Modeling the Duration of Patent Examination at the European Patent Office *

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Preliminary Version

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Abstract

We analyze the duration of patent examination at the European Patent Office (EPO). Our data contain variables that are correlates of the applicants' and examiners' assessments of a patent's economic and technical relevance as well as ex post-application citation measures which indicate the impact of the patent application on the state of the art. We present descriptive statistics for 30 major technology fields. In our multivariate analysis we estimate purely parametric as well as semi-parametric model specifications in order to detect nonlinearities in the impact of some of these variables on the hazard of terminating the examination. We also employ competing risk specifications in order to characterize differences in the processes leading to either a withdrawal of the application by the applicant, a refusal of the patent grant or an actual patent grant by the European Patent Office. All estimations are carried out using Bayesian MCMC simulation techniques.

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1 Introduction

The last two decades have seen an unprecedented increase in patent applications at the USPTO (U.S. Patent and Trademark Office) and the EPO (European Patent Office). We depict these in Figure 1 of our paper.[1] These two offices differ not only in their legal and institutional foundations, but they have also responded to the challenge of two-digit growth rates in applications in somewhat different ways. In this paper, we focus on the determinants of decision-making lags at the European Patent Office. Our objective is to provide a comprehensive analysis of potential drivers of and responses to the recent development.

Other authors (e.g., Popp et al. 2003) have studied the response of the USPTO, but there has been no comprehensive study to date regarding the EPO. Contrasting these two offices is fascinating, since they appear to follow very different philosophies. The USPTO sees itself as a service agency with the mission of allowing patent applications to obtain their patent rights as early as possible. The European Patent Office, while also acknowledging its obligations towards its users and customers, in particular the group of patent applicants, insists that it needs to maintain high quality in patent examination, even at the expense of marginally longer decision lags. Since patent examiners at the EPO typically have to undergo a training of roughly three years, adjustments in search and examination capacity take a long time. Surprising developments in the demand for patent protection will therefore lead to increases in decision lags. These arguments imply that decisions-making lags at the EPO should have been impacted much more by the growing demand for patent protection than the respective durations at the USPTO.[2] Leaving aside the mere growth in patent applications, we also study changes in the complexity of patent applications. We document that over time, the number of claims and the number of references to earlier patents and non-patent literature have been increasing. Moreover, applications filed under the Patent Cooperation Treaty (PCT) have reached a significant share of total filings and give applicants a longer time period to make decisions about actual application. These changes in the characteristics of patent applications pose an additional challenge. We try to disentangle the two sources of decision-making lags in our multivariate analysis.

In section 2 of the paper we first set out in broad terms the institutional background of patent examination processes at the European Patent Office. We then develop in section 3 a qualitative model: on the normative side,

[1] The Japanese Patent Office (JPO) has seen a very similar development, but the time series of applications also reflect major changes in Japanese patent law which we do not consider here.

[2] The term "lag" is used as a neutral description and thus synonomous with the term "duration".

we discuss social benefits and shortcomings of increasing the duration of examination. On the positive side, we formulate a number of priors with regards to the expected impact of various determinants of decision-making lags at the EPO. In section 4, we describe our dataset which represents a ten percent random sample of all EPO applications filed from the start of EPO's operation on June 1^{st}, 1978 to July 25^{th}, 2003. We also give an overview of the potential determinants of decision-making lags that we have identified. In section 5, we first provide a descriptive analysis of our data, before we present the models to be estimated. The final subsection of section 5 summarizes the estimation results. Section 6 concludes and states implications of our findings.

2 Institutional Background: Patent Applications at the European Patent Office

The European Patent Office (EPO) offers a harmonized application and examination path for applicants seeking patent protection in signatory states to the European Patent Convention (EPC). In an EPO application, the applicant designates the EPC member states for which patent protection is requested. The EPO application path is typically preferred over the individual national paths once the applicant seeks protection in more than three EPC countries, since the total cost of a European patent amounts to approximately EUR 29,800, roughly three times as much as a typical national application.

The examination process at the EPO consists of an initial search and subsequent examination phase. Once an EPO application has been filed, a "search report" is generated for the applicant by the The Hague office of the EPO. This report describes the state of prior art regarded as relevant according to EPO guidelines for the patentability of the invention, i.e., it contains a list of references to prior patents and/or nonpatent sources. Unlike in the U.S. system, applicants at the EPO are not required to supply a full list of prior art (see Michel and Bettels, 2001, 191ff). The search report is made public with the A1 or A2 publication document of the application. Within 6 months after the announcement of the publication of the search report in the EP Bulletin, applicants may request the examination of their application. It is possible to request an accelerated examination of the file requiring an extra-payment by the applicant. If examination is not requested (which may be the case if the search report reveals considerable prior art that would make a patent grant seem unlikely), the patent application is *deemed to be withdrawn*. This is one potential outcome of the application procedure.

Eighteen months after the priority date[3] the patent application is published. At this point, the application is normally under examination at the EPO. After an examination has been performed, the EPO either informs the applicant that the patent will be granted as specified in the original application or requires the applicant to agree to changes in the application. Once an agreement has been found between the applicant and the examiner, the patent issues for the designated states and is translated into the relevant national languages. In this process, the applicant may again decide not to pursue the patenting effort since the prospect of actually obtaining an economically valuable patent may be weak. This outcome (*withdrawal*) is again reflected in our data. If the EPO declines to grant a patent, the applicant may file an appeal. This *refusal to grant* is another potential outcome of the application process. The most frequent outcome with about two thirds of the cases is an actual *patent grant*. In rare cases, the patenting process is terminated because an independent inventor has deceased and the heirs do not pursue the application. In other cases, it is decided to merge the patent application with another one that was initially submitted. We comment on these cases in more detail below.

Applications filed under the Patent Cooperation Treaty (PCT) require particular attention, since they now constitute a large share of all filings at the EPO and are subject to specific institutional treatments. Strictly speaking, a PCT filing is not a patent application, but grants the filing party the option to launch patent applications in up to 115[4] PCT signatory countries within 30 months of the filing date (which becomes the priority date). Any patent application already filed can be turned into a PCT filing within the priority year. PCT filings are advantageous for several reasons. First, they allow the expansion of patent protection to a large number of countries without incurring the full costs and complexity of national applications. Second, 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. Third, the PCT filing, when compared to a national or regional application[5], has greater option value, since it allows applicants to delay decisions about the countries for which they want to designate the application for up to 30 months after the priority date. Costly decisions can thus be deferred for 30 months (and not just for the duration of the priority year, as with national and regional

[3]Note that the date of publication is often only six months after the application at the EPO, since many applicants choose to first file their application at one of the national offices before deciding to enter the European application path. They may do so within the priority year, so that the EPO publication frequently appears about six months after the application has been filed at the EPO.

[4]As of April 1, 2002. See WIPO (2002, p. 12).

[5]National applications are filed at the respective national patent office. The term "regional application" refers to filings at the European Patent Office (EPO) which is the granting authority for countries that have signed the European Patent Convention (EPC).

applications). PCT filings can also receive a preliminary international examination which is authorative, but not binding for the national/regional offices finally granting the patent. The World Intellectual Property Organization (WIPO) also claims that "(...) any patents subsequently granted by the national or regional Offices on the international application can be relied on by the applicant to a greater extent than would have been the case without the benefit of the international search report and the international preliminary examination report" (WIPO 2002).

3 Theoretical Background

3.1 The Optimal Decision Duration

Many theoretical models in the industrial organization literature use the assumption of perfect or imperfect patent protection. This assumption allows researchers to come to a convenient and tractable structure regarding the *post*-invention market structure. For example, the classical patent race models developed by Loury (1979) or Lee and Wilde (1980) assume that a patent entitles the winner of the R&D race with full patent protection equivalent to some prize while the losers will receive nothing (winner-takes-all). But in reality, neither is a patent equivalent to a monopoly, nor is its effect immediate after filing an application. A patent endows the patent owner with the right to exclude other parties from utilizing the patented invention. Somewhat paradoxically, the patent does not even grant the patent owner himself the right to utilize the patented technology - in the case of overlapping or blocking rights, e.g. in the case of an improvement over a previously patented invention, the patent holder does not have the right to utilize the invention without the consent of the holder of the earlier patent. In some models (see, e.g., de Fraja 1993), the winner-takes-all assumption is relaxed in order to accomodate more realistic conditions under which even the second-in-place can earn some prize.[6]

Irrespective of what is assumed in the IO literature about the extent of patent protection, the typical assumption is that the patent unfolds its efficacy immediately. The stochastic nature of the patent examination process is not taken into account. However, the fact that applicants are facing a process with unknown duration and unknown outcome has some impact on their actual behavior. The anticipated behavior of the patent examiner even has direct implications on the way in which patent applications are drafted by patent attorneys. This is pointed out in a qualitative study of patenting behavior by Harhoff and Reitzig (2001).

