Erasmus University Rotterdam
Erasmus School of Economics
Bachelor thesis Strategy Economics

Abolishing extensive examination as an element of the patent granting process

The evolution of patent quality after the Dutch 1995 patent reform

Name student:	Sophie van Zonneveld
Student number:	494335
Supervisor:	Dr. A.S. Bhaskarabhatla
Second assessor:	Prof. Dr. H.P.G. Pennings
Date:	4-7-2021

Abstract

This paper investigates the effect of abolishing extensive examination as a part of the patent granting procedure by studying the Dutch 1995 patent reform. This reform altered the patent granting process in the Netherlands. As of 1995, there is no prior extensive examination of applications and meeting the formal requirements is sufficient to receive a patent. The research question is *"How did the quality of patents filed for at the Dutch Patent Office evolve after the 1995 patent reform?".* The research question is studied based on a survival analysis that estimates the hazard of patent lapsing since the filing date. The aim of the analysis is to evaluate how the quality of patents, represented by their lifespan, has evolved during three post-reform periods (1995-1999, 2000-2004, 2005-2009).

A smoothed hazard estimated hazard curve, Nelson-Aalen cumulative hazard curve, and Kaplan-Meier estimated survival curves are used to analyze the survival of patents. Based on the results of a log-rank test, the conclusion is that in the years after the 1995 patent reform, the quality of patents, represented by their survival time, did not change significantly. Based on the results of a survival model regression analysis, it is concluded that the year in which patents were filed may reduce the hazard of lapsing before the expiration date. Patents of which the residence country of the first applicant is the Netherlands may have an increased hazard of lapsing before the expiration date. Moreover, the International Patent Classification section a patent falls under may have a hazard increasing impact.

Keywords:
Patents, quality, granting process, examination

Table of contents

List of used abbreviations

DPO	Dutch Patent Office
EPO	European Patent Office
EU	European Union
IPC	International Patent Classification
IPI	International Patent Institution
OVB	Omitted Variable Bias
UPC	Unified Patent Court
WIPO	World International Property Organization

1. Introduction

The concept of patenting is almost 600 years old: the first patent regulation was applied in Venice in 1474. Without permission from the inventor, the city council did not allow other people to remake a device for ten years after its invention (Schippers, 2016). Thereafter, patenting regulation was adopted by more countries and in the present, there is patent legislation in most of all countries on earth. In 2019, 3.2 million patent applications were filed worldwide (World International Property Organization, 2020).

Patents are the subject of a long-lasting economic and political debate. The first topic of discussion is whether patents are beneficial and for whom. This topic is again proven to be relevant in the era of the global COVID-19 pandemic. The question has arisen whether it is ethical that companies with the ingredient list to a life-saving vaccine in their possession can file for patents and secure a monopoly position in making the vaccine. However, the option of monetizing the vaccine, made easier by the existence of patents, might have been a key motivator for the pharmaceutical companies to invest time and funds into researching the disease. Andries and Faems (2013) argue that both large firms and small-to-medium enterprises benefit from patenting in terms of commercializing product innovations. This contributes to higher profit margins. Besides, patenting activities do not cause significant cost disadvantages for either type of company.

The second topic of discussion concerns what patent legislation and the patent granting process must look like. For example, not all institutions agree on what should be patentable subject matter. In the United States, the 1980 *Diamond v. Chakrabarty* case allowed scientists to patent living bacteria. The court ruled that since the bacteria were created by humans and did not exist in nature, they are patentable (US Supreme Court, n.d.). However, Article 53 of the European Patent Convention includes a list of biotechnological inventions that are not patentable on ethical grounds (European Patent Office, 2020). Moreover, what conditions must be met by inventors who want to apply for a patent can be a topic of discussion.

In 1995, a patent law reform completely altered the patent granting process in the Netherlands. This reform abolished the patent council that had been responsible for the extensive examination of patent applications since 1910. Since the reform, patents can be applied for at the Dutch Patent Office, which grants patents without prior extensive examination. Meeting the formal requirements is sufficient to receive a patent (Rijksoctrooiwet 1995, 2020).

To contribute to existing literature, the research question of this paper forms as following:
"How did the quality of patents filed for at the Dutch Patent Office evolve after the 1995 patent reform?"

The research question is answered based on a survival analysis that estimates the hazard of patent lapsing since the filing date. The aim of the analysis is to evaluate how the quality of patents, represented by their lifespan, has evolved during three post-reform periods (1995-1999, 2000-2004, 2005-2009).

This research is both academically and practically relevant. First, the findings are useful for the Netherlands Enterprise Agency and the Dutch Patent Office, since they can assist them in evaluating how the quality of patents evolved after the 1995 patent reform. Besides, the research is of use to other patent offices and lawmakers. It can help them in deciding whether their patent granting policy is optimal or if their current policy could benefit from a patent reform that abolishes extensive examination. The research will contribute to the existing literature on the effect of patent legislation or policy on patent quality. Patent granting policy has been an object of research since the 1940s. This research is relevant because it studies the effects of a major patent reform that has not often been a topic of research before.

The rest of the paper is organized as follows. In the second chapter, a brief history of patent legislation in the Netherlands, the relevance of the 1995 Dutch patent reform, similar research on patent policy changes, and methods to define the quality of patents are presented. This is followed by a discussion of the data and the methodology of a survival analysis that estimates the hazard of patent lapsing since the filing date. Thereafter, the results of the analysis will be presented. Consequently, a conclusion with an answer to the research question will be discussed. Lastly, the validity and limitations of the analysis and recommendations for further research will be put forward.

2. Theoretical Framework

2.1. What is a patent?

A patent is a writing securing for a term of years the right to exclude others from making, using, or selling an invention (Merriam-Webster, n.d). Patents must be filed in each country where protection is desired. Currently, to obtain a patent in the Netherlands, an application can be filed at the Dutch Patent Office (DPO). It is possible to obtain a collection of national patents for multiple European countries, including the Netherlands, at the European Patent Office (EPO). Patents for non-EU countries can be applied for at the World Intellectual Property Organization (WIPO) (Netherlands Enterprise Agency, n.d.-a).

To keep a patent valid, a yearly annual fee must be paid starting from the fourth year after the application for the patent was submitted. The annual fee becomes higher every year. It is the responsibility of the patent holder to detect any infringements of their intellectual property rights and to act if necessary. Patent holders can exploit their idea themselves, sell the patent, or grant licenses to other parties who want to exploit the idea (Netherlands Enterprise Agency, n.d.-c). All Dutch patents are available for inspection online in a database called the patent register. The only patents not included in the register are patents that must stay secret. According to an employee of the Patent Office, an example of patents that fall into this category are patents owned by the Ministry of Defense of the Netherlands.

To assist inventors in carrying out searches in patent-related databases, more than 100 countries including the Netherlands use the International Patent Classification (IPC). This is a hierarchical system to classify patents using sections, classes, subclasses, groups, and subgroups (World Intellectual Property Organization, n.d.-b).

2.2. Patent statuses

A patent can have different statuses. It can be in force, meaning that the patent is valid, and the invention is protected by it. If the patent is not in force, it can have expired because the validity period of the patent has passed, or it can have lapsed prematurely. A patent can lapse by procedure or because the owner stops paying for the yearly annual fee (Netherlands Enterprise Agency, n.d.-b). Moreover, a patent can also be fully or partly renounced by the proprietor. A renounced patent is not in force but differs from a lapsed patent. Renouncing has a retroactive effect from the grant date, meaning that the renunciation date is equal to the grant date of the patent (Rijksoctrooiwet 1995, 2020).

The Dutch patent register provides information on the status of each patent. However, for lapsed or renounced patents, the patent register does not provide information on what motivated the patent holder to stop patent protection for the invention. Since there is an annual fee to be paid, a possible motivation may be that keeping the patent in force is not financially advantageous for every invention. Patents that are annulled after they were challenged are not included in the patent register (Netherlands Enterprise Agency, 2021).

2.3. Historical review on patenting in the Netherlands

2.3.1. The Dutch Patent Act

Between 1869 and 1910, the Netherlands purposedly did not have any patent legislation. The government believed that a lack of patents would stimulate the Dutch economy since entrepreneurs were allowed to use inventions from abroad without costs. Besides, the government expected that other countries would follow and also abolish patent legislation. Both assumptions did not appear to be true. On the contrary, there was a growing number of Dutch inventors applying for patents abroad and the Netherlands experienced pressure from other countries to develop a new patent law (Schippers, 2016).

