Patent Technological Diversity and Examination Outcomes in China

by

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Author Declaration

I hereby declare that I am the sole author of this thesis. This is a true copy of the thesis, including any required final revisions, as accepted by my examiners.

I understand that my thesis may be made electronically available to the public.

Abstract

This study examines how the duration of patent examination is affected by technological diversity of patent applications, using a sample of all pharmaceutical patent applications filed between 1985 and 2017 at State Intellectual Property Office of China (SIPO). Patent examination is a crucial process to evaluate the patentability of technological inventions. To understand what factors influence patent examination duration can offer strategic insights for both patent applicants and patent system designers. Although China has been leading the world's patent applications since 2011, it is surprising that little research has been conducted on the process of patent examination in China. This thesis takes a step to fill this gap.

This study complements prior research (Harhoff and Wagner, 2009; Tong et al., 2018) by zooming into the effect of technological diversity, which is one of the most important characteristics of patent applications. Competing risks hazard rate models show an inverted U-shaped relationship between patent applications' technological diversity and the rates of decisions of both grant and rejection. It means that when a patent application combines technological elements with a moderate level of diversity, it will facilitate the assigned patent examiner to make the decision faster, whether it is grant or rejection. In addition, it is also found that the effect of technological diversity on the rate of grant, but not the rate of rejection, is significantly weakened for applications with more than 10 claims. A discussion of these findings and their implications is included at the end of the thesis.

Acknowledgements

This thesis would not have been possible without the constant support that I received from a number of people.

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I am extremely grateful to my parents and my fiance for supporting me and being with me even during the toughest times.

Finally, I want to say thanks to myself, for never give up along the way.

Dedication

I dedicate this thesis to my beloved parents for their unconditional love, support, and care.

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Abbreviations

CFDA China Food and Drug Administration 36

CNIPA China Intellectual Property Administration 1

EPO European Patent Office 1, 2, 26, 43, 62, 64

IP Intellectual Property 11, 34

IPC International Patent Classification ix, x, 14–17, 27, 37, 42, 43

JPO Japanese Patent Office 1

KIPO Korean Intellectual Property Office 1

PCT Patent Cooperation Treaty x, 8–10, 12, 13, 16, 19, 20, 45, 46, 49, 62

PRC Peoples Republic of China 6

SIPO State Intellectual Property Office of China iii, ix, x, 1–4, 6, 10, 12–14, 16–20, 22, 33, 34, 36, 37, 42, 43, 45, 51, 62, 64, 66, 67

TRIPS Trade-Related Aspects of Intellectual Property Rights 10

USPC United States Patent Classification 27

USPTO United States Patent and Trademark Office 1, 64

WIPO World Intellectual Property Organization 1, 6, 13

WTO World Trade Organization 10

Chapter 1

Introduction

1.1 Research Question

The patent system is a complex system that aims to provide monopoly rights of a limited time to inventors and to protect the patent rights from infringement yet requires a detailed public disclosure of an invention. In recent years, there has been a fast growth of patent applications all over the world. According to a recent report from the World Intellectual Property Organization (WIPO), approximately 3,127,900 patent applications were filed worldwide in 2016, compared to 2,888,800 in 2015 and 2,680,900 in 2014 (WIPO, 2017). The five largest patent offices, which are the State Intellectual Property Office of China (SIPO)[1] , United States Patent and Trademark Office (USPTO), Japanese Patent Office (JPO), Korean Intellectual Property Office (KIPO) and European Patent Office (EPO) accounted for 84 % of the total patent filings all over the world. Notably, SIPO has been receiving the highest number of patent applications since 2011, and the fast growth

[1]Since August 28th, 2018, SIPO changed its name into China Intellectual Property Administration (CNIPA). This study was completed prior to this date, and all the data and information we collected were published by SIPO, thus, we use SIPO in the thesis as abbreviation of the State Intellectual Property Office of China.

of patent applications filed in China has made SIPO the largest patent office in the world (see Figure 1.1).