[6]For a more detailed survey of the literature see Tirole (1989, ch. 10) or Bester (2000, ch. 5).

While a formal model of these tradeoffs would be far beyond the scope of this paper[7], we briefly summarize arguments that would favor a very quick examination of patent rights (in the extreme case a mere registration system) versus a view in which it is advantageous to let some time pass in order to subject the patent to a thorough review, particularly in the light of new information that arrives some time after the application has been filed. The first argument that speaks in favor of (relatively) thorough examination of patents is that this process is presumably less costly – socially and privately – than litigation of patents. According to this view, patents serve to signal to patent holders and possible rivals an ex ante assessment of the actual distribution of rights that would be maintained even after litigation has taken place. The more "robust" a patent is in the legal sense, the less attractive will litigation be. With mere registration, a large number of court decisions have to be expected that will actually declare void a large number of patent rights. Hence, registration systems will provide less certainty for investors than examination systems.

At the same time, this argument helps to understand that a very long examination period may also be counterproductive. Typically, patent applicants have - during the examination period - only some limited protection against infringement. In some legal systems, they are not entitled to full damages during the examination phase. Hence, the longer the examination period, the more precise the delineation of the patent right becomes; conversely, the weaker will be investment incentives due to the weak legal position the patent holder has. While this constitutes a positive *ex post* effect on welfare since there is more competition in product markets, *ex ante* research incentives will suffer.

A second argument in favor of extending the period of examination (at the margin) is that the quality of the patent office's decision-making is likely to improve over time due to new information becoming available. As new scientific and technological information arrives, examiners will be able to determine more precisely the optimal scope and breadth of the patent when it issues. Granting too broad a patent will harm *ex post* welfare by creating too much market power, systematically granting too narrow a patent would harm *ex ante* research incentives.

It is difficult and maybe not even possible to determine the optimal tradeoff between precision of patent examination on the one hand and its duration on the other. Yet, the question will become more important as policy-makers have discovered the issue and argue for a reduction of grant lags. In the U.S., the quick growth in demand for patent protection has led to some increase in the duration of examination.[8] At the same time,

[7]Regibeau and Rockett (2003) have developed a theoretical model of some of these tradeoffs. They apply the model to patent data covering subject matter related to genetically modified food.

[8]Popp et al. (2003, Figure 4) show that the grant lag was at an all-time low with 26.5

the USPTO is currently being criticized for a number of weaknesses, including the bad quality of patent examination.[9] In Europe, the development of patent examination over time has not been studied as of yet. The following sections are meant to cast some light on the actual process of patent examination at the European Patent Office.

3.2 Determinants of Decision-Making Lags

The determinants that are the focus of this study come in three categories: the demand for patent protection relative to the supply of examiners, the difficulty of the examination task itself, and institutional factors that would ceteris paribus lead to an acceleration or deceleration of the examination process.

First, in the short-run a patent office will not be able to adjust search and examination staff optimally to short-term changes in the demand for patent protection unless quality standards are allowed to deteriorate.[10] The EPO provides a telling example in this context. Since the training of patent examiners takes up to three years, we should expect major lags in the adjustment of examination capacity. Increases in the average workload (pending patents relative to patent office employees available) should therefore lead to slower patent examination and longer lags.

Second, the nature of patent examination has changed over time. Patent applications are increasing in complexity and volume – both factors should lead to longer examination durations. Below, we introduce various measures of complexity, such as the number of claims, the number of backward and forward citations and other aspects. We also document the development of these characteristics over time.

Third, various statutory and legal provisions have direct implications for the processing of patent applications. These need to be considered carefully in order to avoid spurious results in a multivariate setting. For example, PCT applications allow patent applicants to delay major decisions for thirty months past the priority date. Inevitably, this institutional characteristic of PCT patents will have implications for the duration of examination. Moreover, institutions like the request for accelerated examination (available to applicants at the EPO) are likely to reduce the overall time of examination. These variables are introduced below.

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months in 1990 but has increased to more than 31 months in 1996. Since they have no data on pending cases, no information is available for years after 1996.

[9] See Graham et al. (2003) for a discussion of these issues and further references.

[10] By patent quality, we mean the degree to which the patent examiner takes into account the full state of prior art and the extent to which the applicant is forced to reveal its invention fully. While the first aspect reflects the quality of document search in the patent office, the second is a measure of how skillful the examiner is in the negotiation with the patent applicant.

4 Data and Descriptive Statistics

4.1 Data Source

The European Patent Office (EPO) provides comprehensive patent information with its *Online European Patent Register* at http://www.epoline.org. This database covers published European patent applications as well as published international patent applications (PCT) seeking patent protection in one or more member states of the European Patent Convention. It provides not only bibliographic data but also procedural information covering all legal decisions made in the life of an individual patent application. The data cover the time period from the foundation of the European Patent Office until now. Our dataset is an image of this data as provided by the EPO on March, 31^{st}, 2003 via www.epoline.org and covers 1,266,506 patent files with application dates ranging from June, 1^{st}, 1978 to Juli, 25^{th}, 2002. In addition, we have obtained information on the number of claims from the EPASYS directory excerpts of which were kindly made available by the EPO. Moreover, in order to have an estimate of the EPO's processing capacity, we obtained the average number of employees by year from the Annual Report 2003.

The inclusion of forward citations in our multivariate analysis requires a restriction of the dataset to patents with applications dates prior to February 14th of 1998. This restrictions eliminates truncation problems in the number of citations received by other patents which is computed as the total number of citations within five years after application.

4.2 Variables

In the following, we briefly describe the variables computed from our two datasources.

Decision lag. The data from the Online European Patent Register include the date of filing of a patent application as well as the date of the termination of the subsequent examination procedure and the outcome of the process. Using this information, we compute the duration of the examination period (DECISION LAG) as the difference between the two dates measured in terms of six months. This variable reflects the duration we want to model in the subsequent part of the paper.

Status of the application. We know for each application, whether it is still under examination (PENDING) or whether the examination procedure has been terminated by the end of our observation period. Once an application has been granted (GRANTED) or once the examiner has issued a final refusal to grant (REFUSED), the examination procedure is closed.

Additionally, the examination can also be terminated for reasons which lie outside the control of the patent office: First, the patent applicant might decide to withdraw (WITHDRAWN) his application from the office - perhaps due to unsatisfying results from the search report or an unsatisfying interlocutary decision. Second, applications might drop out of the examination procedure for extra-ordinary reasons like the death of the applicant or the non-payment of fees. Since the number of these losses is extremely small and causes for these types of losses are outside of the procedureal focus we apply here, we code these cases also as withdrawals. The categorial variable STATUS contains the information on the according status of the patent application.

Workload. We compute this variable in order to characterize the capacity sitation at the EPO. We define WORKLOAD as the number of pending cases divided by the number of examiners ('a-posts') at the EPO at a given point of time. The number of pending cases is computed on a daily basis, but the employee figures are only available on an annual basis reflecting the recruiting policy of the EPO. We distinguish the number of pending cases for 30 different technological fields and compute WORKLOAD_IPC as an approximation for the workload within each class defined by the number of pending cases in a technological class divided by the total number of examiners at the EPO at a given point of time.

Number of claims. Each patent contains a set of CLAIMS that marks the boundaries of the patent. The claims of a patent state essential features of the underlying invention, but also describe detailed features of the innovation. The total number of claims can be interpreted as one measure of a patent's breadth and Lanjouw and Schankermann (1999) argue that this measure is highly correlated with the value of a patent. We employ it with a more neutral interpretation in mind – the number of claims simply indicates the complexity of the cases; hence, a larger number of claims should lead to an increase in the time needed for examination.

