she fullfils the following criteria:
1. is qualified in one of the Contracting States,
2. has his place of business within such State, and
3. is entitled, within the said State, to act as a professional representative in patent matters.

of the model. These dummies can, to some extend, also be interpreted as a proxy for firm size.

H10: Stock listed firms have, compared to other company forms, a lower propensity to withdraw their applications and a higher probability of grant

Large firms, in our case stock listed firms, are expected to have a higher propensity to pursue their applications, since this type of firms have more resources and typically have an IP department.

6 Descriptive statistics

6.1 Outcomes of the patent applications

The number of Danish patent applications has been steadily increasing since 1978, following a trend at the EPO level, see Kaiser et al. (2005). A major challenge related to this unprecedented increase in patent applications and increasing workload is to maintain high quality in patent examination.

Figure 2 presents the timing of the application process with the number of occurrences at the different stages. A patent grant is the most frequent outcome, followed by withdrawals during examination. Relatively few applications are directly refused a grant by the EPO.

Figure 2: Timing of the application process

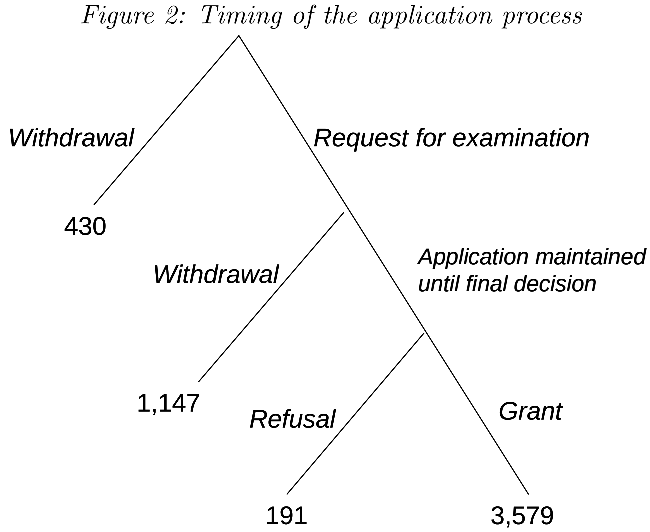

Figure 3 displays the distribution of the outcomes of the patent examinations by application years from the beginning of 1978 to the end of 1997. In order to include citation measures, I only take into account the applications published by the EPO. A majority of patent applications, 66%, is granted in the time window covering the application years of this study, from 1978 to 1997, while a relatively high number of applications, 29%, are withdrawn by the applicants. As pointed out by Harhoff and Wagner (2005), the withdrawal of a patent application occurs generally after the applicant received a "sufficiently negative search report or skeptical communication from the examiner". In addition, about 3.5% of the applications end up with a refusal. The 316 pending applications (for which the outcome is not known yet) are discarded from the analysis. The sample under consideration contains 5347 observations.

Figure 3: Distribution of outcomes

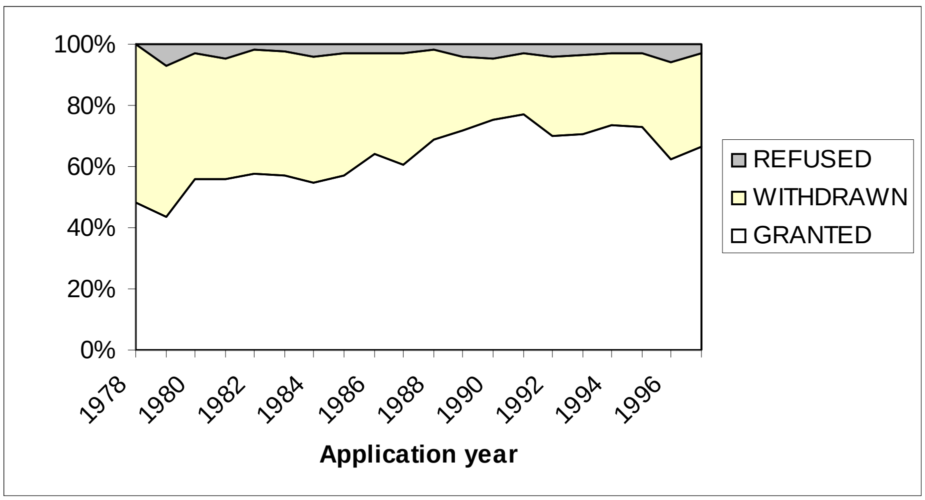

Table 2 summarizes the outcome of the applications between 1978 and 1997 by technology class, using the so called OST classification, provided by the “Office des Sciences et Techniques”, the French Patent Office (INPI) and the Fraunhofer ISI Institute, which is based on a concordance with IPC classes. The table shows an uneven distribution of outcomes across technology classes. When considering the six aggregated technology classes, one can see that the grant rate varies from 63.8% in "mechanical engineering" (technology class V) to 69.9% in "Processing Engineering" (technology class IV). In the 30 more narrow areas, the differences are even stronger, but the low number of applications in some of the areas makes it difficult to compare them. Notice, however, the relatively high grant rate, 69.7%, in "organic fine chemicals" (area 9), which is the area where the Danish patent applicants are most active in (446 applications) and in "Macromolecular chemistry, polymers" (area 10) in which the grant rate is 80.7% with 119 applications.