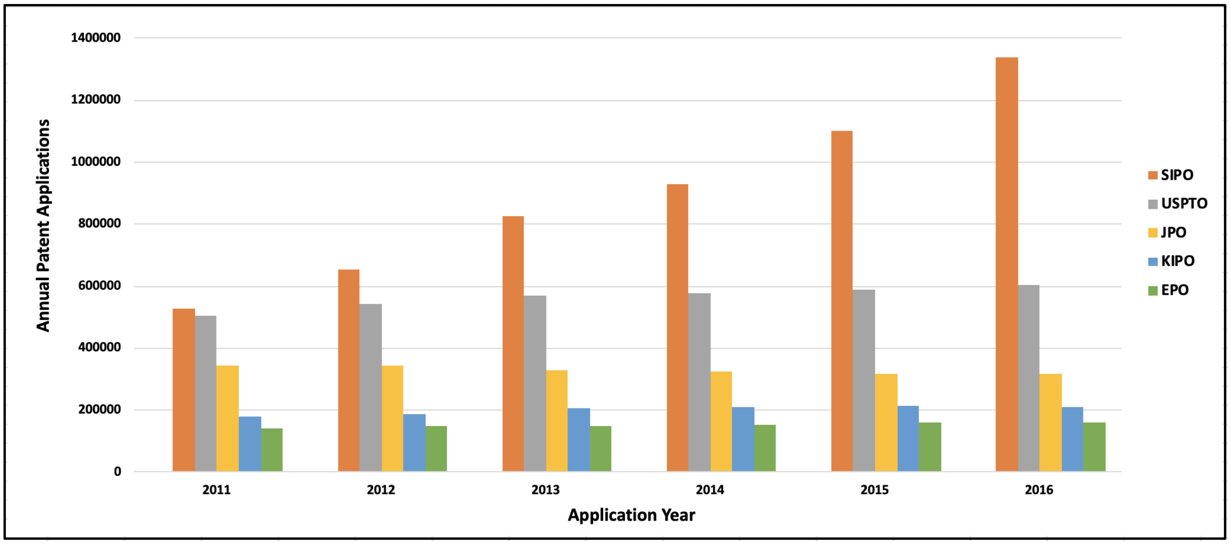

Figure 1.1: The Trend in Patent Applications at the Top Five Patent Offices (2011 - 2016)[2]

There has been an increasing number of studies that try to explain the recent upsurge of Chinese patenting (Hu and Jefferson, 2009; Li, 2012). However, not much research has paid attention to the process of patent examination and the resulting decisions, especially the decisions other than grant. Tong et al. (2018) is one exception. They replicated Harhoff and Wagner (2009)'s research on EPO applications in China. Using a dataset that covers the invention patent applications ranging from 1993 to 2006 at SIPO, they examined the effects of characteristics of applicants, applications, and environment on the pendencies for the three outcomes following the patent examination process grant, rejection and withdrawal, respectively. In general, they replicated many findings reported in Harhoff and Wagner (2009) and confirmed that many factors have different effects on pendencies for different outcomes. In addition, they also highlighted the differences across the two patent offices.

[2]Source: http://www.wipo.int/ipstats/en/. Last visited October 25th, 2018.

While the above two studies have provided us with an overview of what can affect the durations leading to different outcomes of patent examination, we still do not have a clear understanding of how and why certain characteristics of patent applications influence the pendencies of outcomes. We aim to fill this gap in this study. Specifically, we focus on technological diversity of patent applications, and analyze how it affects the duration of patent examination that leads to either grant or rejection.

Prior research shows that there is a non-linear relationship between firm-level technological diversity and innovation performance. Firms with a moderate level of the technological diversity achieve the highest innovation performance in terms of number and usefulness (or impact) of granted patents (Dindaroğlu, 2017; Huang and Chen, 2010; Strumsky and Lobo, 2015). At the patent level, how does a patent application's technological diversity affect its examination outcome? So far, we do not have a clear answer to this question. This study aims to answer this question, by using hazard rate models to analyze all patent applications in the field of pharmaceuticals in SIPO from 1985, the year when the Chinese patent system was established, to the end of 2017.