The patent-free period of the Netherlands occurred around the time of the industrial revolution. The excitement of the industrial revolution caused countries to cooperate more. In 1883, representatives of more than 140 countries met in Paris in an attempt to align all national laws about the protection of industrial property. This led to the Paris Convention for The Protection of Industrial Property (Netherlands Enterprise Agency, 2020). This Convention contains rules concerning patents that all Contracting States must follow. One of these rules is that the states must validate the right of priority. When an inventor has filed a patent application in one of the participating countries, it has a certain period of time to file an application for the same idea in a different country. During this period, the applicant has priority over patents filed by other inventors (World Intellectual Property Organization, n.d.-d). In 1886, the Berne Convention for the Protection of Literary and Artistic works was adopted. This is an agreement on the protection of intellectual property (World Intellectual Property Organization, n.d.-a).

The Netherlands was a participant in both conventions, despite still not having national patent laws. The Dutch government was already criticized by other countries for their lack of legislation during the Paris convention, but during the Berne Convention, the pressure on the

Netherlands became even stronger. Soon after this, the government announced to start working on a patent law. However, the project did not get off the ground quickly. It was 1905 when the second chamber of the government received a proposal and 1910 when the Dutch Patent Act was finally implemented (Schippers, 2016).

From this moment on, there would be a Dutch patent office that would judge patent applications on their novelty, inventiveness, and industrial applicability. The process was complicated and required assessors with specific technical knowledge and experience to pass judgment. The duration of protection patents received was initially 15 years. After the implementation of the Dutch Patent Act, the number of patent applications steadily rose during the years. There was a period of decline during the second world war. After the war the number of applications increased strongly, reaching its height during the sixties and seventies. During this period, the number of yearly patent applications varied from 14.000 to 18.000 (Snethlage, 2016). The Dutch patent office performed very well and was praised by foreign patent institutions (Hoyng, 2016). There were few invalidity proceedings initiated against patents from the Dutch office. Until 1964, the average yearly number of patents that were challenged by infringement proceedings was 2 per 2200 patents (Eskes, Driessen, and Grootoonk, 2015).

2.3.2. International developments in the field of patenting

The growing number of yearly patent applications and a shortage of technical staff caused the patent office to increasingly fall behind on handling applications. Since inventors had to apply for the same invention separately in every country, the question arose whether cooperation between countries would lead to a more productive patent system. In 1947, the International Patent Institution was established. This institution did prior art searches for its member countries Belgium, Luxembourg, France, and the Netherlands. The establishment of the IPI did not solve the capacity problems that the Dutch Patent Office faced (Eskes, Driessen, and Grootoonk, 2015).

In 1963, the Dutch Patent Office made a time-saving change to their patent granting procedure. A large number of patents lapsed shortly after they were granted, possibly because they were not economically relevant anymore. To avoid spending a lot of time on these patents, the examination of all patent applications on novelty, inventiveness, and industrial applicability was postponed. Applications underwent a smaller examination instead, the novelty report, to investigate whether the chances of the inventor receiving a patent were high enough. After this, inventors had seven years to decide whether the invention was useful enough for protection and extensive examination. To improve transparency for third parties, applications were available for inspection 18 months after the application date. The system was successful and 5% of the applications did not make it to the extensive examination. Almost all industrialized countries now use the 18-month term for inspection (Eskes, Driessen, and Grootoonk, 2015).

After the establishment of the International Patent Institution, there were more developments on an international scale. Many treaties were made to improve cooperation between national patent offices. For example, The Strasbourg Agreement of 1971 established the International Patent Classification that is still used to this day (World Intellectual Property

Organization, n.d.-c). In 1973, a radical change happened when fifteen countries signed the European Patent Convention. These countries, including the Netherlands, agreed on the establishment of the European Patent Office. This office would enable inventors to file a patent application and receive patents for all countries participating in the Convention. The European Patent Office started in München and establishments in several cities followed (Netherlands Enterprise Agency). Other countries joined the agreement in the years after its start and there are currently 38 states members of the European Patent Organization (European Patent Office, n.d) The patent granting procedure of the European Patent Office is similar to the procedure of the Dutch Patent Act from 1910. The biggest difference is that the EPO does not offer the option of postponed extensive examination (Eskes, Driessen, and Grootoonk, 2015). After joining the European Patent Convention, the Netherlands also became a member of the World Intellectual Property Organization (WIPO) in 1975 (European Patent Office, n.d.-b).

The European Patent Office immediately was very popular. Therefore, its establishment had consequences for the Dutch Patent Office. After years of success, the number of patent applications filed at the Dutch Patent Office decreased dramatically. In 1975 there were 15.267 applications filed and in 1990 there were 2.991 applications filed. The Dutch Patent Office feared it would not have enough work for the specialized technicians it hired for the judgment of applications if the decrease would continue. A committee that investigated the issue concluded that there must be at least 750 filed applications per year for all office employees to have enough work. The government did not expect the number of applications to stabilize around this level.

2.3.3. The Dutch 1995 patent reform

Despite the decrease of incoming applications, the Dutch government concluded that there still was a demand for a national patent office. A national patent office was expected to have benefits for small and medium-sized enterprises that did not need patents in multiple countries. Besides, all other countries that were a member of the European Patent Organisation had a national patent office. This led to the development of a new law, the Dutch Patent Act 1995, that introduced a new patent granting procedure. The granting procedure was inspired by the Belgian procedure and adopted to be more accessible for applicants (Snethlage, 2016).

Applicants that applied for a patent after 1995 always received a patent as long as they met the formal requirements. There was no longer an extensive examination of the applications on inventiveness and industrial applicability. Patents were available that granted six years of protection and patents that granted 20 years of protection. Applications for the latter option required an examination of the novelty of the invention. Possible infringement cases were handled by the court. Monitoring possible infringements was the responsibility of inventors (Rijksoctrooiwet 1995, 2020).

After the 1995 patent reform, there was a period of uncertainty for the employees of the Dutch Patent Office. Applications that were filed before the implementation of the new law were still handled using the procedure of the Dutch Patent Act from 1910. It was unsure how much time it would take to finish these applications and how long there would be work for the employees of the council that did the extensive examination. In 2004, the last patent was granted that had undergone extensive examination. After this, the council that had once received so much praise was abolished (Eskes, Driessen, and Grootoonk, 2015). However, after the 1995 patent reform, the number of patent applications stabilized. There were 2.651 patent applications applied for at the Dutch Patent Office in 1995. In 2008 the Dutch Patent Act was altered. The patent of six years protection was abolished and applications in English were allowed since the alteration (Snethlage, 2016).

2.4. Academic and practical relevance of the 1995 patent reform

The 1995 patent reform is a relevant topic of study since the reform drastically changed the patent granting process. The patent granting process before the reform included obligatory extensive examination and therefore was quite a strict procedure. The abolishment of this examination led to a simplification of the granting process, which has made filing for a patent more accessible. Inventors might have been more willing to apply for patents after 1995, knowing that the requirements are easier to fulfill. If this is the case, inventors might have filed for patents on inventions that they would not have applied for if the old patent granting process was still used. This would imply that the quality of patent applications may have changed after the patent reform. The goal of the patent reform was to make the patent granting process at the Dutch Patent Office more economically viable. This result has been accomplished. However, if the new granting process has lowered the quality of patents, this may be an unwanted side effect of the reform. If the new granting process has not impacted the quality of patents or even improved the quality of patents, then the conclusion can be made that in the Netherlands extensive examination has not been necessary to ensure that the patents granted are of sufficient quality for a functioning patent granting system. The effects of this reform on patent quality can be relevant for other governments that consider adjusting their patent granting procedure as well. Especially for national patent offices that include extensive examination in the patent granting process, it is useful to study the effects of the reform.

2.5. Similar research on the effects of patent policy reforms

Numerous economists have attempted to measure the effects of patent policy reforms before. De Rassenfosse and Jaffe (2017) analyze the effect of the Patent Law Amendment Act of 1982 on patent quality. The Patent Law Amendment Act of 1982 led to increased patenting fees at the U.S. Patent and Trademark Office, and this resulted in filtering out low-quality patents. Mowery and Ziedonis (2002) analyze the effect of the Bayh-Dole Act, which was implemented in 1980, on the quality and quantity of academic patents in the United States. The results suggest that the patents issued to institutions that started patenting after the implementation of the Bayh-Dole Act are less important and less general than the patents granted before and after 1980 to universities with more experience in patenting. Heikkilä (2017) investigates the effect of the abolition of the short-term patent system in the Netherlands in 2008 on the patent filing activity at the Dutch Patent Office, using a synthetic control method. The results suggest that the abolition of the short-term patent system is associated with a temporary decrease in the level of patent applications. Deng (2007) quantifies the effect of the establishment of the European Patent Office on the private value of patents from France, Germany, and the United Kingdom. He argues that the private value of EPO patents is on average higher than the private value of patents obtained through the national patent office of the three countries studied. Bekkers, Martinelli, and Tamagni (2020) evaluate the impact of an EPO policy change in 2004. They find that after the European Patent Office started to include documents from setting technical standards into the prior art, the patent grant rate was reduced by approximately 19% in some fields. However, the policy did not affect the scope of granted patents. Jaffe (2000) analyses the major changes in patent policy and practice in the United States that have occurred between 1980 and 2000. The results suggest that the changes in the patent system did not affect the innovation process. This could be due to the complexity of measuring the parameters of patent policy, or due to the complexity of getting statistically significant results when multiple things are changing over time. Allred and Park (2007) argue that patent reform can impact different stages of the innovation process in varying ways. Besides, patent reform can have a different effect on innovation in developed economies than it has on innovation in developing economies. In developing economies, patent strength has a negative effect on domestic patent filings and an insignificant effect on R&D and foreign patent filings. In developed economies, patent strength has a positive effect on R&D and domestic patent filings and a negative effect on foreign patent filings.