Table 2: Outcomes by technology areas

area	OST technology class	Granted (%)	Refused (%)	Withdrawn (%)	Total	% of total
	I Electricity - Electronics	**66.30**	**2.99**	**30.71**	**368.00**	**6.88**
1	Electrical devices - electrical engineering	65.87	3.59	30.54	167.00	
2	Audiovisual technology	71.43	3.81	24.76	105.00	
3	Telecommunications	69.64	1.79	28.57	56.00	
4	Information technology	51.52	0.00	48.48	33.00	
5	Semiconductors	42.86	0.00	57.14	7.00	
	II Instruments	**68.94**	**3.05**	**28.01**	**689.00**	**10.73**
6	Optics	71.11	6.67	22.22	45.00	
7	Analysis, measurement, control	65.64	3.37	30.98	326.00	
8	Medical engineering	72.01	2.20	25.79	318.00	
	III Chemicals, pharmaceuticals	**67.41**	**3.16**	**29.44**	**1,488.00**	**23.17**
9	Organic fine chemicals	69.73	3.59	26.68	446.00	
10	Macromolecular chemistry, polymers	80.67	1.68	17.65	119.00	
11	Pharmaceuticals, cosmetics	59.05	3.81	37.14	210.00	
12	Biotechnology	59.38	1.96	38.66	357.00	
13	Materials, metallurgy	76.47	1.31	22.22	153.00	
14	Agriculture, food	70.44	5.91	23.65	203.00	
	IV Process engineering	**69.86**	**3.37**	**26.77**	**919.00**	**14.31**
15	General technological processes	72.55	1.96	25.49	153.00	
16	Surfaces, coatings	51.72	3.45	44.83	29.00	
17	Material processing	71.13	3.78	25.09	291.00	
18	Thermal techniques	68.89	2.22	28.89	135.00	
19	Basic chemical processing, petrol	66.67	2.78	30.56	144.00	
20	Environment, pollution	71.86	5.39	22.75	167.00	
	V Mechanical engineering	**63.78**	**4.57**	**31.65**	**1,226.00**	**19.09**
21	Mechanical tools	65.55	5.04	29.41	119.00	
22	Engines, pumps, turbines	77.95	2.36	19.69	127.00	
23	Mechanical elements	62.77	5.19	32.03	231.00	
24	Handling, printing	63.24	3.78	32.97	370.00	
25	Agriculture & food machinery	58.33	5.95	35.71	252.00	
26	Transport	63.25	4.27	32.48	117.00	
27	Nuclear engineering	66.67	0.00	33.33	3.00	
28	Space technology, weapons	42.86	14.29	42.86	7.00	
	VI Other	**65.91**	**3.81**	**30.29**	**657.00**	**10.23**
29	Consumer goods & equipment	59.75	3.46	36.79	318.00	
30	Civil engineering, building, mining	71.68	4.13	24.19	339.00	
	Total	66.93	3.57	29.49	5,347.00	**100.00**

6.2 Firm-level data

There are 2,510 unique applicants in the dataset, which are summarized in Table 3 with respect to their ownership structure. Table 4 indicates the weight of each company form in the total number of patent applications. 34% of the firms in the dataset are stock listed limited companies (A/S), accounting for 64% of the patents applied. The database counts a high number of "persons" or private applicants (25.7% of the applicants) which are involved in 10.7% of the applications. An applicant is defined as being "private" if (i) there is no indication that the applicant is non-private (for example there is no "A/S" for stock listed firms), (ii) the applicant name is a family name followed by first names and (iii) the applicant could neither be found by our manual nor by our automatic searches. Sole proprietorships, foreign (co-) applicants and private limited companies (ApS) follow. Notice that the legal form could not be determined for 1.4% of the applicants, corresponding to 0.7% of the applications. These firms were typically out of business by the time we made the search and we were not able to find information about them. The other company forms account for less than 1% of the applications. The table shows that the grant rate is rather high for applications in which foreign firms are involved, as well as for applications by public firms or stock listed companies. The grant rate is lower than the average for applications involving private applicants (persons) and sole proprietorships.

Table 3: Firm structures - Number of unique applicants

Legal form	Number of firms	%
Limited company (A/S)	850	33.9
Person	645	25.7
Foreign firm (with no connexion to Denmark)	369	14.7
Sole proprietorship	283	11.3
Private limited compagny (APS)	246	9.8
Form unknown	35	1.4
General partnership (I/S)	29	1.2
Foundation (FON)	11	0.4
Public firm	8	0.3
Non-profit association	8	0.3
Cooperative with limited liability (AmbA)	7	0.3
Limited partnership (K/S)	5	0.2
Cooperative (AND)	4	0.2
Foreign firm-wich has registered a branch or place of business in Denmark	3	0.1
Branch of foreign limited company (FAP)	2	0.1
Insurance company (FAS)	2	0.1
Commercial foundation (ERF)	1	0.0
Company with limited liability (SmbA)	1	0.0
Limited partnership by shares (P/S)	1	0.0
total	2,510	100.0

Table 4: Distribution of outcomes by firm structure

Legal form	Number of patents	%	Granted (%)	Refused (%)	Withdrawn (%)
Limited company (A/S)	4,009	64.5	70.4	3.4	26.2
Person	666	10.7	56.6	4.1	39.3
Foreign firm (with no connexion to Denmark)	563	9.1	74.4	2.8	22.7
Private limited compagny (APS)	380	6.1	63.9	3.7	32.4
Sole proprietorship	347	5.6	59.1	4.6	36.3
Non-profit association	50	0.8	50.0	4.0	46.0
Form unknown	45	0.7	55.6	2.2	42.2
General partnership (I/S)	35	0.6	54.3	5.7	40.0
Public firm	33	0.5	84.8	0.0	15.2
Foundation (FON)	23	0.4	65.2	0.0	34.8
Foreign firm (wich has registered					100.0
a branch or place of business in Denmark)	17	0.3	76.5	0.0	23.5
Limited partnership (K/S)	15	0.2	73.3	0.0	26.7
Cooperative with limited liability (AmbA)	10	0.2	40.0	10.0	50.0
Cooperative (AND)	8	0.1	75.0	0.0	25.0
Branch of foreign limited company (FAP)	6	0.1	100.0	0.0	0.0
Limited partnership by shares (P/S)	5	0.1	20.0	0.0	80.0
Company with limited liability (SmbA)	3	0.0	33.3	33.3	33.3
Insurance company (FAS)	2	0.0	100.0	0.0	0.0
Commercial foundation (ERF)	1	0.0	0.0	0.0	100.0
total	6,218	100.0			

6.3 Past success and outcome of the patent application

Since the relationship between past success and outcome of the patent application is central in our analysis, it deserves further attention. An advantage from having applied for patents at the EPO in the past is expected. One may therefore expect patenting history to increase the applicants' chances of getting their patents granted. I will study the effect of application portfolios, as a measure of firms' experience.

The relationship between the stock of applications and the outcome in Table 5 is not clear. The grant rate increases with the stock of applications up to a certain threshold and then decreases. This issue will be discussed in Section 7.2, together with the other results.