Number of designated states. The number of designated states is equivalent to the number of jurisdictions in which patent protection is applied for. Currently, a patent application at the EPO can designate 31 states which are either members or affiliated to the European Patent Treaty. Harhoff et. al. (1999) find that the number of designated states is positively correlated with the value of a patent.

Backward Citations. The search report published by the EPO yields information on the state of the art relevant for the patentability of the application. The state of the art is mostly documented by patents or by non-patent literature and is published in the patent role. In our analysis we include three variables based on backward citations. First, we include the total number of backward citations to the patent literature. Additionally, we include the share of citations made by the examiner (type A citations) and the share of citations made by the patent applicant (type X citations). A detailed description of the use of patent citations in economic analysis can be found in Michel and Bettels (2001).

References to the non-patent literature. In order to document the prior state of the art the patent office also refers to non-patent literature (mainly scientific publications). We include a simple count of the total number of citations to non-patent literature in our analysis. One might argue, that the number of references to non-patent literature measures the strength of a patent's science linkage. However, this argument is not undisputable. For a survey of the literature on this topic see Meyer (1999).

Forward Citations. Similar to scientific publications, citations received from other future patents are an indicator that the cited patent has contributed to the state of the art in a certain field. For each patent in our sample, we compute the number of forward citations as the number of citations a patent received from subsequent European patents within five years after application. Numerous studies found that forward citations are highly correlated with the monetary value of patents (see Harhoff et. al. (1999) , Lanjouw and Schankermann (1999) or Trajtenberg (1990)).

Measures of Originality and Generality. The ORIGINALITY and GENERALITY indicators are citation-based indices which measure different aspects of the patented innovation and their links to other innovations.The GENERALITY measure is based on the forward citations a patent receives and is defined as

$$GENERALITY = 1 - \sum_{k=1}^{n_i} s_{ik}^2$$

where s_{ik}^2 is the percentage of citations received by a patent i that belong to patent class k out of n_k patent classes. The GENERALITY index will be high, if a patent is cited by subsequent patents that belong to a wide range of fields and low, if most referring citations are concentrated in a few fields. Hence, a high GENERALITY index suggests, that the patent influenced subsequent innovations in a variety of different fields and is more general. ORIGINALITY is defined in the same way with the only difference, that it is based on backward citations. A low ORIGINALITY index indicates, that the patent cited only patents from a narrow set of technologies is therefore less original than an patent with a high ORIGINALITY index.

Both measures have been first proposed by Trajtenberg et. al. (1997). For our analysis we compute both indices distinguishing between 30 different technological classes.

Request of Accelerated Research. When filing a patent application the applicant can request an accelerated examination leading to a shortened examination procedure (see Section 2). We included a binary variable indicating whether this is true or not for the patent under consideration.

International Patent Classification (IPC) assignment. A patent is assigned to one or more 9-digit categories of the IPC system during the examination period depending on its applicability in different technological areas. Lerner (1994) introduced the total number of different 4-digit IPC-categories a patent was assigned to as a measure of patent breadth. He finds that broader patents (i.e. applicable in high number of different technological fields) tend to be more valuable than other patents.

PCT-Application. For each patent we include a dummy variable indicating, whether an international application within the PCT-framework (see Section 2 for details) has been filed.

4.3 Descriptive Statistics

Before working with datasets that are random samples from the population, we present descriptive statistics of the overall population outcomes. We start in Table 1 by displaying basic statistics on decision lags by year of application. The lion share of EPO applications is actually granted – in our time window covering the years from 1978 to 1995, the grant rate is 63.5 percent. Only 5.1 percent of the cases are actually explicitly refused by the patent examiner, while 27.4 percent are withdrawn by the applicants themselves after receiving a sufficiently negative search report or "sceptical" communication from the examiner. Note that even when we restrict the sample to applications from 1978 to 1995, 3.9 percent of all cases are still pending. The final two columns show that of the refused cases, a relatively large share (on average about one fifth) enter the appeal against refusal to grant, and about half of these cases are then awarded a patent grant.

Table 2 summarizes times to grant, grant after appeal and withdrawal for PCT and non-PCT applications separately. The distinction seems warranted given the strong institutional differences between PCT and non-PCT patent applications. Indeed, the duration data confirm this expectation. According to our dataset, once a patent application has been filed, 4.3 years elapse on average before a decision is made by the office to grant the patent. For PCT application, this duration is 0.3 years longer. Withdrawals occur much faster with 3.0 years of decision-making time for non-PCTs and 4.0 years for

PCT-path applications. If applicants choose to appeal a refusal to grant the patent right and are successful, the time to appeal is 7.1 (6.9) for (non-)PCT applications. These numbers are approximate, since there is some censoring in the data even if we limit ourselves to application years 1978 to 1995.

In Table 3, we use a patent classification introduced by Schmoch to distinguish between different technological fields. We would expect to see some variation in decision-making processes depending on the relative novelty and complexity of the technical matter embedded in the patent applications. The grant rate varies between 56.5 percent in consumer goods and equipment (area 29) and 70.8 percent in nuclear engineering (area 9). Low grant rates are concomitant with high numbers of withdrawals, while the share of applicants receiving an explicit refusal is quite stable across technical fields. Exceptions exist, though: in semiconductors (area 5), macromolecular chemistry (area 11) and chemical engineering (area 18) the rate of refusals exceeds six percent. In semiconductors, almost every third refusal is contested in the appeals procedure, and only one third of them are successful. This may attest to the rivalry around intellectual property in this area. Using the same technological classification, Table 4 displays the time to grant, to grant after appeal and to withdrawal for each area separately. Decisions are taking particularly long to reach in the areas of information technology (6.2 years, area 5), biotechnology (5.7 years, area 13) and semiconductors (5.6 years, area 5). Again, PCT applications take somewhat longer.

Taking a look at the demand side of patent protection we find that applications rose from an annual number of 12,384 in 1979 to 101,048 in 2001 (see Figure 1). Since the examination of each patent application takes several years, the growth in application numbers led to the emergence of a backlog of pending cases at the EPO, which grew to more than 400,000 pending patent applications at the end of 2001 (see Figure 2). The most evident explanation for this strong growth of the backlog is an insufficient expansion of the workforce at the EPO leading to a growing workload for each examiner and hence longer examination duration for individual patents. Figure 3 shows that the number of examiners (A-posts) at the EPO grew from 545 to 3,861 in the period from 1978 to 2001. Dividing the number of pending cases by the according number of examiners yields the average workload of each examiner which dramatically increased since the foundation of the EPO (see Figure 3). This strong increase in the workload of the patent examiner might be one explanation for the lengthening of the examination procedure.

Another potential explanation for the lengthening of the examination procedure can be found in the growing complexity of patent applications over the last two decades. Table 5 shows the development of several measures of an application's complexity on an annual basis. The average number of claims per patent, for example, rose by more then 50% from 9.84 in 1978 to 15.36 in 1998. Since an examiner has to validate the formulation and the justification of each of the claims, it is obvious that a growing number of claims leads to a longer examination period everything else being qual. Additionally, the fraction of patent applications at the EPO which include an international patent application for some or all countries of the PCT grew even faster: in 1998, 50% of the applications filed also applied for international patent protection, which is more than the sixfold of the level in 1978. The examination of a combined EPO/ PCT-application is more time-consuming than a pure EPO-application, since the patentability of the underlying invention and the formal correctness of the application has to be validated with regard to different legal frameworks - the EPO and the PCT guidelines. Table 5 also shows the average number of references made to previous patents and to non-patent literature. While the number of backward citations to previous patents rose slightly at the end of the 90's the number of references to non-patent literature (mostly scientific publications) rose by almost 50% within the same period. Both variables indicate higher demand for the search capacity at the EPO.

5 Survival Analysis

5.1 Model Specification

In order to analyze the determinants of the duration of the examination process at the European Patent Office we consider survival time as a non-negative random variable T.[11] A basic concept for the analysis of survival times is the hazard function $\lambda(t)$, which is defined as the limit

$$\lambda(t) = \lim_{\Delta t \to 0} \frac{P(t \leq T < t + \Delta t \mid T \geq t)}{\Delta t}$$

and measures the instantaneous failure rate at time t given that the individual survives until t. In the following, we estimate different survival models where the hazard function depends on a set of covariates $x' = (x_1, \ldots, x_p)$ that influence the survival time T.