2.6. Measuring patent quality

Hall, Graham, Harhoff, and Mowery (2004) define criteria for high-quality patents. The invention must be truly new, not obvious, and must have utility. The patent application must disclose enough details about the invention and the description must enable others to implement the invention. There can be little uncertainty over the breadth of the claims of the patent. Different methods can be used to define the quality of patents and patent applications. Trajtenberg (1990) introduces patent counts weighted by citations as possible indicators of the value of innovations. Harhoff, Narin, Scherer, and Vopel (1999) investigate inventions made in the United States and Germany and argue that the higher the economic value estimate of an invention, the more citations the patent received. Hall, Jaffe, and Trajtenberg (2005) find that if a firm's quality of patents increases and the patents receive on average one additional citation, the market value of the firm increases by 3%. Harhoff, Scherer, and Vopel (2003) find a correlation between patent value and citations received from subsequent patents. Besides, they argue that backward citations to the patent applications, patent family size, and successful defenses against opposition and annulment claims are predictors of patent value.

Lanjouw and Schankerman (2004) develop a minimum-variance index of patent quality using four indicators: the number of claims, forward citations to the patent, backward citations to the patent application, and the number of countries in which an invention is patented. They argue that using multiple indicators decreases the measured variance in patent quality. Bessen (2008) argues that when a patent owner pays the yearly renewal fee, this implies that the patent is worth more than the fee. He uses patent renewal data to estimate the value of U.S. patents, controlling for the characteristics of the patent and its owner. Wang, Chiang, and Lin (2010) also use patent renewal decisions as an indicator of patent quality. Chen and Chang (2010) use four patent quality indicators: relative patent position, revealed technology advantage, Herfindahl-Hirschman index of patents, and patent citations. Van Zeebroeck and Van Pottelsberghe de la Potterie (2011) demonstrate that the strategies patent applicants use to draft, file, and manage their applications are positively associated with more valuable patents. Specifically, the number of claims filed, the drafting of priority filings, using the PCT route, and the parents of divisional applications are positively associated with more valuable patents. Squicciarini, Dernis, and Criscuolo (2013) develop a composite indicator of patent quality using forward citations, patent family size, number of claims, generality index, backward citations, and grant lag. All components are given equal importance.

Dang and Motohashi (2015) analyze the quality of patent applications using the patent grant rate and the value of granted patents. They define the patent grant rate as the number of granted patents divided by the number of all patent applications. Low-value patents have a narrow independent claim, which can easily be bypassed by the competition. Higham, De Rassenfosse, and Jaffe (2021) argue that popular post-grant measures of patent quality are often not in agreement as to which are the patents of the highest quality. Moreover, ex-ante characteristics of patents differ significantly in their relationship to post-grant outcomes. The quality of patents can vary Thompson (2016) argues that between 84% and 90% of Switzerland's national patents have a high likelihood of not surviving examination at the European Patent Office.

3. Methodology

To analyze how the quality of patents filed for at the Dutch Patent Office evolved after the 1995 patent reform, this study is based on quantitative research. The lifespan of patents is used as an indicator of their quality. Every year that patents are valid, the owner estimated the value of the patent to be worth more than the annual fee that must be paid to keep the patent valid. Therefore, it is assumed that if a patent has a long lifespan, the patent is of high quality. For the analysis, the dataset on patents from the Dutch patent register is processed in the statistical software program Stata. This program is used to perform simple survival analysis. The event of interest in this survival analysis is the lapsing of patents before their expiration date has passed. The study uses this as an event of interest because if a patent lapses before its expiration date has passed, this can be seen as a failure.

3.1. Data collection

3.1.1. The dataset

The data used is retrieved from the Dutch patent register. This register is a database from the Netherlands Enterprise Agency. It contains information about published patent applications, patent rights, and certificates since 1912. The register is complete and contains information about all patents that the Dutch Patent Office granted. The register is complete, except for patents that are not public. The register is accessible online free of charge and is available in two languages, Dutch and English. On the website, it is stated that the register is updated regularly. The register shows the publication number, publication date, status, IPC code, applicant, and legal type of patents in the database. The status of the patent shows if the patent is still in force, expired, or lapsed (Netherlands Patent Office, n.d.)

The patent reform took place in 1995. To examine how the quality of patents evolved after the reform, data is used from fifteen years after the reform. This includes all patents in the register that were filed for between January 1, 1995, and December 31, 2009. European patents granted for the Netherlands are excluded from the database so that only patents filed at the Dutch Patent Office are included. 28 out of the 34504 patents in the dataset have been renounced. Since it is stated by law that the renunciation date of a patent is equal to its grant date, it is not possible to calculate the lifespan of renounced patents. Therefore, the 28 observations that have a renunciation date are dropped from the dataset. The dataset is exported from the website of The Dutch Patent Office to an Excel file. The variables that are used for the analysis including their definition are listed in table 1.

Table 1. Variables in the original dataset

Variable	Definition
applicationnumber	The application number of a patent, used as an identifier.
filingdate	The filing date of a patent.
lapsedate	The lapse date of patents that lapsed by procedure before the expiration date. For patents that did not lapse by procedure, the variable has no value.
lapsebynonpaymentannualfeedate	The lapse date of patents that lapsed before the expiration date because the owner stopped paying the annual fee. For patents that did not lapse because the owner stopped paying the annual fee, the variable has no value.
lapsebyexpirationdate	The lapse date of patents that lapsed because their expiration date was due. For patents that did not lapse because the expiration the expiration date was due, the variable has no value.
classification	The patent type in IPC classification.
firstapplicantresidencecountry	The country of residence of the first applicant of the patent.

3.1.2. Preparing the dataset for survival analysis

First, the data is prepared so it can be used to perform survival analysis. For survival analysis, there must be a variable that represents the lifespan of each patent. To measure the lifespan of the patents, two observations are needed of each patent: the filing year and the year in which the patent lapsed.

The variable *filingdate* is used to generate a new variable *filingyear* that represents only the year in which each patent was filed instead of including the day and month of filing. Patents in the dataset have three possible causes of lapse and this is represented by three variables in the dataset, as explained in table 1. The variables *lapsedate*, *lapsebynonpaymentannualfeedate* and *lapsebyexpirationdate* are used to generate three new variables *lapsedateyear*, *lapsebynonpaymentannualfeeyear* and *lapsebyexpirationyear* that represent only the year in which each patent lapsed instead of including the day and month of lapse. To create one variable that represents the year a patent lapsed in, no matter the cause of the lapse, the missing observations of *lapsedateyear* are replaced with the values from the other two lapse variables so there is one single variable that has a lapse year observation for each patent. To calculate the lifespan of each patent, a new variable is generated that has values that are calculated by subtracting the year of filing from the year of lapsing, resulting in the number of years that the patent was in force. This variable is given the name *spell* and this is the variable that is used in the survival model.

Since the event of interest is the lapsing of patents, there must be a variable that indicates whether the patent has lapsed during the study period or not. A dummy variable *event* is generated that has value 1 if the patent has lapsed prematurely (not including patents that lapsed because their expiration date was due). If the variable has value 0, the patent is censored. This means that during the observation period the patent was not observed to have lapsed prematurely.

To see whether the quality of patents varies amongst different stages of the post-patent reform period, three dummy variables are generated. *Group1* has value 1 if a patent is filed for between the years 1995 and 1999, *group2* has value 1 if a patent is filed for between the years 2000 and 2004. *group3* if a patent is filed for between the years 2005 and 2009. Moreover, a string variable *group* is generated that indicates to what group every patent belongs.