Table 5: Applications stock and incidence on outcomes

	Outcome			
Application stock	Grant	Refusal	Withdrawal	Total
0	1,083	77	695	1,855
	58.4%	*4.2%*	*37.5%*	*100.0%*
(0, 10]	1,242	69	431	1,742
	71.3%	*4.0%*	*24.8%*	*100.0%*
(10, 100]	846	29	189	1,064
	79.5%	*2.7%*	*17.7%*	*100.0%*
>100	408	16	262	688
	59.5%	*2.3%*	*38.2%*	*100.0%*
Total	3,579	191	1,577	5,347
	66.9%	*3.6%*	*29.5%*	*100.0%*

Pearson chi2(6) =184.1900 Pr = 0.000

Pearson's Chi squared test, given at the bottom of the table, rejects the hypothesis of independence between applications stock and outcomes. Thus, there seems to be a relationship between applicants' patenting history and the outcome of the current applications.

6.4 Dependent variables

Summary statistics for all variables used in the analysis are presented in Table 6. Firms have, on average, 44.5 applications in their stock. However, the median, 1.99, indicates that the distribution is highly skewed and that large application portfolios are owned by few firms. The number of patent references ranges from 0 to 26, with, on average, 0.83 type X citations, 0.55 type Y citations, and 0.16 type D citations per patent. The number of forward citations ranges from 0 to 35, with a mean of 1.90 citations received per patent and has the typical skewed distribution, see figure 4 in Appendix A. The patents have on average two IPC assignments and 12.57 claims. The applicants typically designate about eleven states. 16.3% of all applications went through the PCT Chapter I procedure and

48.6% through Chapter I and II. Regarding the number of claims, comprised between one and 170 in our data, the division into two sub-groups is motivated by the fact that applicants seem to be sensitive to the rule stating that a fee is to be paid for each claim above the tenth. Moreover, the number of claims has a mode and a median of ten, see the distribution of the number of claims in figure 5 (Appendix B). Therefore, I use a dummy variable for those applications having more than ten claims rather than the total number of claims.

Table 6: Descriptive statistics

	All applications				
Variables	**mean**	**sd**	**min**	**max**	**median**
Experience					
Stock of applications	44.55	103.14	0	510.84	1.99
Citations					
Backward citations	4.22	2.42	0	26	4
Number of type X citations	0.83	1.50	0	17	0
Number of type Y citations	0.55	1.24	0	20	0
Number of type D citations	0.16	0.54	0	6	0
Forward citations	1.90	2.93	0	35	1
Patent characteristics					
Number of IPC assignments	2.09	1.19	1	6	2
Number of claims	12.57	11.94	1	170	10
Number of claims>10	40.5%		0	1	
Application ways					
Number of designated states	11.28	4.17	2	18	11
PCT Chapter I only	16.3%		0	1	
PCT Chapter I & II	48.6%		0	1	
Legal representative	87.8%		0	1	
Number of applicants	1.29	0.62	1	6	1
Number of inventors	1.88	1.34	1	19	1
Number of observations			5347		

Table 6 (continued)

Variables	Applications withdrawn after search report				Applications withdrawn during examination				non-withdrawn applications			
	mean	**sd**	**min**	**max**	**mean**	**sd**	**min**	**max**	**mean**	**sd**	**min**	**max**
Experience												
Application stock	6.73	33.07	0	360.32	78.49	141.29	0	510.83	38.53	91.35	0	509.42
Citations												
Backward citations	5.00	2.88	0	18	4.17	2.53	0	26	4.14	2.30	0	26
Number of type X citations	1.00	1.90	0	17	0.97	1.62	0	15	0.77	1.40	0	12
Number of type Y citations	0.55	1.37	0	8	0.62	1.37	0	20	0.52	1.19	0	15
Number of type D citations	0.10	0.42	0	4	0.15	0.51	0	5	0.18	0.56	0	6
Forward citations	1.14	1.67	0	13	1.53	2.39	0	22	2.10	3.16	0	35
Patent characteristics												
Number of IPC assignments	1.73	0.97	1	6	2.14	1.18	1	6	2.11	1.21	1	6
Number of claims	8.53	7.84	1	91	13.41	11.72	1	90	12.78	12.30	1	170
Number of claims>10	20.7%		0	1	43.8%		0	1	41.7%		0	1
Application ways												
Number of designated states	9.20	3.69	2	18	11.753	4.41	2	18	11.37	4.08	2	18
PCT Chapter I only	46.9%		0	1	17.3%		0	1	12.5%		0	1
PCT Chapter I and II					52.2%		0	1	53.1%		0	1
Legal representative	43.8%		0	1	84.8%		0	1	94.0%		0	1
Number of applicants	1.10	0.36	1	3	1.29	0.62	1	6	1.31	0.63	1	6
Number of inventors	1.41	0.79	1	6	2.04	1.46	1	11	1.89	1.34	1	19
Number of observations	430				1147				3770			

The comparison between the groups of withdrawn and non-withdrawn applications shows interesting differences. The applications stock is surprisingly lower for non-withdrawn applications compared to the ones withdrawn under examination. A possible explanation is that there are strategic decisions involved. One could think that applicants with large applications portfolios apply for a high number of patents, possibly for the same invention, and wait for a final decision by the patent office only when the probability of grant is high, that is, when no conflicting prior art has been found and when positive information has been received from the examiner.

The average number of "type X" and "type Y" references are higher for withdrawn applications, whereas the number or forward citations is much higher for non-withdrawn applications.

Two other important variables seem to be the presence of a legal representative and PCT Chapter II applications.

The number of IPC assignments, the number of claims, the number of designated states and the number of applicants are higher for non-withdrawn applications, but the difference is very small.