For the estimation of different models we rely on an extension of the well-known piecewise exponential model (PEM) that allows for nonlinearities in the predictor η. The basic idea of PEMs is to divide the time axis $[a_0, \infty)$ into k intervals $[a_0, a_1]$, $(a_1, a_2]$, …, $(a_{s-1}, a_s]$, …, (a_q, ∞), $q = k - 1$ and to assume that all values that depend on time t are piecewise constant on this grid. Defining a sequence $\gamma_{0s} = \log \lambda_s$ of baseline parameters where $s = 1, \ldots, q$, the PEM regression model for survival data is given by a sequence of hazard rates

$$\lambda(t, x) = \exp(\gamma_{0s} + \eta), \quad t \epsilon (a_{s-1}, a_s], \quad s = 1, \ldots, q.$$

[11] The survival time is the time between the filing of a patent application at the patent office and the final decision on the application.

The log-likelihood for the vector of unknown parameters in this model can be shown to be in the form of the log-likelihood of a log-linear Poisson model with an offset Δ_s (see Fahrmeir and Tutz (2001)), where

$$\Delta_s = \max\{0, \min\{a_s - a_{s-1}, t_i - a_{s-1}\}\}.$$

In this framework, we firstly specify a purely parametric model where the predictor η contains only linear additive terms of the form $x_j'\beta_j$. In a second step we incorporate also nonlinear terms for the effect of some metrical covariates using a predictor η of the form $\eta = \sum f_j(x_j) + x_{-j}'\beta_{-j}$ with $f_j(x_j)$ being the unknown nonlinear effect of the metrical covariates x_j and $x_{-j}'\beta_{-j}$ the remaining linear part of the predictor. The estimation of these models is based on the principles of P-spline regression, first introduced by Eilers and Marx (1996) in a frequentist setting. We use the Bayesian version of the P-spline approach proposed by Lang and Brezger (2002) employing MCMC simulation techniques implemented in *BayesX*, a software package for Bayesian generalized additive regression based on MCMC techniques.[12] comprehensive introduction into Bayesian semiparametric modeling of survival models is presented in Hennerfeind and Fahrmeir (2003). One of the major advantages of the Bayesian approach to non-linear regression using P-splines is that the optimal smoothing parameter is estimated jointly with the other parameters avoiding the problems of specifying a smoothing parameter ex ante. The major drawback of MCMC simulation techniques is their computational intensity. Since a multivariate analysis of the complete dataset with over 1 million observations would require too much computation time, we ran our simulations using a 0.5% random sample of the total population. Therefor, our estimations are based on the resulting sample of 4,608 patents.

5.2 Results

In the following, we present estimation results based on the models described in the previous subsection using a 0.5% random sample of the total population of European patents. In order to characterize differences in the processes leading to either withdrawal of the application, a refusal of the patent grant or an actual patent grant, we show not only results from the survival analysis based on pooled data ignoring the outcome of the examination process, but also results from competing risk specifications. Note that all covariates are treated as time-invariant regressors. Additionally, we include random effects for 30 technological fields in the estimation, which we don't report here.[13] Table 6 summarizes our results. In the second column of each block, we display the coefficients of those variables which we include

[12] The program is available free of charge at `http://www.stat.uni-muenchen.de/~lang`.

[13] Results for the random effects are available upon request.

parametrically. The nonparametric results are summarized in Figures 6, 7, 8 and 9. For the sake of brevity, we include the non-parametric results from the pooled risks estimation only. The corresponding figures for the individual risks are very similar to the ones presented here. Figure 5 contains a depiction of the piecewise constant hazard rates, overlaying the results from the parametric and the semiparametric estimation for pooled outcomes and each of the three individual risks.

We comment on the pooled risk estimates with parametric specification first (Table 6, column (1)(a)). This column would be relevant for a policy-maker who knows that all three outcomes consume the same amount of ressources or does not attach any other form of relevance to the different outcomes. In the first column of Table 6, we have attached an asterix to coefficients whose 2.5%/97.5% confidence intervals do not include zero. With the exception of our generality measure, the request for accelerated examination, the forward citations and the number of designated states, all coefficients are statistically relevant and carry the expected sign. The estimated hazard (Figure 5, top-left panel) is non-monotonic so that a standard Weibull or Gompertz specification would clearly be inappropriate. Conversely, modeling the process in the AFT mode (accelerated failure time) as a log-normal or log-logistic process would be in rough concordance with the time of hazard we see.

When we specify the last four variables non-parametrically, most of the results and the shape of the hazard (Figure 5) remain largely unchanged. The nonparametric modeling does reveal – in the four variables treated non-parametrically – some interesting variations. In Figure 6, we plot the the effect of our workload variable which has a negative slope, as expected. As the workload increases the hazard of reaching a decision is decreasing. The same is true for the number of forward citations (Figure 7) and the number of claims (Figure 9). The effect of the number of designated states is non-monotonic and it may very well reflect complexities in the decision-making of patent applicants. Note that we treat countries as equal, but we know that most patents seek patent protection in Germany, the UK and France. The non-monotonicity may be an indicator that we need a refined variable for the regional scope of protection.

In columns (2), (3) and (4) of Table 6, we present the results from our competing risks specification. These results are interesting, since they demonstrate that some of the effects apparent in column (1) come about as a complex combination of individual risk determinants. For example, while the generality variable does not appear to affect the overall hazard, it is clearly instrumental in affecting the grant hazard positively. More general patent applications receive grants faster, while the withdrawals and refusals are not affected. Another interesting effect concerns the request for accelerated examination (RACCEXAM) which is statistically unsurprising in column (1) and quite a strong determinant of all three risks when these are treated separately. Grants are accelerated by this request, while withdrawals and refusals are not. This is presumably reflecting an endogenous component of the applicant's behavior. Inventions for which applicants seek an accelerated procedure are potentially valuable - they are not abandoned as easily as other patent applications.

6 Conclusion

In this paper, we have presented first results from an analysis of decision-making lags and outcomes in the patent examination phase at the European Patent Office (EPO). The lag between patent application and final patent office decision is often taken as a measure of the efficacy of patent granting procedures. We have presented estimates from a duration analysis in which we model the pooled hazard of outcomes as well as separate hazards of the application becoming a granted patent, being withdrawn or being refused. In line with our theoretical expectations, we find that decisions on more complex and more highly cited patents require more time than decisions regarding an average patent. But allowing for a competing risks specification, we find more complex patterns which reflect largely the endogenous behaviour of the applicants. Our results also confirm an earlier finding by Griliches (1990) who demonstrated that the number of examiners (relative to the workload they have to shoulder) is an important determinant of grant lags.

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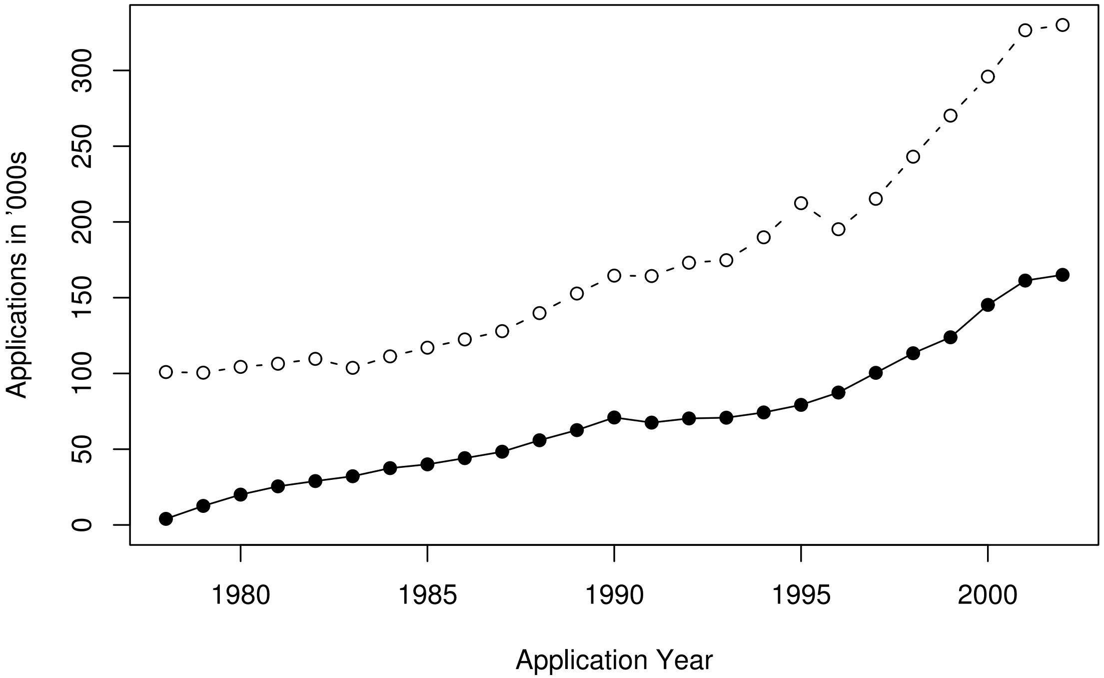