To control for whether the residence country of the first applicant is the Netherlands, the string variable *firstapplicantresidencecountry* is altered so that it becomes a numeric dummy variable with value 1 if the residence country of the first applicant is the Netherlands and 0 if the first applicant resides in another country. The variable is renamed *dutch*. To control for the IPC section of patents, eight dummy variables are generated, using the variable *classification,* that represent whether the patent is classified in section A, B, C, D, E, F, G, or H. Several patents are assigned to multiple classes or groups. Often these are in the same section, but in some cases, the patents are assigned to classes or groups in different sections. If a patent has more than one IPC code, the section letter of the first code is used.

Since Stata does not automatically recognize survival-time data, it is declared in the program that survival-time data is used. Stata is informed of the central variables and their role in the analysis. It is declared that the time variable is *spell*. The failure variable, in other words, the variable that declares whether the event of interest has occurred, is *event*. It is declared that *group* is the group variable, resulting in separate results for the different stages of the post-patent reform period. After declaring to Stata that that survival-time data is used, the program drops four observations in the data set because they end before the study period. As a result, there are 34472 subjects used in the analysis.

3.2. Data analysis

3.2.1. Survival analysis

Survival analysis is a method to measure the time to an event of interest. This type of research cannot be done using an Ordinary Least Squares regression since in linear regression, the residuals $\in_j$ are assumed to be distributed normally. In other words, it is assumed that time conditional on x_j follows a normal distribution:

$$time_j \sim \mathrm{N}(\beta_0 + \beta_1 x_j, \sigma^2), \qquad j = 1, \dots, 5$$

This assumption cannot be made for many event data. The distribution for time to an event cannot be expected to always follow a normal distribution. For example, if there is an event with a prompt risk of taking place that is consistent over time, the distribution of time would be exponential. In the case of a serious surgical procedure, the distribution might have two modes: some patients may die after the procedure, but some patients may die if the disease returns later. Linear regression is not robust to normal distribution violations like bimodal distribution. Survival analysis does not rely on an assumption about the distribution of event times (Cleves, Gould, Gutierrez, and Marchenko, 2008).

Survival analysis uses a survivor function *S(t)*. Assume T is a random variable that is not negative and indicates the time to an event of interest. In survival analysis jargon, the event of interest is called the failure. The survivor function describes the probability that failure does not occur before time *t* and is the reverse cumulative distribution function of T:

$$S(t) = 1 - F(1) = \Pr(T > t)$$

The hazard function *h(t)* describes the rate of failure. It is the chance that the failure event takes place in a certain time interval, conditional upon the subject's survival to the start of that interval and divided by the width of the interval. The hazard rate can vary over time and is determined by the process that is analyzed (for example, surgery or drug addiction). You can interpret the hazard function by saying that if the hazard rate would continue for one period of time, this is the number of failures you would expect.

$$h(t) = \lim_{\Delta t \to 0} \frac{\Pr(t + \Delta t > T > t | T > t)}{\Delta t} = \frac{f(t)}{S(t)}$$

The cumulative hazard function *H(t)* describes the total risk that has been accumulated at the time of *t*. An interpretation of this function is that it monitors the number of times you would expect to observe failures over a specific period if in the case that the failure event can happen more than once.

$$H(t) = \int_0^t h(u)du$$

$$H(t) = \int_0^t \frac{f(u)}{S(u)} du = -\int_0^t \frac{1}{S(u)} \left\{ \frac{d}{du} S(u) \right\} du = -ln\{S(t)\}$$

In a data analysis, not all observations may have experienced failure before the study period has ended. In this case, it is not known whether a failure has occurred for all observations, it might be possible that an observation experiences failure after the study period. That is where censoring is useful: using a dummy variable that has value 1 if a failure occurred during the study period and 0 if there has not. The most common form of censoring is right censoring, which is used when subjects are not observed after the study period ends (Cleves, Gould, Gutierrez, and Marchenko, 2008).

The Kaplan-Meier estimate is a non-parametric statistic that can be used to estimate survival over time. The Kaplan-Meier survival curve is characterized by the probability of surviving in a specified length of time while time is considered in numerous small intervals. The Kaplan-Meier estimate relies on three assumptions. It is assumed that censored subjects have the same probability to survive as the subjects that continue to be studied. Besides, it is assumed that the chances of survival are equal for subjects recruited late and early in the study. Lastly, it is assumed that the event takes place at the time that is specified. The Kaplan-Meier estimate of the survival curve is calculated by the following formula:

$$S_t = \frac{Number\ of\ subjects\ living\ at\ the\ start - Number\ of\ subjects\ died}{Number\ of\ subjects\ living\ at\ the\ start}$$

Subjects that are censored are not counted in the denominator since they are not deemed to be at risk. A graph can be plotted with the estimated survival probabilities on the Y-axis and the time past after entry into the study on the X-axis. The graph will be drawn as a series of declining horizontal steps. The estimated survival curves of two different groups can be compared statistically with a log-rank test. The null hypothesis of this test is that there is no difference regarding survival amongst the two interventions (Kumar Goel, Khanna and Kishore, 2010).

In a log-rank test, the expected number of events in both groups is calculated, E_1 and E_2. The expected number of events in each group are O_1 and O_2.

$$Log - rank\ test\ statistic = \frac{(O_1 - E_1)^2}{E_1} + \frac{(O_2 - E_2)^2}{E_2}$$

The null hypothesis of the log-rank test is that the groups are equal in respect of survival. If the test statistic value is larger than the critical value in a chi-square table for the degree of freedom 1, then we can say there is a significant difference between the groups in respect of survival (Kumar Goel, Khanna, and Kishore, 2010).

In survival analysis, it is also possible to estimate a cumulative hazard function. This is estimated as minus the natural logarithm of the product-limit estimate of the survivor function (Peterson, 1977). The Nelson-Aalen estimate gives results that are asymptotically equivalent to the Kaplan-Meier estimate. Therefore, it is also a step function.

$$\widehat{H}_{NA}(t) = \sum_{\frac{i}{t_i}<t} \left(\frac{d_i}{n_i}\right)$$

(Colosimo, Ferreira, Oliveira, and Sousa, 2002).

Several distributions can be used as a model for the parametric estimation of duration data. If a sample contains both very long and very short durations, the Weibull distribution may be an adequate description of the data. This distribution has two parameters ($\gamma > 0$ and $\alpha > 0$) and the following hazard function:

$$\lambda(t) = \gamma \alpha t^{\alpha-1}$$

In this function, t represents survival time and $\lambda(t)$ represents an unknown hazard function. The parameter γ can depend on explanatory variables. If $\alpha > 1$, the hazard function is increasing in duration, if $\alpha < 1$ it is decreasing, and if $\alpha = 1$ it is constant. Duration dependence is not dependent on the value of γ. The survival function under the Weibull distribution is as follows:

$$S(t) = \exp\left(-\gamma t^{\alpha}\right)$$

If the family of duration distributions under consideration has been specified, the data distribution is known up to a vector of parameters. The likelihood function is the joint probability distribution of the sample as a function of these parameters. As mentioned, for the Weibull distribution the parameters are γ and α. The parameters are often estimated by maximum likelihood. Maximum likelihood estimation is used for parametric regression survival-time models.

The log-likelihood function for the Weibull distribution is:

$$L(\gamma, \alpha) = \sum_{i=1}^{n} d_i ln\gamma + \sum_{i=1}^{n} d_i ln\alpha + (\alpha - 1)\sum_{i=1}^{n} d_i ln t_i - \gamma \sum_{i=1}^{n} t_i^{\alpha}$$

Assume that $d_k = 1$ if the kth spell is uncensored and $d_k = 0$ if censored. If censoring is ignored, this can lead to bias in the estimated hazard or overstatement of the conditional probability of the ending of a spell (Kiefer, 1988).

3.2.2. Nonparametric estimation

First, the nonparametric estimation is started by the generation of descriptive statistics, including frequency plots of the filing year and spell of patents in the dataset. There are separate summary statistics generated for the patents filed between 1995 and 1999 (group 1), 2000 and 2004 (group 2), and 2005 and 2009 (group 3). The total time at risk, the number of subjects, the incident rate, and the survival time of the patents are inspected. Then a smoothed hazard estimate curve is generated to analyze the rate of patent lapsing before the expiration date and a Nelson-Aalen cumulative hazard estimate curve to inspect the accumulated total risk at different times. Thereafter, a Kaplan-Meier survival estimate curve and a Kaplan-Meier survival estimate curve for the three filing year groups separately are generated. Subsequently, it is analyzed whether the survival estimates of the three separate groups are similar. To statistically compare the survival estimates of the three groups, a log-rank test is performed, and the log-rank test statistic is used to detect if there is a significant difference between the estimated survival curves. The null hypothesis of the log rank test is that the estimated survival curves of group 1, group 2, and group 3 are equal.