7 Empirical analysis

7.1 Econometric specification

Suppose y_{i1}^* and y_{i2}^* are latent variables representing the expected net present (private) profits to the firms (or individuals) applying for patent i, after receiving the search report and during examination respectively. Moreover, assume that y_{i3}^* is the social welfare function that the patent office seeks to maximize. These variables are not directly observable. However, we can observe whether the applications are withdrawn or not and whether they are granted or refused by the patent office. Suppose that the latent variables are functions of observable value and quality characteristics of the patent (x_i) and an unobserved part (ϵ_i) assumed to be jointly normally distributed, which leads to a Trivariate Probit Model with Double Selection, which is an extension of the Bivariate Probit Model with Sample Selection due to Van de Ven and Van Praag (1981). The choice of this model is motivated by the fact that it may not be appropriate to analyze the patent office's decision to grant the patent or to refuse the grant by using a single-equation model, since this decision is related to the applicants' choice to withdraw the application or not, prior to the patent office's decision. In this model, data on a variable y_3 (the EPO's decision to grant the patent or not) are observed only when another variable, y_2 (the applicants decision to request for the EPO's final decision or to withdraw the application) is equal to one, which in turn, is only observed when the third binary variable y_1 (the applicants decision to request for examination or to withdraw the application before the substantial examination phase) equals one. Formally we have:

$$
\begin{aligned}
y_{i1}^* &= \beta_1 x_{i1} + \epsilon_{i1},\ \ y_{i1} = 1 \text{ if } y_{i1}^* > 0, \text{ 0 otherwise} \\
y_{i2}^* &= \beta_2 x_{i2} + \epsilon_{i2},\ \ y_{i2} = 1 \text{ if } y_{i2}^* > 0, \text{ 0 otherwise} \\
y_{i3}^* &= \beta_3 x_{i3} + \epsilon_{i3},\ \ y_{i3} = 1 \text{ if } y_{i3}^* > 0, \text{ 0 otherwise} \\
\begin{pmatrix} \epsilon_{i1} \\ \epsilon_{i2} \\ \epsilon_{i3} \end{pmatrix} &\sim N\left[\begin{pmatrix} 0 \\ 0 \\ 0 \end{pmatrix}, \begin{pmatrix} 1 & \rho_{12} & \rho_{13} \\ . & 1 & \rho_{23} \\ . & . & 1 \end{pmatrix} \right] \\
&(y_{i2}, x_{i2}) \text{ is observed only when } y_{i1} = 1 \\
&(y_{i3}, x_{i3}) \text{ is observed only when } y_{i2} = 1
\end{aligned}
\tag{2}
$$

Thus, there are four types of observations with unconditional probabilities that need to be taken into account in the construction of the log-likelihood function[5]:

[5] The moel is estimated by Maximum Simulated Likelihood using the GHK simulator, see for example Gourieroux and Montfort (1996)

$$
\begin{aligned}
L &= \sum_{y_1=0} \ln \Phi\left(-\beta_1 x_{i1}\right) + \sum_{y_1=1,y_2=0} \ln \Phi_2\left(\beta_1 x_{i1}, -\beta_2 x_{i2}, \rho_{12}\right) \\
&\quad + \sum_{y_1=1,y_2=1,y_3=0} \ln \Phi_3\left(\beta_1 x_{i1}, \beta_2 x_{i2}, -\beta_3 x_{i3,} \rho_{12}, \rho_{23}, \rho_{31}\right) \\
&\quad + \sum_{y_1=1,y_2=1,y_3=1} \ln \Phi_3\left(\beta_1 x_{i1}, \beta_2 x_{i2}, \beta_3 x_{i3,} \rho_{12}, \rho_{23}, \rho_{31}\right)
\end{aligned} \tag{3}
$$

Where Φ, Φ_2 and Φ_3 denote, respectively, the univariate, bivariate and trivariate normal cumulative distribution functions, and the ρ_{ij} are the correlation coefficients between the error terms. The likelihood function is maximized with respect to the β_k and ρ_{ij} $(k, i, j = 1, 2, 3,\ i \neq j)$.

As Equation 2 suggests, sample selection arises because the observation of y_3 (the patent is granted or refused) is not random, but conditional on the observation of $y_2 = 1$ (the applicants do not withdraw the application under examination) and $y_1 = 1$ (the applicants request for examination). If the correction was not specified, the model would take into account the outcomes that are not feasible.

If all the $\rho_{ij} = 0$, the model can be estimated using three independent probit regressions. However, if the ρ_{ij} are significantly different from zero, using single equation estimates will generate biased coefficients.

Due to the absence of reasonable and economically sound exclusion restrictions I do not use any. Strictly speaking, exclusion restrictions are not needed, because the model is identified by non-linearity.

7.2 Results

Table 7 shows the result of the Trivariate Probit estimation. In this section, I discuss the implication of the estimation results on my set of hypotheses.

H1: Experienced firms are more likely to maintain their applications and to have them granted.

The applications stock has a positive effect on the probability to request for examination in Table 7, while the effect is negative on the probability to pursue the application under examination and then positive again on the grant rate[6]. The intuition of this result is that firms with large portfolios proceed by "trial and error", meaning that they apply for a high number of patents, maintain the applications until they received full information on the patentability of the invention through the search report and informal

[6] A quadratic specification of the application portfolio has been tried, leading to similar results, i.e., the squared term was non significant.

communications (or negotiations) with the examiner and thereafter wait for a final decision only when the probability of grant is high. This is fully is reflected by the positive effect of the variable in the third stage. The results suggest that experienced firms push the application as far as possible and only wait for a final decision by the EPO when the chances to get the patent granted are high.

H2: Conflicting prior art leads applicants to withdraw their applications and the EPO to refuse the grant.

Applications containing high numbers of type X citations tend to be withdrawn more often. This result is intuitive, given that this type of citations is potentially damaging to the novelty requirement of the claimed invention. This mirrors a scenario in which firms withdraw their applications after receiving a negative search report. During examination the effect of X references is also negative (*final decision/withdrawal under examination* equation), as well as the Y references, which where insignificant at the first stage. This result suggests that applicants withdraw their applications after they receive the search report only when the existence of conflicting prior art is obvious (X references). On the other hand, applications for which the demonstration of the existence of damaging prior art is more subtile (Y references, that have to be combined with each other in order to demonstrate conflicting with prior art) are more likely to be withdrawn during examination, possibly because of communications between the examiner and the applicants. This means that information given to the applicant by the examiner is consistent with the results of the search report. In the *Grant/Refusal* equation, the number of type X citations, the most harmful to the novelty requirement, has a negative impact on the probability of grant, as expected.

H3: Applicants mastering the state of the art are less likely to withdraw their applications.

This hypothesis is not confirmed. One possible explanation is that type D references are often self-citations (a reference to a patent previously applied for by the same applicant) and do not necessarily mean that the applicant has a good command of prior art.