1.2 Motivations

Understanding the patent examination process has great strategic implications for applicants (Jell, 2011), who rely on protected patent rights to recoup the costs of inventing and of patent examination and maintenance, and to gain further benefits from it. For example, Gans et al. (2008) find that applicants sometimes would delay patent examination process to create the uncertainty for winning bargaining power for future patent licensing and assignment. The higher uncertainty level, the greater bargaining power. Being able to predict the patent examination outcomes and influence the examination duration is therefore essential for applicants to manage their patenting activities. We are motivated by this purpose and develop our research on how patent factors affect examination outcomes.

Patenting rules and requirements are different across countries, so are the patent examination systems. Previous research always focuses on the U.S. (Xie and Giles, 2011; Carley et al., 2015) and European patent systems (Fleming and Sorenson, 2001; Harhoff and Wagner, 2009). Since SIPO has become the world's largest patent office since 2011 due to the highest patent application volume, it attracts researchers to take a close look at the Chinese system. However, not much research has paid attention to the patent examination outcomes, especially the rate of each examination outcome. Therefore, our research tries to fill in the research gap.

1.3 Contributions

This study has at least two contributions. First, we focus on the relationship between patent applications' technological diversity and the duration of examination. Even though prior research has examined various attributes of patent applications and the pendency for various examination outcomes (Harhoff and Wagner, 2009; Tong et al., 2018), no one has yet paid attention to the effect of patent technological diversity, which is one of the most important characteristics of patent applications. Using hazard rate model, we find an inverted U-shaped relationship between patent technological diversity and the rates of decisions of both grant and rejection. It means that when a patent application has a moderate level of technological diversity, it will facilitate the assigned patent examiner to make the decision faster, regardless if it is grant or rejection. In addition, we examine the moderating effect of the number of claims and find that the effect of technological diversity on the rates of decisions is weaker for the applications with more than 10 claims than those with less than 10 claims.

Second, our methodology is more rigorous in two aspects. The first one is that we define our risk set more rigorously. Prior research assumes that all patent applications enter the risk set automatically when they are filed (Harhoff and Wagner, 2009; Tong et al., 2018). However, this is not accurate, because only applications that have entered the stage of substantive review can receive examiners decision of grant or rejection. Applications do not enter substantive review automatically. Applicants must make the request within three years since the filing date, otherwise, their applications will be regarded as withdrawn. Therefore, we only include those applications that have entered substantive examination into our analysis, because only those applications can possibly receive an examination decision. Secondly, we use competing risks hazard rate models (Fine and Gray, 1999) to analyze the rates of all three possible patent examination outcomes, such as, grant, rejection, and withdrawal (applicants can still decide to withdraw their applications after they request substantive examination), simultaneously, even though we are only interested in decisions of grant and rejection. Traditional survival analysis encodes objects that have experienced non-interested events as right-censored cases, which are equivalent to the pending cases that remain in the risk set. This can potentially lead to biases. Competing risks models, however, compute hazard rates by excluding the cases that have experienced non-interested events from the risk set. Therefore, the results are less likely to be subject to biases.

1.4 Outline of the Thesis

The rest of the thesis is structured as following. Chapter 2 introduces the background of Chinese patent system, including the evolution of patent legal system and the patent examination process. Chapter 3 provides a literature review on related topics, based on which we develop our hypotheses on the impact of patent technological diversity on the rates of examination decisions, as well as on the moderating effect of claims. Chapter 4 describes our data and the methods we use to test our hypotheses. Chapter 5 shows the results of our empirical analysis. And finally, Chapter 6 summarises the main findings of the thesis with a discussion on the limitations and directions of future research.