3.2.3. Parametric estimation

For parametric estimation, four regressions are run based on a survival-time model with a Weibull distribution. The independent variables of the first model are the three *group* variables. In the second model, the dummy variable *dutch* is added and in the third model the *category* variables. The fourth model includes two interaction variables, *group1*dutch* and *group2*dutch.* The dummy variables for *group3* and *categoryH* are not included in the models to avoid a dummy trap. The dependent variable of all analyses is the duration of patent survival. Stata is informed that the output of the analysis must report coefficients, not hazard ratios. Thereafter, the likelihood ratio chi-square test statistic is observed to test the overall model fit relative to a normal model. The p-value will indicate whether the model overall is fitting the data significantly better than a normal model. Thereafter, the individual coefficients are observed to determine their significance, and it is interpreted what they mean. The coefficients are interpreted as the predicted change in log hazard.

4. Results

4.1. nonparametric estimation

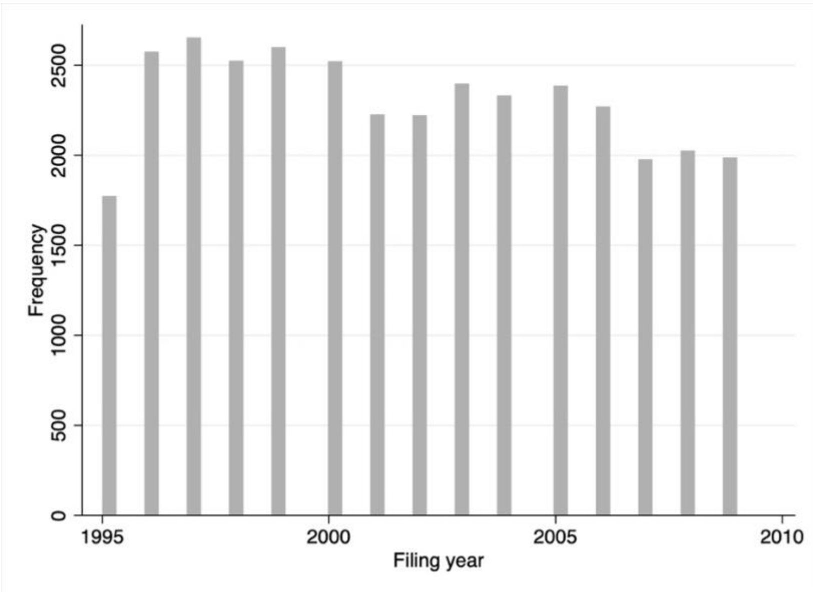

Figure 1 Frequency plot of the filing year of patents (variable filingyear)

Figure 1 displays that the smallest number of patents in the dataset were filed in 1995. The most frequent filing year of patents is 1997. The number of patents per filing year has fluctuated between 1997 and 2009 but a decreasing trend is visible. Figure 2 displays that very few patents in the dataset have lapsed during the first or second year after filing. Most patents lapse after four, five, or six years. 740 of the patents that lapse after six years are six-year protection patents that lapsed because the expiration date was due. The number of patents that lapse after a certain lifespan is reached shows a decreasing trend the longer the lifespan of the patents.

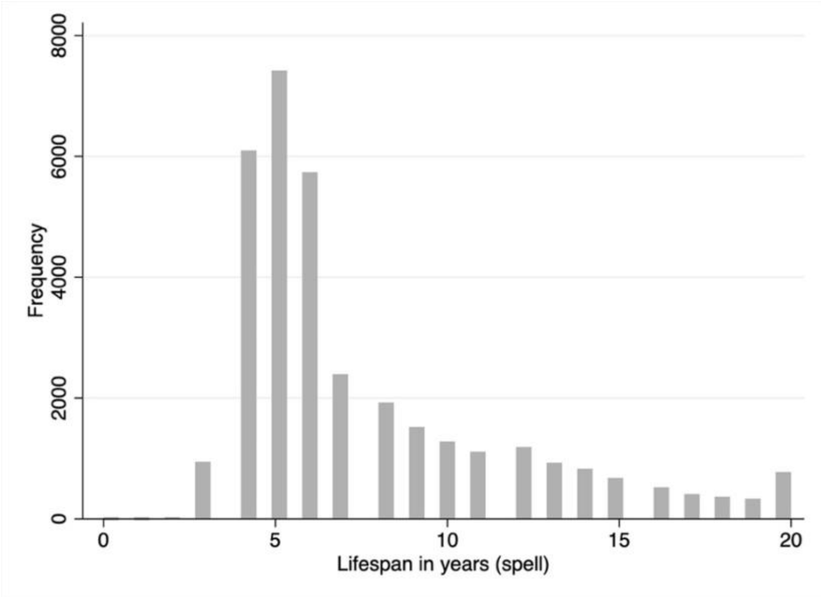

Figure 2 Frequency plot of the lifespan of patents in years (variable spell)

Table 2 Summary statistics for three filing year groups separately

group	time at risk	incidence rate	no. of subjects	survival time 25%	survival time 50%	survival time 75%
1	95053	0.122	12127	5	6	9
2	90692	0.120	11699	5	6	10
3	75595	0.114	10646	4	6	10
total	261340	0.119	34472	5	6	10

The summary statistics describe the total time at risk of each group, which in this case represents the cumulative life spans of patents in the sample. The cumulative life span of patents is highest amongst the patents that were filed for between 1995 and 1999. This is also the period with the most subjects, in other words, the period during which the most patents were filed. Moreover, the incident rate of lapsing before the expiration date is highest amongst patents in group 1. Equal in all three groups, 50 percent of the patents survive for six years. 75 percent of the patents in group 1 survives for nine years or longer, while 75 percent of the patents in groups 2 and 3 survive for 10 years or longer.

Figure 3 displays what the estimated hazard curve looks like if the curve is smoothed. It shows that the risk that a patent lapses prematurely increases during the first years of the lifespan of a patent. The risk reaches a peak around eight years after the filing year of a patent. After this, the risk of lapsing decreases at an evenly pace until around twelve years after the filing year of a patent. After twelve years, there is a small increase in the risk of lapsing. After this small increase, the risk decreases again but with a smaller decrease rate than before. The curve implies that if a patent is still in force around eight years after the filing year, the chances of it lapsing before the expiration date decrease every following year, except for a small increase of risk around twelve years after the filing year.

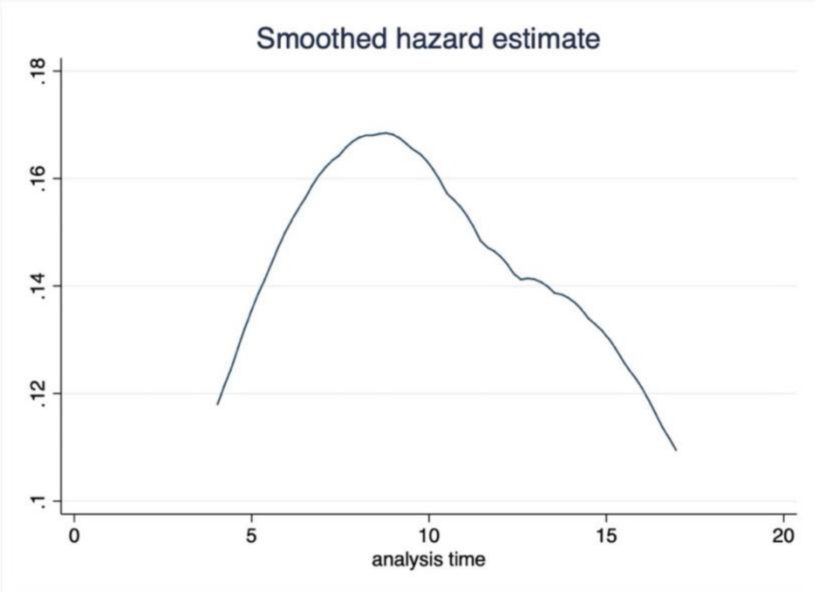

Figure 3 Smoothed estimated hazard curve

The Nelson-Aalen cumulative hazard estimate in figure 4 displays the total amount of risk that has been accumulated at different times of the analysis. Moreover, it shows the expected number of patents that lapse before their expiration date is due if it were possible that patents lapse more than once. The estimated curve is slightly convex. This implies that the accumulated risk of lapsing before the expiration date experiences a stronger increase during the first years of the lifespan of a patent and a smaller increase during later years of the lifespan of patents.