H4: Valuable or technologically important patents are more likely to be granted and less likely to be withdrawn.

My estimation confirms the expectation regarding the number of forward citations, which is associated with positive and significant coefficients, meaning that "important" and valuable patents have lower withdrawal rates and higher probabilities of grant. This suggests that both the applicants and the examiner are aware of the technological importance of the applications.

H5: Time-zero value correlates positively influence the probability for an application to be granted.

The technical characteristics (number of claims and number of IPC assignments) are insignificant in the grant/refusal stage, suggesting that the breadth of the application and/or the precision of the description of the claimed invention has no effect on the outcome.[7] However, applications containing more than ten claims (i.e. for which applicants have to pay additional fees) have a higher probability to go through examination, which suggests that applications involving more than ten claims, for which additional fees have to be paid are abandoned less quickly.

H6: The higher the number of designated states, the higher the probability of grant and the lower the probability to withdraw the application.

Regarding the number of designated states, no significant effect is observed.[8] Time-zero value correlates have in general almost no effect on the application process. This could be a sign that applicants are either unaware of the potential value of their invention, or if they are, they do not act consequently.

H7: Applications that went through the PCT procedure Chapter I only, have a higher probability of early withdrawal, whereas applications that went through the whole PCT procedure (Chapter I and II) have a lower probability of withdrawal.

Applications that went through the PCT procedure Chapter I are more likely to be withdrawn under examination, while PCT applications Chapter II have a positive impact at this stage. This confirms the results found by Guellec and Van Pottelsberghe (2002). PCT I applications have unclear market potential given that it provides the applicants with more time to decide whether to extend the right of the patents, whereas applicants who wait until their application reached the Chapter II procedure are usually more aware of the market potential of the invention.

H8: Collaborations between applicants and inventors lead to successful applications.

The total number of applicants has a positive effect on the probability to wait until a final decision is taken by the EPO, which underlines the importance of collaborations for successful applications, but is insignificant at the other stages. The number of inventors does not have a significant effect on either stage of the model. The individual characteristics of inventors are probably more important in the determination of the "quality" and the value of an application. Gambardella et al. (2006) indeed found that the characteristics of an inventor are an important determinant of the private value of a patent.

[7] A linear relationship between the number of claims and the outcome gave the same result.

[8] Different non-linear specifications have been tested regarding the designated states, following Guellec and Van Pottelsberghe (2000, 2002), with the same result.

H9: Firms legally represented are less likely to withdraw their applications.

Professional representatives are successful in pushing the application as far as possible in the procedure, but no significant effect is found on the *grant/refusal* decision.

H10: Stock listed firms have, compared to other company forms, a lower propensity to withdraw their applications and a higher probability of grant

Finally, regarding the ownership structures, the stock listed firms, typically big firms, are the only ones to carry a positive and significant effect, on the probability to wait until the grant/refusal decision, while the "other" type of firms have a negative impact at this stage, which is not surprising, since most of these firms did not survive after 1990.

These result highlight another interesting point. Only three variables are significant in the *grant/refusal* equation. This means that the granting process itself is more difficult to predict than the unconditional grant/refusal model investigated by earlier studies.

In addition to the model described before, I perform several robustness checks. Appendix C reports the result of a probit model of the probability to grant against the other outcomes (i.e. the two types of withdrawals and the refusals are pooled), one can see that it is much more difficult to define which effect is induced by which player and at which stage. Moreover, the application stock has an overall negative effect, which is difficult to interpret.

Withdrawals during examination can be interpreted as expected refusals, since applicants typically withdraw their applications once the examiner asserted that the application is likely to be refused a grant. In Appendix D estimates of a bivariate probit model with selection are reported, in which refusals and withdrawals that took place under examination are pooled, since the latter can be considered as refusals. The results do not change very much, but again, the overall negative effect of the stock of applications is difficult to interpret. The results in Table 7 show that the most "important" or valuable inventions are maintained until the EPO's final decision is taken, which suggests that refusals and withdrawals should be treated separately.

In Appendices E and F, I report the estimation results of an ordered probit model and an ordered probit with selectivity, respectively. The dependent variable is assumed to be ordered, because outcomes can be ranked with respect to their implications for the profits of the applicant, i.e., a refusal is assumed to be the worst outcome possible for the applicants followed by a withdrawal and a grant. There is no major difference with the models previously estimated, but again, the stock of applications carries a negative sign.

Table 7: Estimation results

	Request for Examination/ Withdrawal		Final Decision/ Withdrawal during examination		Grant/refusal	
	Coeff.	S.D.	Coeff.	S.D.	Coeff.	S.D.
Experience						
Stock of applications	0.005 ***	0.000	-0.002 ***	0.000	0.001 ***	0.000
Citations						
Number of backward citations	-0.006	0.015	-0.001	0.010	-0.001	0.017
Number of type X citations	-0.053 ***	0.023	-0.037 ***	0.015	-0.052 **	0.024
Number of type Y citations	-0.019	0.027	-0.057 ***	0.033	-0.009	0.029
Number of type D citations	0.004	0.064	0.025	0.041	-0.030	0.065
Number of Forward citations	0.043 ***	0.018	0.054 ***	0.009	0.056 ***	0.019
Patent characteristics						
Number of IPC assignments	0.031	0.034	0.009	0.019	-0.030	0.031
Number of claims>10	0.178 **	0.078	0.015	0.046	0.081	0.076
Application ways						
Number of designated states	-0.005	0.010	-0.001	0.006	-0.014	0.010
PCT Chapter I only	0.402 ***	0.102	-0.200 ***	0.074	-0.153	0.119
PCT Chapter I & II			0.211 ***	0.107	-0.121	0.099
Number of applicants	0.210	0.147	0.113 **	0.056	-0.012	0.097
Number of inventors	0.041	0.039	-0.019	0.017	-0.007	0.029
Legal representative	2.168 ***	0.096	0.372 ***	0.115	0.101	0.158
Ownership structure						
Stock listed firms	0.149	0.243	0.315 ***	0.114	0.222	0.197
Persons	0.147	0.252	-0.076	0.121	0.150	0.203
Foreign firm	0.367	0.233	-0.072	0.094	0.110	0.169
Limited compagnies	-0.099	0.249	0.062	0.126	0.201	0.212
Sole proprietorships	0.429	0.266	-0.166	0.128	0.116	0.213
Others	0.075	0.252	-0.239 **	0.123	-0.018	0.209
Technological areas						
Electricity-electronics	-0.022	0.142	-0.156 *	0.097	0.095	0.167
Instruments	0.154	0.127	-0.058	0.084	0.066	0.137
Chemicals, pharmaceuticals	0.255 **	0.133	-0.137 *	0.081	-0.027	0.128
Process engineering	0.189	0.120	0.008	0.080	0.010	0.126
Mechanical engineering	-0.027	0.103	0.026	0.075	-0.072	0.114
Constant	-1.784 ***	0.286	0.055	0.247	1.768 ***	0.326
ρ12; ρ31; ρ32	0.139 (0.235); -0.529 * (0.326); -0.708 ** (0.316)					
Number of Observations	5347					
Log-Likelihood	-4071.647					