Figure 1: Number of yearly patent applications: - - USPTO, — EPO.

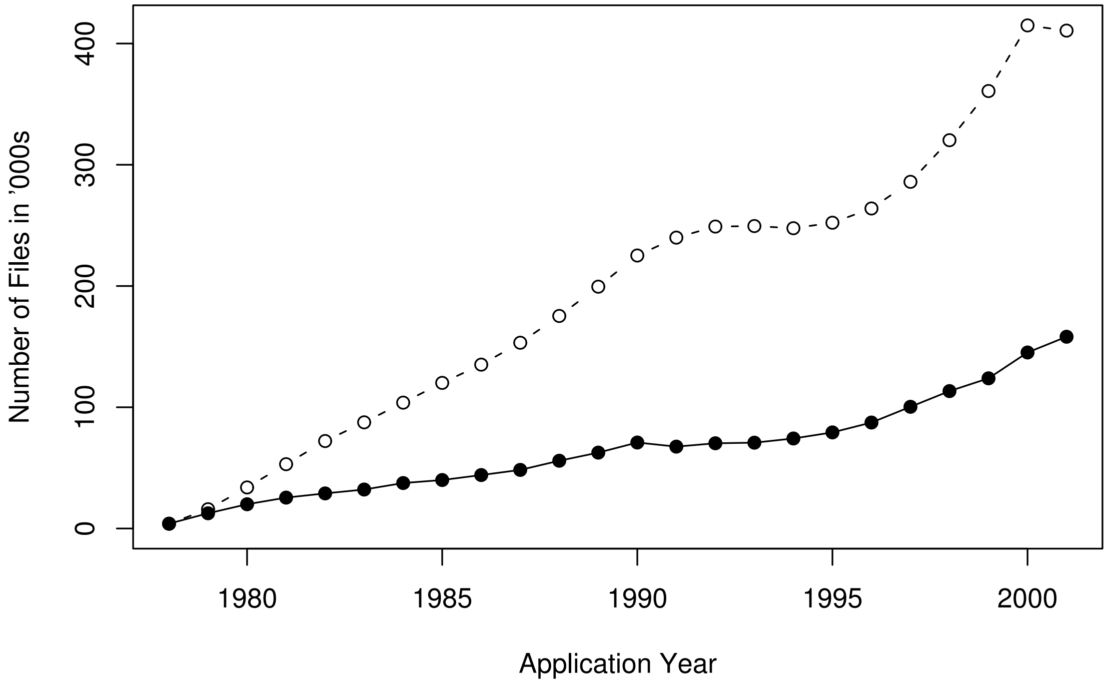

Figure 2: - - Number of pending cases at the EPO, — Number of applications at the EPO.

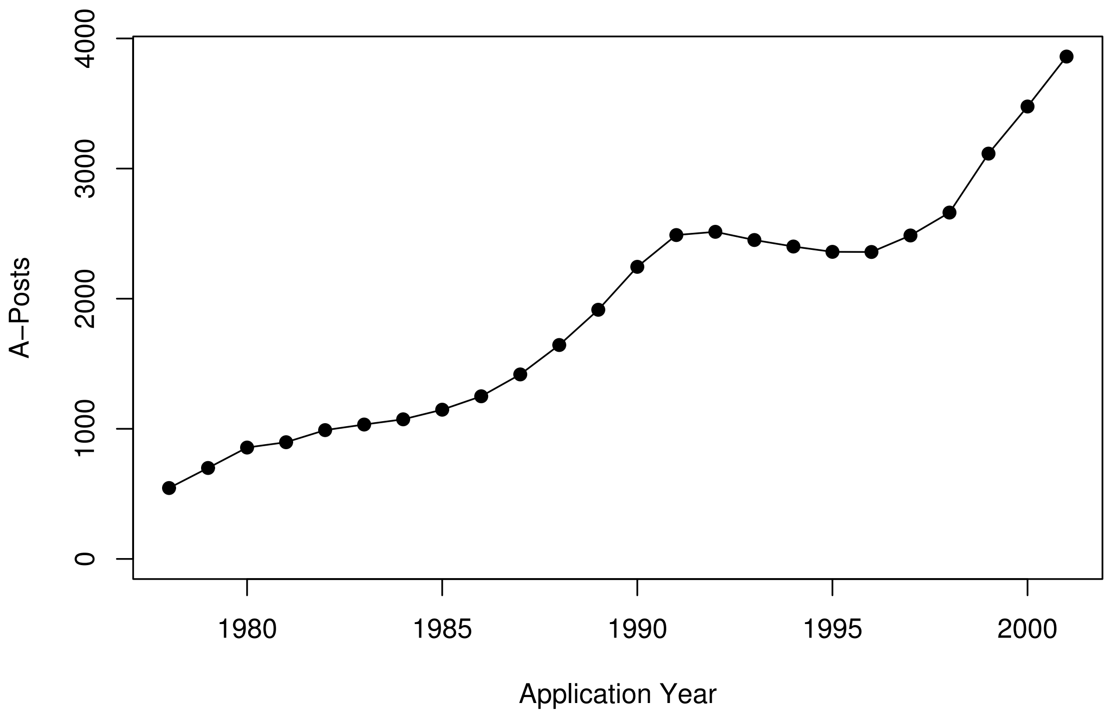

Figure 3: Number of examiners (A-posts) at the EPO.

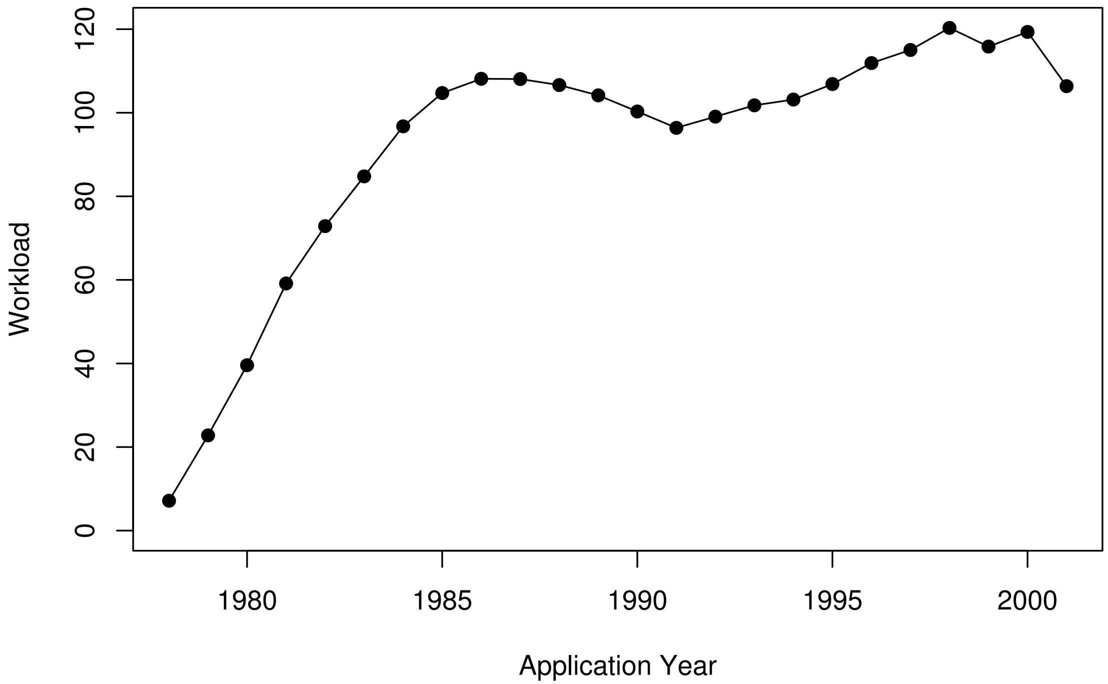

Figure 4: Number of pending cases per examiner.