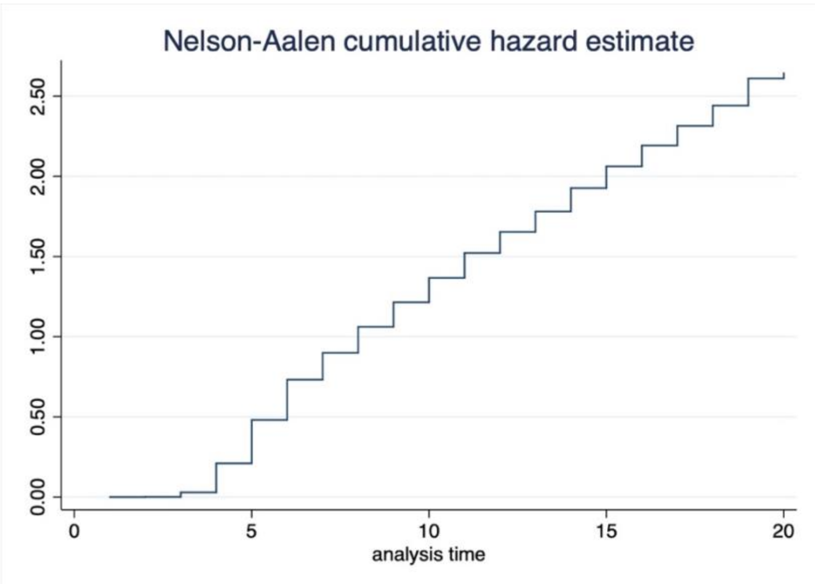

Figure 4 Nelson-Aalen estimated cumulative hazard curve

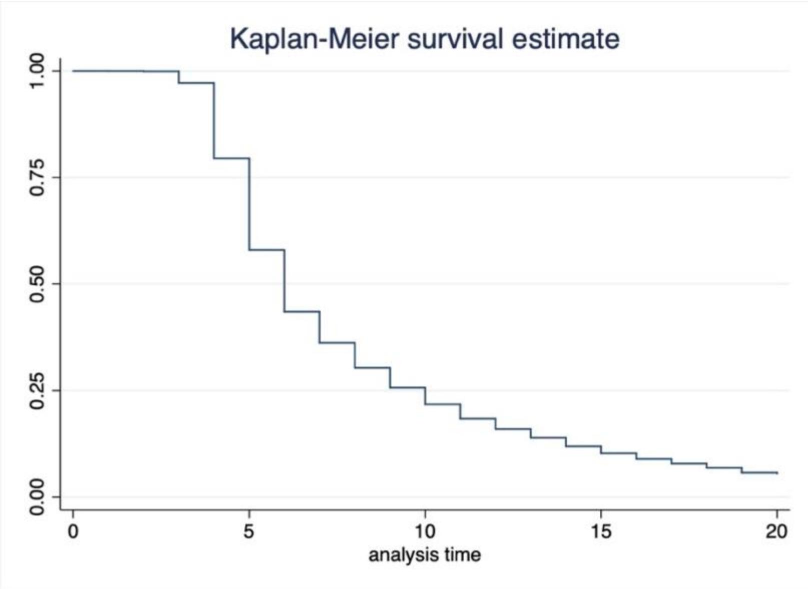

Figure 5 Kaplan-Meier estimated survival curve

The Kaplan-Meier estimated survival curve in figure 5 is convex and shows a strong decrease in the first years of the lifespan of patents and a smaller decrease in the later years of the lifespan of patents. The decrease rate grows smaller around eight years after the filing year of the patent. This implies that many patents experience lapsing before their expiration date during the first eight years of their lifespan. After eight years of the patent lifespan, lapsing before the expiration date occurs less often.

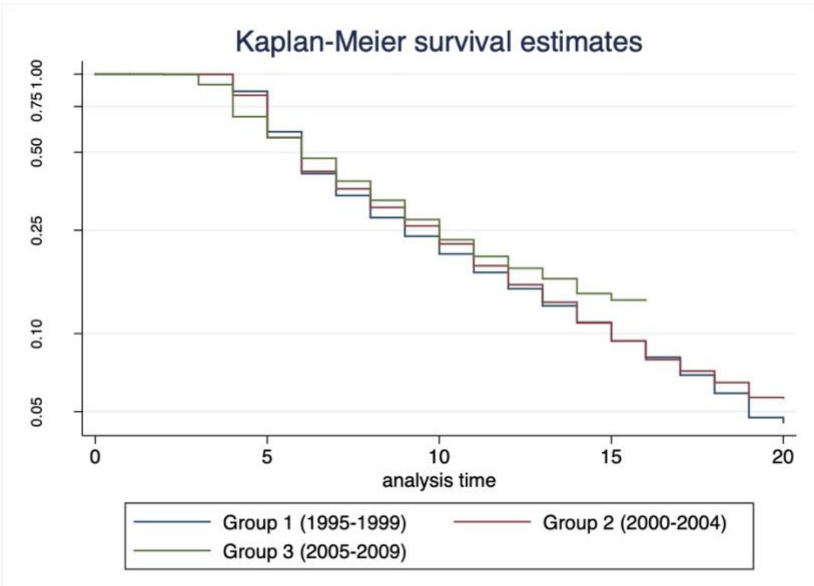

Figure 6 Kaplan-Meier estimated survival curves by filing year, Y-axis in log scale

Figure 6 displays the Kaplan-Meier estimated survival curves for the three patent filing year groups separately. The Y-axis is of the graph is set in log scale for visually clearer patterns. All three survival curves follow a similar path, with a strong decrease in the first years of the lifespan of patents and a smaller decrease in the later years of the lifespan of patents. This is similar to the Kaplan-Meier estimated survival curve in figure 5. It appears that there are small differences between the survival estimates of the three separate groups. The curve of group 3 has the steepest slope and decreases the most during the first years of the patent lifespan.

After five years, it is passed by the curves of groups 1 and 2. After 15 years past the filing year of patents, the curve of group 3 finishes while the curves of groups 1 and 2 continue decreasing to a lower level. However, besides these small differences, the three Kaplan-Meier estimated survival curves appear to be similar.

Table 3 Log-rank test for equality of survival functions

Group	Events observed	Events expected
1	11576	11459.52
2	10848	10867.53
3	8625	8721.95
total	31049	31049.00

The log-rank test for equality of survival functions shows that the observed number of patents lapsing before the expiration date amongst each group is very similar to the expected number of lapsed patents. The P-value of the log-rank test is 0.2345. Since 0.2345 is bigger than 0.050, there is no evidence to reject the hypothesis that the three survival curves are equal.

4.2. parametric estimation

Table 3 displays summary statistics for the variables used to perform a regression analysis. The average lifespan of patents is 7.580 years. This is in line with the results of the non-parametric estimation. For instance, the smoothed estimated hazard curve in figure 1 that displays that the risk of lapsing before the expiration date is highest around eight years after the filing year. This is an indication of the reliability of the parametric estimation. 90.1 percent of the patents in the dataset lapse before their expiration date is due. Moreover, the summary statistics show that the most popular patent sections are section A and section B, human necessities and performing operations and transporting. The least popular category is section D, textiles and paper.

Table 3 Summary statistics for regression variables

Variable	Description	Mean	Standard deviation
Spell	Lifespan of the patent in years	7.580	4.124
Event	Dummy variable that takes value 1 if the patent lapsed before the expiration date was due	0.901	0.300
Dutch	Dummy variable that takes value 1 if the country of residence of the first applicant is the Netherlands	0.800	0.400
Group1	Dummy variable that takes value 1 if the patent was filed for between the years 1995 and 1999	0.352	0.478
Group2	Dummy variable that takes value 1 if the patent was filed for between the years 2000 and 2004	0.339	0.474
Group3	Dummy variable that takes value 1 if the patent was filed for between the years 2005 and 2009	0.309	0.462
CategoryA	Dummy variable that takes value 1 if the patent is categorized in IPC section A	0.203	0.402
CategoryB	Dummy variable that takes value 1 if the patent is categorized in IPC section B	0.241	0.428

CategoryC	Dummy variable that takes value 1 if the patent is categorized in IPC section C	0.041	0.198
CategoryD	Dummy variable that takes value 1 if the patent is categorized in IPC section D	0.005	0.071
CategoryE	Dummy variable that takes value 1 if the patent is categorized in IPC section E	0.086	0.280
CategoryF	Dummy variable that takes value 1 if the patent is categorized in IPC section F	0.070	0.256
CategoryG	Dummy variable that takes value 1 if the patent is categorized in IPC section G	0.086	0.280
CategoryH	Dummy variable that takes value 1 if the patent is categorized in IPC section	0.051	0.220