*** significantly different from the rejection rate at the 1 percent level
** significantly different from the rejection rate at the 5 percent level
* significantly different from the rejection rate at the 10 percent level
Annual year dummies are included in all equations.

The results are summarized in Table 8 and compared to the hypothesis made in Section 5. Columns 1, 2 and 3 correspond respectively to the "Request for examination/withdrawal", "Final decision/withdrawal" and "Grant/refusal" equations.

Table 8: Summary of results

hypothesis	expected (1)	expected (2)	expected (3)	observed (1)	observed (2)	observed (3)
H1: Stock of applications	+	+	+	+	-	+
H2: X references	-	-	-	-	-	-
H2: Y references	-	-	-	0	-	0
H3: D references	+	+	+	0	0	0
H4: Forward citations	+	+	+	+	+	+
H5: Claims	+	+	+	+	0	0
H5: IPC assignments	+	+	+	0	0	0
H6: Designated states	+	+	+	0	0	0
H7: PCT I only	-	-	+/-	+	-	0
H7: PCT I & II		+	+		+	0
H8: Number of applicants	+	+	+	0	+	0
H8: Number of inventors	+	+	+	0	0	0
H9: Legal representative	+	+	+/-	+	+	0
H10: Stock listed firms	+	+	+	0	+	0

8 Conclusion

The aim of this paper was to analyze the determinants of the outcomes of patents applied for by Danish firms at the EPO and to study the impact of the firms' experience on these outcomes. I used a database of 5,347 patent applications over the period 1978-1998 and applied a Trivariate probit model accounting for self-selection.

The applicants' patenting history, as measured by the stock of applications, is found to be an important factor in all stages of the application process. It seems that firms having large patents portfolios act following a "trial and error" strategy, by applying for huge numbers of patents and thereafter maintain the application only when the expected probability of grant is high, leading to a positive effect of the size of the applications portfolio on the probability of grant.

The paper also investigates the determinants of the withdrawal decision of patent applications. The results show that applicants tend to withdraw their applications when the result of the preliminary search report issued by the patent office is negative. Thus, the applicants update their information set after receiving the search report and if the expected probability of grant is low, that is, the search report shows evidence that the claimed invention is not novel, they tend to withdraw their application. Withdrawals also occur during examination, where the applicant can obtain additional information from the examiner regarding the patentability of the invention. The results show that this information is consistent with the results of the search report, since withdrawals are more likely to occur when conflicting prior art exists. A withdrawal is then an expected refusal.

Other important results of the paper are the following:

- The technological importance of a patent, as measured by the number of forward citations is a crucial determinant of a successful application. Since an invention becomes potentially valuable if a patent is granted, the applicants are less likely to withdraw it. Our results suggest that both applicants and examiners are aware of the potential value of the application, since these applications have on average a higher probability to be granted.

- Time-zero value correlates have little explanatory power.

- the grant/refusal decision made by the patent office is more difficult to predict than earlier studies using an unconditional grant/other outcomes suggest.

In addition to the economic considerations, implications for the strategic management of intellectual property rights can also be derived from the empirical model. Applicants should be aware of the market potential of their applications and use the appropriate application ways and filing strategies. Filing an application under the PCT treaty before sending the application to the EPO in order to gain more time is not necessarily a good strategy and can be costly for the applicants.

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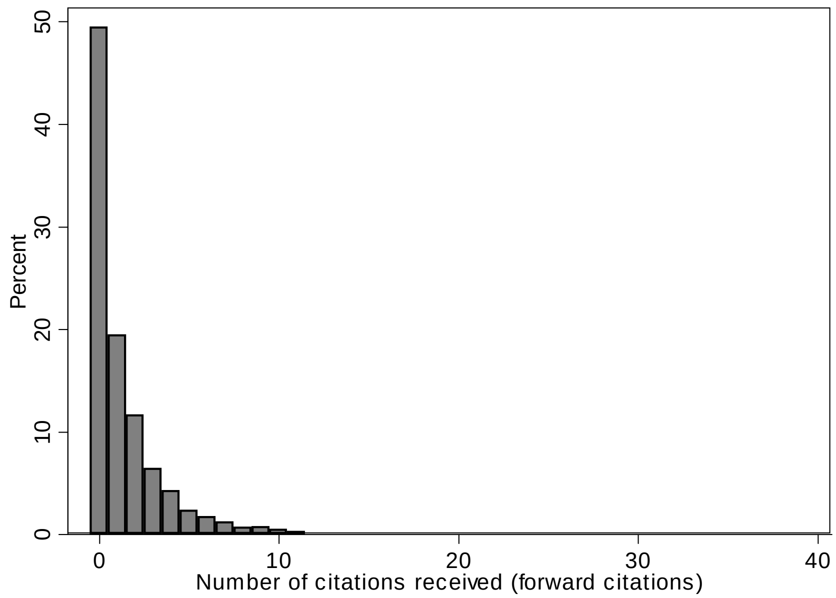
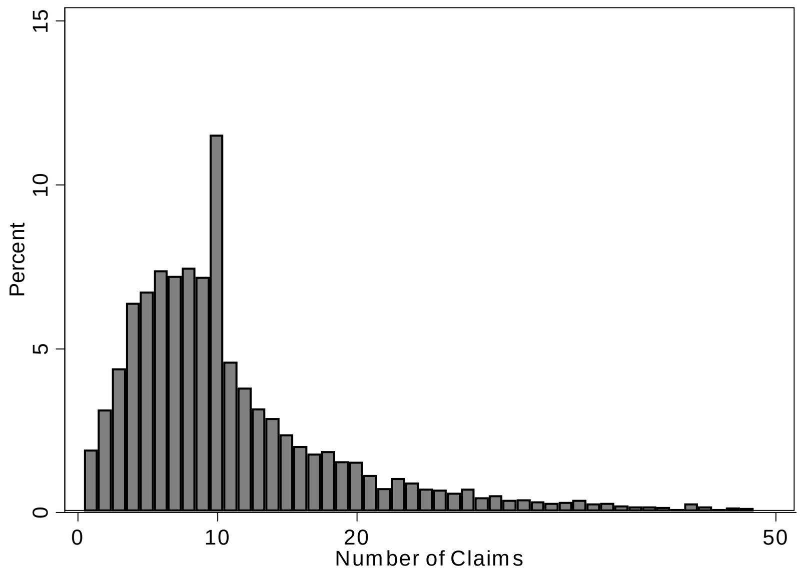
A Distribution of forward citations