Chapter 2

Background and Related Work

The concept of patent system can usually have narrow and broad meanings. The narrow meaning of patent system stays at an administrative level, which refers to the examination process and the outcomes of patent applications. The broad meaning of patent system includes both the patent legal system and the patent examination system established following the law. In this chapter, we will introduce the patent system of China in the broad sense (Yasong and Connor, 2008), including the Patent Law and the patent administration SIPO.

2.1 Patent Legal System of China

In June 1980, the Chinese government rode the wave of reform and became a member of the WIPO. To better connect with other WIPO members, China started to establish its modern patent system since the 1980s. In March 1984 the Patent Law of the Peoples Republic of China (PRC) was enacted during the Sixth National Peoples Congress. The new patent law went into effect on April 1st, 1985 aiming to protect patent rights, encourage invention-creations and promote the development of science and technology. As time passes by, the Patent Law of China has been amended three times in 1992, 2000 and 2008, respectively, and is still in use nowadays.

2.1.1 The Founding of the Patent Law System of China

The first version of the patent law set the foundation for the patent system of China, including the patent application and examination procedures, patent authorization conditions, and regulations for patent right protection. There are three kinds of patents defined in the first version of the patent law, which are inventions, utility models and designs [3]. According to the Patent Law, any technology can be patented, including a product, a process or an improvement of a product or a process, except for the following seven things, including 1) scientific discoveries, 2) rules and methods for intellectual activities, 3) methods for diagnoses or treatments of diseases, 4) foods, beverages and condiments, 5) pharmaceutical products and substances obtained by means of a chemical process, 6) animal and plant varieties, and 7) substances obtained by means of nuclear fission[4] (Article 25, Patent Law of China, 1985[5]). It is noteworthy that although pharmaceutical products could not be patented from 1985 to 1992, the process of manufacturing pharmaceutical products could during this time. As a result, we can still observe some patent applications in the category of pharmaceutical technology.

The first version of the Patent Law of China stipulated the conditions for granting

[3]According to the Rules for the Implementation of the Patent Law of the Peoples Republic of China, Article 1: Invention patents means technical solution relating to a product, a process or an improvement thereof. Utility model refers to any new technical solution relating to a product's shape, structure, or a combination thereof, which is fit for practical use. And design patent represents the new design of a product's shape, pattern or a combination thereof, as well as its combination with the colour and the shape or pattern of a product, which creates an aesthetic feeling and is fit for industrial application.

[4]Source: http://iprchina.blogspot.com/. Last visited August 20th, 2018.

[5]Patent Law of the People's Republic of China (1985): http://www.lawinfochina.com/display.aspx?id=38&lib=law&SearchKeyword=&SearchCKeyword=%d7%a8%c0%fb%b7%a8. Last visited July 25th, 2018.

patents. According to the law, an application can be granted patent right only if it is characterized by novelty, inventiveness, and practical applicability. Novelty means that the patented technology must be a new technological solution which has never shown up in domestic or foreign publications, known to the public or been filed with the Chinese Patent Office before the filing date. Inventiveness means that the invention has substantively distinguishing features and represents a significant improvement compared with the extant technologies. And practical applicability of a patent means that the invention can be manufactured, is usable, and can produce positive results (Article 22, Patent Law of China, 1985). Applications that do not conform to these three requirements, even after being given the opportunity to be revised, will be rejected (Article 38, 42, 43, Patent Law of China 1985).

In addition to outlining the requirements for granting, this version of the Patent Law also stipulated that applicants can withdraw an application at any time before the patent right is granted (Article 32, Patent Law of China, 1985). Applications can be deemed to have been withdrawn if applicants do not respond promptly and effectively to the requirements of the patent office, for instance, when an applicant does not submit the required documents in time or fails to respond to the patent examiners' amendment requests within the time limit (Article 35, 36, 37, 41, Patent Law of China, 1985).

The first version of Patent Law of China laid a solid foundation for its subsequent development. It not only established the patent system in China, but also regulated the specific principles for the implementation of the law, such as examination and approval of patent applications, a compulsory license for exploitation of a patent, and protection of the patent rights.