Table 4 parametric survival-time model (Weibull distribution) regression results

Variable	**Hazard of lapsing (1)**	**Hazard of lapsing (2)**	**Hazard of lapsing (3)**	**Hazard of lapsing (4)**
Group1	-0.052*** (0.014)	-0.029** (0.014)	-0.167*** (0.015)	-0.358*** (0.033)
Group2	-0.054*** (0.014)	-0.044*** (0.014)	-0.123*** (0.015)	-0.150*** (0.033)
Dutch		0.381*** (0.014)	0.322*** (0.015)	0.219*** (0.028)
Group1*Dutch				0.236*** (0.037)
Group2*Dutch				0.030 (0.037)
CategoryA			0.725*** (0.017)	0.723*** (0.017)
CategoryB			0.656*** (0.017)	0.656*** (0.017)
CategoryC			0.414*** (0.030)	0.415*** (0.030)
CategoryD			0.659*** (0.079)	0.664*** (0.079)
CategoryE			0.554*** (0.023)	0.553*** (0.023)
CategoryF			0.516*** (0.024)	0.516*** (0.024)
CategoryG			0.665*** (0.022)	0.663*** (0.022)

Notes: This table includes the coefficients of four parametric survival-time model regression analyses with a Weibull distribution. The dependent variable of each model is the hazard that a patent lapses before its expiration date is due. Standard errors are displayed between brackets. The number of stars displayed are based on the p-values of a two-tailed t-test.
*** Significance at 1 percent level,
** Significance at 5 percent level,
* Significance at 10 percent level.

The P-values of all four models in table 4 are significant at 1 percent level. This means the four models overall are a significant fit to the data relative to a normal model. The coefficients of the variables represent the predicted change in log hazard. In the first model, the coefficients of *group1* and *group2* represent a negative effect. This indicates that the year patents were filed may reduce the hazard of lapsing before the expiration date to a varying degree. The coefficients of model 1 imply that the hazard is lowest for the patents that were filed between 1999 and 2004, but the difference is very small. This is in line with the results of the log-rank test in table 3, which imply that there is no significant evidence that the separate survival curves of the three groups are not equal. In the second model, the coefficients for *group1* and *group2* are still negative and significant. However, the difference between the coefficients is slightly bigger in this model than in the first model. The coefficient for *dutch* is positive and significant. This implies that patents of which the residence country of the first applicant is the Netherlands, have a higher risk of lapsing before the expiration date.

In the third model, the signs of the coefficients of the variables *group1, group2* and *dutch* have not changed. IPC section variables all have positive coefficients. This implies that the IPC section a patent falls under can have a hazard increasing impact. The results suggest that patents categorized in section A have the most increased risk of lapsing before the expiration date and patents in section C have the smallest increased risk of lapsing before the expiration date. In the fourth model, the signs of the coefficients of the variables have not changed compared to the third model. However, in the third model, the effect of *group1* and *group2* have been underestimated and the effect of *dutch* has been overestimated. The coefficients of the IPC category variables in model four are very similar to the coefficients of these variables in the third model. The coefficient of the interaction variable *group1*dutch* is positive and significant. This implies that the hazard of lapsing is higher for patents filed between 1995 and 1999 of which the residence country of the first applicant is the Netherlands. However, the interaction variable *group2*dutch* is not significant.

5. Discussion

5.1. Conclusion

In this paper, the effect of abolishing extensive research as a part of the patent granting procedure is investigated by studying the Dutch 1995 patent reform. The research question is: "*How did the quality of patents filed for at the Dutch Patent Office evolve after the 1995 patent reform?*". To answer the research question, a survival model is used which estimates the hazard of patent lapsing since the grant date as a function of three dummy variables that describe whether a patent was filed for between 1995 and 1999, 2000 and 2004 or 2005 and 2009. This is followed by a parametric survival-time model regression analysis with dummy variables to control for the location of the first author of the patent and the IPC section of the patent is presented. The average lifespan of the patents is 7.580 years and 90.1 percent of the patents in the study lapse before their expiration date is due. The results of a log-rank test for equality of survival functions do not provide evidence to reject the null hypothesis that the three survival curves are equal. The conclusion is that in the years after the 1995 patent reform, the quality of patents, represented by their survival time, did not change significantly. Besides, it can be concluded that the year in which patents were filed may reduce the hazard of lapsing before the expiration date. If the residence country of the first applicant is the

Netherlands, patents have an increased hazard of lapsing before the expiration date. Moreover, the IPC section a patent falls under may have a hazard increasing impact. Patents categorized in section A have the most increased hazard of lapsing before the expiration date and patents in section C have the smallest increased hazard of lapsing before the expiration date. There may be an increased hazard of lapsing for patents filed between 1995 and 1999 of which the residence country of the first applicant is the Netherlands. There is no significant interaction effect found for patents filed between 2000 and 2004 of which the residence country of the first applicant is the Netherlands.

5.2. Internal validity

To draw conclusions correctly, the research must be internally valid. This means that the method used is a correct and fitting method to draw conclusions. The dataset used is complete and a good representative for patent grants during the study period since it includes all granted patents that public and filed for at the Dutch Patent Office between 1995 and 2009. The research uses the lifespan of patents as an indicator of their quality. The life span of patents has been used before as an indicator and has gained widespread acceptance as a patent quality measurement (Bessen, 2008; Wang, Chiang, and Lin, 2010). Survival analysis is a fitting method for analyzing event data (Cleves, Gould, Gutierrez, and Marchenko, 2008).

However, during the survival analysis, Stata dropped four variables because they ended before the study period. This means that there were four patents included in the original dataset that did not belong. Moreover, 28 patents are excluded from the dataset because the patents have a renunciation date, and it is not possible to calculate the lifespan of these patents. However, if a patent is renounced, this might be associated with its quality. One would not expect a patent owner to renounce a patent of very high quality. Therefore, the exclusion of these patents may impact the results. Another threat to internal validity is omitted variable bias. This occurs when a statistical model leaves out one or more variables that influence both the dependent and the independent variable. The regression model may be biased. An example of a variable that might have been a good addition to the model is the size of the company that filed for the patent. Whether a company is small or big may influence the hazard of lapsing before the expiration date and may influence if the residence country of the first applicant is the Netherlands.

5.3. External validity

For a study to be externally valid, it must be possible to generalize the findings to different situations and settings. The findings of this study are not fully externally valid. The study focuses on a specific patent granting reform that took place in the Netherlands. The results of the study do not completely represent what the effects of abolishing extensive examination as a part of the patent granting process will be if other countries or states implement this policy. The study is exclusively representative of countries or states that are similar to the Netherlands in respect of innovation and economic climate. Examples of characteristics that must be somewhat similar are gross domestic product and research and development spending.

Besides, it is important to note that the Dutch Patent Office is not the only office that grants patents that are valid in the Netherlands. Since inventors who want to receive patents that are available in multiple countries will apply at the European office, this may have an impact on the average characteristics of patents that are filed for at the Dutch office. The results are likely to be most accurate for member countries of the European Patent Organization that also still have a national patent office where applications can be submitted.

5.4. Limitations

This research has several limitations. The aim of the thesis is to investigate how the quality of patents filed for at the Dutch Patent Office evolved after the Dutch 1995 patent reform. The analyses examine whether there are significant differences in patent quality during three post-reform periods. Due to the lack of data on patents that are filed before 1995, this study cannot compare the characteristics of patents that are filed before and after the reform. As a result, this study cannot make claims on the direct effects of the reform. Moreover, the dataset includes the basic information on each patent. If the data included more specific characteristics, there would have been more variables to control for in the regression. Besides, this study does not provide information on why patent holders who decide to let the patent for their invention lapse choose to do so. Furthermore, the generalizability of the results is limited because the study focuses on a specific reform in the Netherlands.

5.5 Recommendations

To draw stronger conclusions about the effects of policy reform, further research should use data from both before and after the event. In addition, further research is needed to establish whether the attitude towards patenting has changed amongst inventors because of the reform. It would be especially relevant to investigate if their willingness to apply at the Dutch patent office has changed. It may also be useful to investigate why patent holders who decide to let the patent for their invention lapse choose to do so. For this, it must be possible to contact inventors that were professionally active in the years before and after the reform. Moreover, further studies should take into account characteristics of the economic climate during the study period. The state of the economy could influence innovation and the quality of patents and would therefore be relevant to consider.

Bibliography

Allred, B.B. and Park, W.G. (2007). Patent rights and innovative activity: evidence from national and firm-level data. *Journal of International Business Studies,* 38, 878-900

Andries, P. and Faems, D. (2013). Patenting activities and firm performance: does firm size matter? *Journal of Product Innovation Management, 30*(6), 1089-1098

Bekkers, R., Martinelli, A. and Tamagni, F. (2020). The impact of including standards-related documentation in patent prior art: evidence from an EPO policy change. *Research Policy, 49*(7), 1-17.