Figure 4: Distribution of forward citations



B Distribution of the number of claims

Figure 5: Distribution of claims[9]



[9] The distribution is censorded when the number of claims is greater than 50.

C Probit estimation

Probit model, probability to grant against all other outcomes

	grant/other outcomes	
	Coeff.	S.D.
Experience		
Stock of applications	-0.001 ***	0.000
Citations		
Number of Backward citations	0.000	0.009
Number of type X citations	-0.064 ***	0.014
Number of type Y citations	-0.061 ***	0.016
Number of type D citations	0.051	0.037
Number of Forward citations	0.063 ***	0.008
Patent characteristics		
Number of IPC assignments	0.013	0.017
Number of claims>10	0.055	0.042
Application ways		
Number of designated states	-0.008	0.005
PCT Chapter I only	-0.100	0.064
PCT Chapter I & II	0.368 ***	0.053
Number of applicants	0.087 *	0.053
Number of inventors	-0.014	0.016
Legal representative	0.945 ***	0.067
Ownership structure		
Stock listed firms	0.375 ***	0.107
Persons	0.002	0.112
Foreign firm	0.009	0.089
Limited compagnies	0.104	0.117
Sole proprietorships	-0.046	0.119
Others	-0.176	0.115
Technological areas		
Electricity-electronics	-0.081	0.088
Instruments	0.000	0.075
Chemicals, pharmaceuticals	-0.059	0.073
Process engineering	0.060	0.072
Mechanical engineering	0.015	0.067
Constant	-1.244 ***	0.291
Observations	5347	
Log-Likelihood	-3010.5691	

*** significantly different from the rejection rate at the 1 percent l
** significantly different from the rejection rate at the 5 percent le
* significantly different from the rejection rate at the 10 percent le
Annual year dummies are included

D Bivariate probit with selectivity

Here we estimate a Bivariate Probit Model with sample selection due to Van de Ven and Van Praag (1981). In this model, data on a variable y_1 (the patent is granted or refused/withdrawn under examination) are observed only when another variable, y_2 (the applicant's decision to request for examination or to withdraw the application) is equal to one. Formally we have:

$$
\begin{aligned}
y_{i1}^* &= \beta_1 x_{i1} + \epsilon_{i1},\ y_{i1} = 1 \text{ if } y_{i1}^* > 0, \text{ 0 otherwise} \\
y_{i2}^* &= \beta_2 x_{i2} + \epsilon_{i2},\ y_{i2} = 1 \text{ if } y_{i2}^* > 0, \text{ 0 otherwise} \\
(\epsilon_{i1}, \epsilon_{i2}) &\sim BVN(0, 0, 1, 1, \rho) \\
(y_{i1}, x_{i1}) &\text{ is observed only when } y_{i2} = 1,
\end{aligned}
\tag{4}
$$

where the x_i are the characteristics for the ith patent. Thus, there are three types of observations with unconditional probabilities that need to be taken into account in the construction of the log-likelihood function:

$$
\begin{aligned}
L &= \sum_{y_1=1, y_2=1} \ln\left[\Phi_2\left(\beta_1 x_{i1}, \beta_2 x_{i2}, \rho\right)\right] + \sum_{y_1=0, y_2=1} \ln\left[\Phi_2\left(-\beta_1 x_{i1}, \beta_2 x_{i2}, -\rho\right)\right] \\
&\quad + \sum_{y_2=0} \ln\left[1 - \Phi\left(\beta_2 x_{i2}\right)\right],
\end{aligned}
\tag{5}
$$

where Φ and Φ_2 denote, respectively, the univariate and bivariate normal cumulative distribution function, and $\rho = cov(\epsilon_{i1}, \epsilon_{i2})$. The likelihood function is maximized with respect to β_1, β_2 and ρ.

Bivariate probit with selectivity estimation

	Request for Examination/ Withdrawal		Grant/ (Refusal or withdrawal)	
	Coeff.	S.D.	Coeff.	S.D.
Experience				
Stock of applications	0.006 ***	0.001	-0.001 ***	0.000
Citations				
Number of Backward citations	-0.007	0.015	0.000	0.020
Number of type X citations	-0.053 **	0.023	-0.051 ***	0.015
Number of type Y citations	-0.018	0.027	-0.055 ***	0.017
Number of type D citations	0.005	0.064	0.016	0.039
Number of Forward citations	0.043 ***	0.018	0.061 ***	0.009
Technical characteristics				
Number of IPC assignments	0.035	0.034	0.001	0.018
Number of claims>10	0.180 **	0.078	0.036	0.044
Application ways				
Number of designated states	-0.005	0.009	-0.004	0.006
PCT Chapter I	0.401 ***	0.103	-0.232 ***	0.071
PCT Chapter II			0.154 ***	0.057
Number of applicants	0.216	0.147	0.087 *	0.054
Number of inventors	0.040	0.039	-0.019	0.017
Legal representative	2.159 ***	0.097	0.356 ***	0.114
Ownership structure				
Stock listed firms	0.151	0.243	0.358 ***	0.111
Persons	0.151	0.251	-0.016	0.117
Foreign firm	0.357	0.232	-0.031	0.091
Limited compagnies	-0.096	0.248	0.132	0.122
Sole proprietorships	0.424	0.265	-0.111	0.124
Others	0.085	0.252	-0.225 **	0.119
Technological areas				
Electricity-electronics	-0.023	0.141	0.098	0.092
Instruments	0.150	0.127	-0.001	0.089
Chemicals, pharmaceuticals	0.253 **	0.133	0.136	0.090
Process engineering	0.189	0.120	0.134	0.085
Mechanical engineering	-0.024	0.102	0.129	0.094
Constant	-1.467 ***	0.308	-0.576 *	0.345
ρ	-0.060 (0.239)			
Observations	5347			
Log-Likelihood	-3676.463			