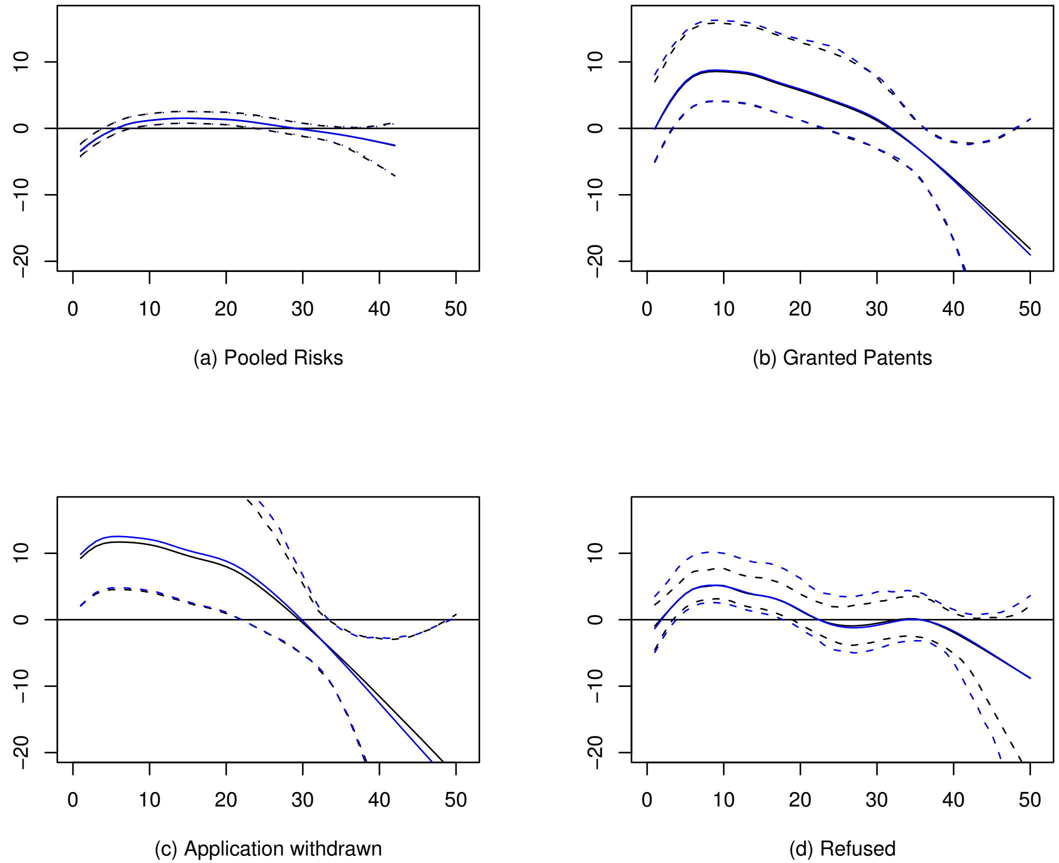

Figure 5: Hazard-rate estimates from semi-parametric (black lines) and parametric specification (blue lines). —Median, - - - 95% credible region.

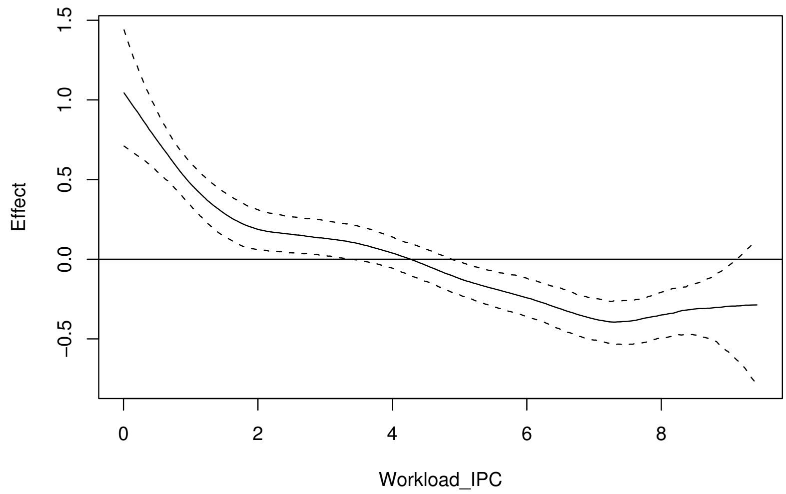

Figure 6: Results for effect of workload (—Median, - - - 95% credible region).

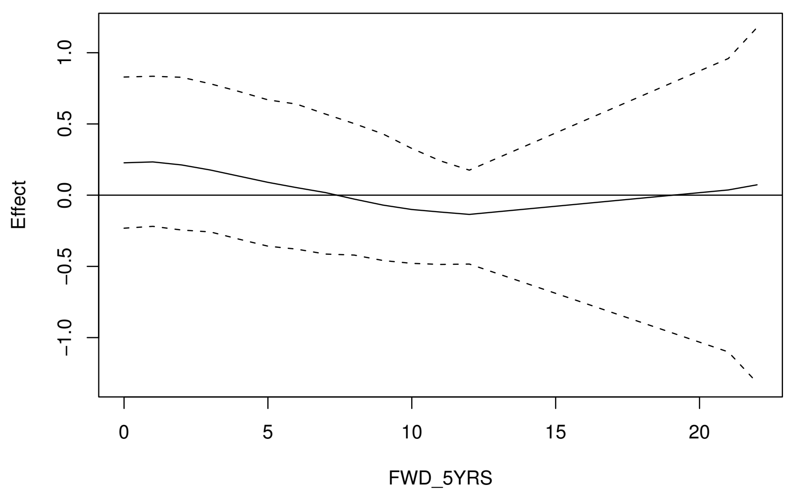

Figure 7: Results for effect of the number of received forward citations within 5 years (—Median, - - - 95% credible region).

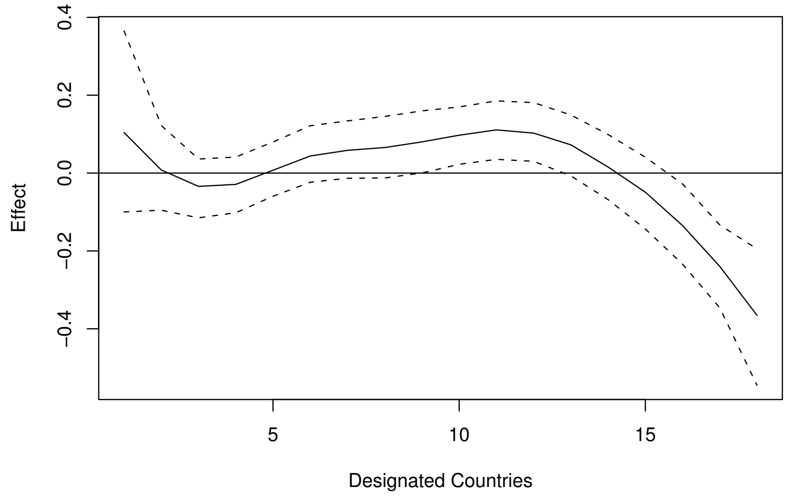

Figure 8: Results for the effect of the number of designated states (—Median, - - - 95% credible region).