Bessen, J. (2008). The value of U.S. patents by owner and patent characteristics. *Research Policy, 37*(5), 932-945.

Chen, Y. and Chang, K. (2010). The relationship between a firm's patent quality and its market value – the case of US pharmaceutical industry. *Technological Forecasting and Social Change, 77*(1), 20-33

Cleves, M., Gould, W., Gutierrez, R. and Marchenko, Y. (2008). *An Introduction to Survival Analysis Using Stata, Second Edition*. Stata Press

Colosimo, E., Ferreira, F., Oliveira, M. and Sousa, C. (2002). Empirical comparisons between Kaplan-Meier and Nelson-Aalen survival function estimators. *Journal of Statistical Computation and Simulation, 72*(4), 299-308

Dang, J. and Motohashi, K. (2015). Patent statistics: a good indicator for innovation in China? Patent subsidy program impacts on patent quality. *China Economic Review, 35*, 137-155

De Rassenfosse, G. and Jaffe, A.B. (2017). Are patent fees effective at weeding out low-quality patents? *Journal of Economics and Management Strategy, 27*(1), 134-148.

Deng, Y. (2007). The effects of patent regime changes: A case study of the European Patent Office. *International Journal of Industrial Organization, 25*(1), 121-138

European Patent Office. (n.d.). *EPO - Member states of the European Patent Organisation*. Retrieved May 8, 2021, from https://www.epo.org/about-us/foundation/member-states.html

European Patent Office. (2020, July 1). Rule 28 – Exceptions to patentability - The European Patent Convention, Implementing Regulations – to the Convention on the Grant of European Patents, Part II – Implementing Regulations to Part II of the Convention, Chapter V – Biotechnological inventions. European Patent Organization. https://www.epo.org/law-practice/legal-texts/html/epc/2016/e/r28.html

Eskes, C., Driessen, J., Grootoonk, R. (2015). De Octrooiraad: van begin tot einde. *Van achterhoede naar spitspositie als het gaat om octrooien.* Agentschap NL, Ministry of Economic Affairs

Gambardella, A., Giuri, P. and Luizzi, A. (2007). The markets for patents in Europe. *Research Policy, 36*(8), 1163-1183.

Gans, J., Hsu, D. and Stern, S. (2008) The Impact of Uncertain Intellectual Property Rights on the Market for Ideas: Evidence from Patent Grant Delays. *Management Science*, 54(5), 982-997.

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

Hall, B., Graham, S. Harhoff, D. and Mowery, D. (2004). Prospects for improving U.S. patent quality via postgrant opposition. *Innovation Policy and the Economy, 4*, 115-143

Hall, B., Jaffe, A. and Trajtenberg, M. (2005). Market value and patent citations. *RAND Journal of Economics, 36*(1), 16-38.

Heikkilä, J. (2017). The Relationship between Patent and Second Tier Patent Protection: The Case of the Dutch Short-Term Patent System Abolition. Retrieved May 25, 2021 from http://dx.doi.org/10.2139/ssrn.2958107

Higham, K., De Rassenfosse, G. and Jaffe, A.B. (2021). Patent quality: towards a systematic framework for analysis and measurement. *Research Policy, 50*(4), article 104219

Hoyng, W. (2016). 100 jaar Rijksoctrooiwet in de polder. *Terugblik in vogelvlucht als het gaat om octrooien.* Agentschap NL, Ministry of Economic Affairs

Jaffe, A. (2000). The U.S. patent system in transition: policy innovation and the innovation process. *Research Policy, 29*(4-5), 531-557

Kiefer, N. (1988). Economic Duration Data and Hazard Functions. *Journal of Economic Literature, 26*(2), 646-679.

Kumar Goel, M., Khanna, P. and Kishore, J. (2010). Understanding survival analysis: Kaplan-Meier estimate. *International Journal of Ayurveda Research, 274-278.*

Lanjouw, J. and Schankerman, M. (2004). Patent quality and research productivity: measuring innovation with multiple indicators. *The Economic Journal, 114*(495), 441-465

Marco, A., Sarnoff, J. and DeGrazia, C. (2019). Patent claims and patent scope. *Research Policy, 48*(9), 103790

Merriam-Webster. (n.d.). *Patent*. The Merriam-Webster.Com Dictionary. Retrieved May 15, 2021, from https://www.merriam-webster.com/dictionary/patent

Mowery, D. and Ziedonis, A. (2002). Academic patent quality and quantity before and after the Bayh-Dole act in the United States. *Research Policy, 31*(3), 399-418.

Netherlands Enterprise Agency. (2021, March 19). *Disputes & advice: nullification of a patent*. https://english.rvo.nl/information/patents-intellectual-property/you-own-a-patent/disputes-advice/nullfication

Netherlands Enterprise Agency. (2020, January 17). *Geschiedenis van octrooien*. https://www.rvo.nl/onderwerpen/innovatief-ondernemen/octrooien-ofwel-patenten/over-octrooicentrum-nederland/octrooigeschiedenis/geschiedenis-van-octrooien

Netherlands Enterprise Agency. (n.d.-a). *How to apply for a patent*. Retrieved May 25, 2021, from https://english.rvo.nl/information/patents-intellectual-property/how-to-apply-for-patent

Netherlands Enterprise Agency. (n.d.-b). *Tarievenoverzicht octrooien*. Retrieved June 6, 2021, from https://www.rvo.nl/onderwerpen/innovatief-ondernemen/octrooien-ofwel-patenten/octrooi-merk-model/octrooirecht/tarievenoverzicht

Netherlands Enterprise Agency. (n.d.-c). *You own a patent*. Retrieved May 25, 2021, from https://english.rvo.nl/information/patents-intellectual-property/you-own-a-patent

Netherlands Patent Office. (n.d.). BPP eRegister. Retrieved June 5, 2021, from https://mijnoctrooi.rvo.nl/fo-eregister-view/

Peterson, A. (1977). Expressing the Kaplan-Meier Estimator as a Function of Empirical Subsurvival Functions. *Journal of the American Statistical Association*, *72*(360a), 854-858.

Rijksoctrooiwet 1995. (2020, April 1). Ministry of the Interior and Kingdom Relations. https://wetten.overheid.nl/BWBR0007118/2020-04-01

Schippers, H. (2016). Worstelen met octrooien, de voorgeschiedenis van de octrooiwet van 1910. *Terugblik in vogelvlucht als het gaat om octrooien.* Agentschap NL, Ministry of Economic Affairs

Snethlage, A. (2016). De totstandkoming van de Rijksoctrooiwet 1995, *Terugblik in vogelvlucht als het gaat om octrooien.* Agentschap NL, Ministry of Economic Affairs

Squicciarini, M., H. Dernis and C. Criscuolo. (2013). Measuring Patent Quality: Indicators of Technological and Economic Value. *OECD Science, Technology and Industry Working Papers*, No. 2013/03, OECD Publishing, Paris

Thompson, M.J. (2016). Measuring patent quality: a claim and search report approach. *World Patent Information, (45)*, 47-54

Trajtenberg, M. (1990). A penny for your quotes: patent citations and the value of innovations. *RAND Journal of Economics, 21*(1), 172-187

US Supreme Court. (n.d.). Diamond v. Chakrabarty, 447 U.S. 303 (1980). Justia Law. Retrieved June, 26, 2021, from https://supreme.justia.com/cases/federal/us/447/303/

Van Zeebroeck, N., and Van Pottelsberghe de la Potterie, B. (2011). Filing strategies and patent value. *Economics of Innovation and New Technology, 20*(6), 539-561

Wang, JC., Chiang, Ch. & Lin, SW. (2010). Network structure of innovation: can brokerage or closure predict patent quality? S*cientometrics 84*, 735–748

World Intellectual Property Organization. (n.d.-a). *Berne Convention for the Protection of Literary and Artistic Works*. Retrieved May 8, 2021, from https://www.wipo.int/treaties/en/ip/berne/

World Intellectual Property Organization. (n.d.-b). *Frequently Asked Questions*. Retrieved May 25, 2021, from https://www.wipo.int/classifications/ipc/en/faq/

World Intellectual Property Organization. (n.d.-c). *Information by Country: Netherlands*. World Intellectual Property Organization. Retrieved May 15 2021, from https://www.wipo.int/members/en/details.jsp?country_id=130

World Intellectual Property Organization. (n.d.-d). *Summary of the Paris Convention for the Protection of Industrial Property (1883)*. Retrieved May 7, 2021, from https://www.wipo.int/treaties/en/ip/paris/summary_paris.html

World Intellectual Property Organization (2020). *World Intellectual Property Indicators 2020*. Geneva: World Intellectual Property Organization.