*** significantly different from the rejection rate at the 1 percent level

** significantly different from the rejection rate at the 5 percent level

* significantly different from the rejection rate at the 10 percent level

Annual year dummies are included in both equations.

E Ordered Probit estimation

Ordered Probit estimation

Ordered probit (0=refusal, 1=withdrawal, 2=grant)

	Coeff.	S.D.
Experience		
Stock of applications	-0.001 ***	0.000
Citations		
Number of Backward citations	0.001	0.008
Number of type X citations	-0.057 ***	0.013
Number of type Y citations	-0.050 ***	0.015
Number of type D citations	0.037	0.036
Number of Forward citations	0.060 ***	0.008
Patent characteristics		
Number of IPC assignments	0.005	0.016
Number of claims>10	0.052	0.040
Application ways		
Number of designated states	-0.008	0.005
PCT Chapter I only	-0.082	0.060
PCT Chapter I & II	0.278 ***	0.051
Number of applicants	0.067	0.050
Number of inventors	-0.013	0.016
Legal representative	0.641 ***	0.058
Ownership structure		
Stock listed firms	0.344 ***	0.101
Persons	0.034	0.106
Foreign firm	0.039	0.085
Limited compagnies	0.124	0.110
Sole proprietorships	-0.018	0.112
Others	-0.126	0.108
Technological areas		
Electricity-electronics	-0.066	0.084
Instruments	0.007	0.071
Chemicals, pharmaceuticals	-0.050	0.069
Process engineering	0.050	0.067
Mechanical engineering	-0.009	0.062
Observations	5347	
Log-Likelihood	-3708.8439	

*** significantly different from the rejection rate at the 1 percent level
** significantly different from the rejection rate at the 5 percent level
* significantly different from the rejection rate at the 10 percent level
Annual year dummies are included

F Ordered Probit with selectivity

Here we estimate an Ordered Probit model with Selection, see for example Hall et al. (2000)[10]. In this model, data on a variable y_2 (the patent is granted refused or withdrawn under examination) are ordered and observed only when another variable, y_1 (the applicants decision to request for examination or to withdraw the application) is equal to one. Formally we have:

[10] The reported estimations should be taken with precautions, since Hall et al. raise concerns about identification of the model. See their paper for more details.

$$
\begin{aligned}
y_{i1}^* = \beta_1 x_{i1} + \epsilon_{i1},\ y_{i1} = 1 \text{ if } y_{i1}^* > 0, \text{ 0 otherwise} \\
y_{i2}^* = \beta_2 x_{i2} + \epsilon_{i2},\ y_{i2} = 1 \text{ if } y_{i2}^* > 0, \text{ 0 otherwise} \\
(\epsilon_{i1}, \epsilon_{i2}) \sim BVN(0,0,1,1,\rho) \\
y_{i2} = 0 \text{ if } y_{i1} = 1 \text{ and } y_{i2}^* \leq t_1 \\
y_{i2} = 1 \text{ if } y_{i1} = 1 \text{ and } t_1 < y_{i2}^* \leq t_2 \\
y_{i2} = 2 \text{ if } y_{i1} = 1 \text{ and } y_{i2}^* > t_2
\end{aligned}
\qquad (6)
$$

Ordered Probit with selectivity

	Request for Examination/ Withdrawal		0=refusal, 1=withdrawal, 2=grant	
	Coeff.	S.D.	Coeff.	S.D.
Experience				
Stock of applications	0.005 ***	0.001	-0.001 ***	0.000
Citations				
Number of Backward citations	-0.008	0.017	0.001	0.010
Number of type X citations	-0.054 **	0.028	-0.511 ***	0.014
Number of type Y citations	-0.019	0.033	-0.469 ***	0.017
Number of type D citations	0.005	0.068	0.006	0.037
Number of Forward citations	0.044 **	0.022	0.582 ***	0.008
Technical characteristics				
Number of IPC assignments	0.033	0.038	-0.005	0.017
Number of claims>10	0.182 **	0.086	0.042	0.042
Application ways				
Number of designated states	-0.005	0.009	-0.006	0.005
PCT Chapter I	0.401 ***	0.155	-0.222 ***	0.068
PCT Chapter II			0.104 **	0.055
Number of applicants	0.220	0.193	0.063	0.051
Number of inventors	0.040	0.047	-0.016	0.017
Legal representative	2.156 ***	0.114	0.278 **	0.117
Ownership structure				
Stock listed firms	0.145	0.380	0.343 ***	0.112
Persons	0.145	0.379	0.019	0.118
Foreign firm	0.359	0.300	-0.002	0.094
Limited compagnies	-0.102	0.387	0.155	0.121
Sole proprietorships	0.421	0.405	-0.066	0.122
Others	0.075	0.377	-0.186	0.118
Technological areas				
Electricity-electronics	-0.028	0.148	-0.095	0.091
Instruments	0.144	0.140	-0.015	0.078
Chemicals, pharmaceuticals	0.250	0.161	-0.107	0.076
Process engineering	0.186	0.136	0.008	0.074
Mechanical engineering	-0.027	0.116	-0.012	0.068
Constant	-1.784 ***	0.366		
ρ	-0.179 (0.240)			
Observations	5347			
Log-Likelihood	-3676.463			

*** significantly different from the rejection rate at the 1 percent level
** significantly different from the rejection rate at the 5 percent level
* significantly different from the rejection rate at the 10 percent level
Annual year dummies are included in both equations.