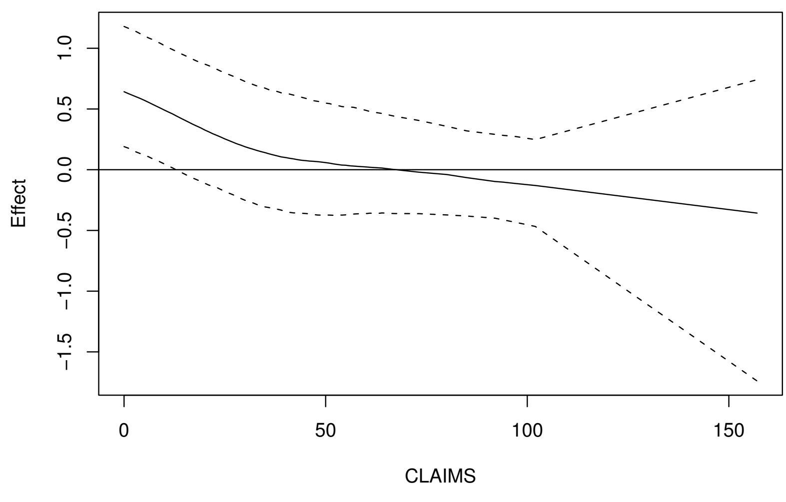

Figure 9: Results for the effect of the number of claims (—Median, - - - 95% credible region).

Application Year	Cases	PCT Application %	Directly Granted %	Withdrawal of Application %	Refusal of Grant %	Application Pending %	Appeal against Grant Refusal %	Granted after Appeal %
1978	3,902	6.4	70	25.2	4.6	0.2	2.5	1.5
1979	12,392	8.9	69.6	24.1	6.2	0.1	2.4	1.4
1980	19,724	9.1	69.3	24.2	6.5	0	1.7	1.0
1981	24,957	8.5	68.7	25.4	5.9	0	1.3	0.8
1982	28,518	9.1	69.0	25.8	5.2	0	1.1	0.6
1983	31,609	9.4	68.3	26.5	5.2	0	1.3	0.8
1984	36,952	8.8	67.4	27.9	4.7	0	1.2	0.7
1985	39,371	12.0	67.0	28.9	4.1	0.1	1.0	0.5
1986	43,080	12.7	66.1	29.0	4.8	0.1	1.2	0.6
1987	45,803	13.1	65.3	29.4	5.2	0.1	1.1	0.6
1988	52,165	15.0	64.5	29.8	5.5	0.2	1.0	0.5
1989	57,669	15.6	62.6	31.3	5.7	0.4	0.9	0.5
1990	63,811	19.0	64.4	29.3	5.6	0.7	0.8	0.4
1991	59,092	24.2	65.2	27.9	5.6	1.3	0.8	0.3
1992	60,186	25.7	64.2	27.8	5.4	2.5	0.7	0.2
1993	59,448	30.3	63.6	25.6	5.2	5.5	0.7	0.2
1994	60,924	34.8	58.3	25.0	4.7	11.9	0.6	0.1
1995	63,402	39.9	47.8	23.7	3.7	24.8	0.4	0.1
1996	68,647	45.4	32.4	20.3	2.7	44.6	0.4	0.1
1997	76,774	47.6	15.2	15.1	1.3	68.4	0.2	0
1998	83,822	48.6	4.4	9.5	0.3	85.8	0.1	0
1999	47,157	14.7	1.1	5.5	0.1	93.3	0	0
2000	12,527	0	0.2	2.2	0	97.6	0	0
Total (1978-1995)	**763,005**	**20.1**	**63.5**	**27.4**	**5.1**	**3.9**	**0.9**	**0.9**

Table 1: EPO Applications and Application Outcomes by Application Year. (Note: The category "application withdrawn" also includes cases in which patents were consolidated or applications were suspended. These are typically less than 0.1 percen of all applications in any year.)

Application Year	Non-PCT Applications: Time to Grant (without Appeal)	Non-PCT Applications: Time to Grant after Appeal	Non-PCT Applications: Time to Withdrawal*	PCT-Applications: Time to Grant (without Appeal)	PCT-Applications: Time to Grant after Appeal	PCT-Applications: Time to Withdrawal*
1978	3.2	5.6	2.0	4.2	6.0	2.4
1979	3.2	5.8	2.2	4.2	5.8	2.9
1980	3.5	6.2	2.3	4.4	6.3	3.1
1981	3.7	6.4	2.5	4.6	6.8	3.2
1982	3.9	6.5	2.6	4.6	6.9	3.2
1983	4.1	6.5	2.8	4.6	7.3	3.2
1984	4.3	7.1	3.0	4.7	7.4	3.3
1985	4.5	7.6	3.1	4.8	7.6	3.4
1986	4.5	7.6	3.1	4.7	8.1	3.7
1987	4.6	7.6	3.3	5.0	7.7	3.8
1988	4.6	7.6	3.4	5.1	7.7	3.9
1989	4.6	7.2	3.3	5.1	7.7	3.8
1990	4.5	7.0	3.2	4.9	7.5	3.9
1991	4.5	6.8	3.1	4.8	7.1	4.1
1992	4.3	6.6	2.8	4.8	6.7	4.3
1993	4.3	6.0	3.1	4.6	6.1	4.4
1994	4.2	5.7	3.1	4.4	6.0	4.3
1995	4.0	4.8	3.1	4.1	5.1	4.1
1996	3.8	4.2	2.9	3.8	4.5	3.6
1997	3.3	3.9	2.5	3.5	4.2	3.2
1998	2.8	3.2	2.0	3.1	.	2.6
1999	2.0	.	1.5	2.3	.	1.8
2000	1.4	.	1.2	.	.	.
Total (1978-1995)	**4.3**	**6.9**	**3.0**	**4.6**	**7.1**	**4.0**

Table 2: Time to Application Outcome by Application Year. (Note: Durations are not corrected for censoring. The share of pending cases is documented in Table 1.)

Area	Area Name	Cases	PCT Applications %	Directly Granted %	Withdrawal of Application %	Refusal of Grant %	Appeal against Grant Refusal %	Granted after Appeal %
1	Electr. Machinery, Electrical Energy	19,276	13.0	64.1	30.4	5.3	0.8	0.5
2	Audiovisual Technology	10,454	11.6	70.7	24.6	4.4	1.1	0.6
3	Telecommunications	13,126	13.8	67.5	26.3	5.8	1.2	0.6
4	Information Technology	10,288	12.9	62.9	30.8	5.8	1.1	0.5
5	Semiconductors	6,813	9.9	59.9	30.3	9.0	3.1	1.1
6	Optics	12,087	13.0	67.6	27.3	4.6	0.9	0.4
7	Analysis, Measurement, Control Tech.	22,061	19.1	62.8	31.9	5.1	0.9	0.5
8	Medical Technology	11,522	22.9	61.2	32.8	5.7	1.1	0.5
9	Nuclear Engineering	1,989	11.2	70.8	24.0	5.1	1.0	0.5
10	Organic Fine Chemistry	23,045	11.6	63.4	30.3	5.9	0.7	0.3
11	Macromolecular Chem., Polymers	15,453	9.1	62.1	31.2	6.5	1.7	0.9
12	Pharmaceuticals, Cosmetics	8,337	24.3	62.4	30.7	6.0	1.0	0.4
13	Biotechnology	6,684	25.0	55.1	36.1	5.9	0.8	0.4
14	Agriculture, Food Chem.	2,824	16.0	64.0	31.3	4.6	0.7	0.4
15	Chem. & Petrol Ind., Basic Mat. Chem.	8,335	13.9	67.0	27.6	5.4	1.4	0.8
16	Surface Technology, Coating	5,910	16.7	66.4	28.2	5.2	0.9	0.6
17	Materials, Metallurgy	9,131	13.8	69.9	24.9	5.1	0.8	0.4
18	Chemical Engineering	10,020	18.0	65.3	28.6	6.1	1.7	1.1
19	Mat. Proc., Textiles, Paper	13,743	13.4	66.7	28.8	4.4	0.7	0.4
20	Handling, Printing	15,883	13.5	67.7	27.6	4.5	0.6	0.4
21	Agricultural & Food Proc.	4,328	14.3	60.3	34.6	5.1	0.9	0.5
22	Environmental Technology	2,213	17.7	62.8	31.8	5.3	1.5	0.7
23	Machine Tools	8,572	16.1	65.2	30.2	4.5	0.8	0.4
24	Engines, Pumps, Turbines	7,124	17.7	70.6	24.7	4.7	1.1	0.6
25	Thermal Proc. & Apparatus	4,321	16.4	64.3	30.2	5.4	1.3	1.0
26	Mechanical Elements	10,817	15.1	69.5	26.5	4.0	0.6	0.4
27	Transport	12,213	13.9	69.5	26.1	4.4	0.4	0.2
28	Space Technology, Weapons	1,970	13.8	62.3	33.3	4.4	0.6	0.2
29	Consumer Goods & Equipment	12,803	15.5	56.5	39.2	4.2	0.5	0.3
30	Civil Eng., Building, Mining	10,536	15.1	64.9	30.4	4.7	0.8	0.4
	Total	**301,899**	**15.0**	**64.8**	**29.7**	**5.2**	**1.0**	**0.5**

Table 3: EPO Application Outcomes by Technical Field (Application Years 1980–1990). (Note: Pending Cases are not documented here.)

		Non-PCT Applications			PCT-Applications		
Area	Area Name	Time to Grant (without Appeal)	Time to Grant after Appeal	Time to Withdrawal*	Time to Grant (without Appeal)	Time to Grant after Appeal	Time to Withdrawal*
1	Electr. Machinery, Electrical Energy	4.7	7.0	3.3	5.0	8.2	3.8
2	Audiovisual Technology	5.3	7.8	3.6	5.2	6.7	3.7
3	Telecommunications	5.4	7.6	3.8	5.5	8.5	4.1
4	Information Technology	6.2	8.4	4.4	5.8	8.1	4.5
5	Semiconductors	5.6	9.5	3.9	5.4	8.4	4.0
6	Optics	5.3	8.1	3.7	5.1	8.2	4.1
7	Analysis, Measurement, Control Tech.	4.8	6.9	3.3	5.2	7.7	4.0
8	Medical Technology	4.7	8.1	3.2	5.2	9.3	4.0
9	Nuclear Engineering	4.3	8.4	3.3	5.1	8.3	4.1
10	Organic Fine Chemistry	4.5	7.3	3.5	5.3	7.3	3.9
11	Macromolecular Chemistry, Polymers	4.9	8.3	3.7	5.4	9.0	3.8
12	Pharmaceuticals, Cosmetics	4.8	8.2	3.5	5.3	8.6	3.9
13	Biotechnology	5.7	9.7	4.0	6.2	10.2	4.4
14	Agriculture, Food Chemistry	4.2	6.7	3.0	4.6	6.6	3.7
15	Chem. & Petrol Ind., Basic Mat. Chem.	4.4	6.8	3.2	4.8	7.6	3.5
16	Surface Technology, Coating	4.4	7.8	3.1	5.0	9.0	3.9
17	Materials, Metallurgy	4.3	7.4	3.0	4.9	8.3	3.5
18	Chemical Engineering	4.2	6.8	3.0	4.6	7.2	3.6
19	Materials Proc., Textiles, Paper	4.4	7.4	3.1	4.7	7.1	3.6
20	Handling, Printing	4.1	6.4	2.8	4.4	6.8	3.3
21	Agricultural & Food Proc.	4.3	6.9	2.8	4.6	7.4	3.4
22	Environmental Technology	3.8	6.2	2.6	4.3	6.8	3.5
23	Machine Tools	4.1	7.0	2.9	4.5	7.4	3.6
24	Engines, Pumps, Turbines	3.8	5.6	2.5	4.1	7.1	3.4
25	Thermal Proc. & Apparatus	3.8	7.0	2.6	4.3	6.5	3.4
26	Mechanical Elements	3.8	5.8	2.6	4.4	7.5	3.5
27	Transport	3.8	6.4	2.6	4.1	6.4	3.2
28	Space Technology, Weapons	3.9	6.0	2.8	4.4	9.2	3.4
29	Consumer Goods & Equipment	4.2	6.8	2.7	4.6	7.2	3.4
30	Civil Eng., Building, Mining	3.8	6.7	2.6	4.3	6.4	3.4
	Total	**4.6**	**7.4**	**3.2**	**4.9**	**7.7**	**3.8**

Table 4: Time to Application Outcome by Technical Field (Applications Years 1980–1990). (Note: See Notes in Table 1 and Table 2.)

Application Year	CLAIMS	PCTAPPL	BWD_TOT	BWD_NP_TOT
1978	9.84	0.06	4.47	0.39
1979	9.97	0.09	4.96	0.40
1980	10.06	0.09	4.73	0.47
1981	10.41	0.09	4.45	0.50
1982	10.73	0.09	4.42	0.55
1983	10.52	0.09	4.36	0.60
1984	10.85	0.09	4.22	0.61
1985	11.16	0.12	4.30	0.67
1986	11.18	0.13	4.27	0.73
1987	11.40	0.13	4.23	0.80
1988	11.54	0.15	4.13	0.81
1989	11.82	0.16	4.11	0.87
1990	12.03	0.19	4.14	0.91
1991	12.32	0.24	4.21	0.98
1992	12.44	0.26	4.30	0.98
1993	12.95	0.30	4.49	0.99
1994	13.29	0.35	4.61	0.98
1995	13.79	0.39	4.73	0.94
1996	14.34	0.45	5.02	0.93
1997	14.80	0.47	4.98	0.90
1998	15.36	0.50	4.84	0.86
Average	**13.40**	**0.30**	**4.18**	**0.80**

Table 5: Yearly means of selected patent indicators.

Outcomes	(1) Pooled Outcomes		(2) Granted		(3) Refused		(4) Withdrawn	
Specification	Parametric	Semi Parametric	Parametric	Semi-Parametric	Parametric	Semi-Parametric	Parametric	Semi-Parametric
INTERCEPT	-1.2097*	-2.7667*	-9.5317*	-9.9423*	-9.737*	-12.7693*	-14.7382*	-17.8812*
BWD TOT	-0.0020	-0.0004	-0.0250*	-0.0238	0.0170	0.0135	-0.0292*	-0.0285*
BWD_NP_TOT	-0.087*	-0.0856*	-0.0032	-0.0018	-0.0140	-0.0076	-0.0838*	-0.0839*
SHARE X	-0.3961*	-0.3815*	-0.7370*	-0.7533*	0.0913	0.1146	0.5814*	0.5950*
SHARE A	-0.2469*	-0.2167*	0.0684	0.0475	-0.0304	-0.018	-0.3231*	-0.3048*
ORIGINALITY	-0.1165	-0.0893	0.0746	0.0589	-1.0165	-0.9540	-0.1307	-0.0971
GENERALITY	0.0860	0.0569	0.3447*	0.2005*	-0.1074	-0.1589	-0.2594	-0.2289
PCTAPPL	-0.3583*	-0.3464*	-0.0142	-0.0472	0.3610	0.4826*	-0.4456*	-0.4028*
RACCEXM	0.0973	0.1055	0.8313*	0.8540*	-1.736	-1.6441	-1.1370*	-1.1392*
IPC_TOT	-0.0413*	-0.0429*	-0.0420*	-0.0409*	-0.0669	-0.0585	0.0293	0.0265
WORKLOAD	-0.1247*		-0.0895*		-0.0105		0.0073	
FWD 5YRS	-0.0193		0.0820*		-0.0906		-0.2409*	
DESG	-0.0048		-0.0115*		-0.0019		0.0148*	
CLAIMS	-0.0131*		-0.0104*		-0.0158		0.0042	
Deviance	31,199.7	31,124.6	24,217.6	24,178.9	2,934.0	2,923.5	14,895.4	14,854.0
pD	48.00	62.09	43.38	59.16	20.03	24.10	28.24	39.63
DIC	31,295.7	31,248.8	24,304.3	24,297.2	2,974.0	2,971.7	14,951.9	14,934.0
Observations	4,608		4,608		4,608		4,608	
Exits	4,287		2,832		194		1,261	

Table 6: Estimation results from alternative piecewise exponential specifications. (*): 95% credible region for parameter estimates excludes 0. pD: Effective number of parameters.