2.1.2 The First Amendment of the Patent Law of China

In September 1992, China revised the Patent law in order to accept more international patent applications and to join the Patent Cooperation Treaty (PCT). The amendment became effective on January 1st, 1993. One year later, in January 1994, China signed the

PCT to become a contracting country. PCT is an international patent law treaty, which outlines a set of unified procedures for filing patent applications and protecting patented technologies in each of its contracting countries. A PCT application is first filed at a receiving office; after an international searching for prior art and an optional preliminary examination, the application will then enter into the initial national application phase of the desired countries and regions.

According to the PCT requirements, China revised the national patent law and conferred a 12-month priority right on both international and domestic applications. For international applications, within 12 months from the date on which any invention patent is first filed in a foreign country, the same patent application enjoys a priory right in China. Similarly, for domestic patent applications, within 12 months from the date on which any invention patent is first filed in China, the same patent application enjoys a domestic priority right (Article 29, Patent Law of China, 1993[6]).

The first amendment added pharmaceutical products as patentable technology (Article 25, Patent Law of China, 1993). Thus, since 1993, both pharmaceutical products and its manufacturing processes have been patentable. The change tripled the number of patent applications in pharmaceutical, from 576 in 1992 to 1755 in 1993.

Compare to the first version of the Patent Law of China, the first amendment improved in many important aspects that further encouraged innovation. For instance, it increased the term of invention patent protection from 15 years to 20 years; it also added domestic patent priority right based on international priority right; and it allowed pharmaceutical products to be patented. If the period from 1985 to 1992 right after the establishment of the Patent Law of China system was considered as an exploratory time for Chinese patent system, then the second period from 1993 to mid 2001 offered a better developed legal environment for both foreign and domestic inventors.

[6]Patent Law of the People's Republic of China (1992 Amendment): http://www.lawinfochina.com/display.aspx?id=290&lib=law&SearchKeyword=&SearchCKeyword=%d7%a8%c0%fb%b7%a8. Last visited July 25th, 2018.

2.1.3 The Second Amendment of the Patent Law of China

Like the first amendment, which prepared China to join the PCT, the second amendment of the Patent Law of China was also closely related to an important move of China. In December 2001, China joined the World Trade Organization (WTO), and a series of legal regulations were subsequently amended to fulfill WTO's requirements, including the Patent Law. The second amendment of Patent Law of China was initiated in August 2000 and went into effect on July 1st 2001. In order to comply with WTO's requirements, especially those outlined in the Agreement of Trade-Related Aspects of Intellectual Property Rights (TRIPS), the third version of the Patent Law of China included more regulations related to importing and exporting patented products. These regulations raised the threshold of infringements in China for imported patents. For instance, anyone uses or sells a non-Chinese patented product in China will not be deemed as patent right infringement if the product was made or imported with the permission of the patentee (Article 63, Patent Law of China, 2001[7]). Such a friendly patent legal environment has attracted many patent applications from foreign countries and encouraged trading between China and other countries since 2001.

Another update of this version is the addition of provincial patent offices responsibilities of managing disputes over patent rights. As the patent system got increasingly mature, hundreds of thousands of patent applicants had been flooding into SIPO (formerly National Patent Office, renamed in 1998). This drastically increased the workload of the Office. Consequently, in the second amendment, in order to relieve the Office's workload and help it focus on examining patent applications more efficiently, the responsibilities of managing disputes over patent rights was delegated to the provincial patent administrative departments with the general guidance of the Intellectual Property Office of China (Article 3, Patent Law of China, 2001; Chapter 7, Implementing Regulations of the Patent Law of China, 2002).

[7]Patent Law of the People's Republic of China (2000 Amendment): `http://www.lawinfochina.com/display.aspx?id=4983&lib=law`. Last visited July 25th, 2018.

2.1.4 The Third Amendment of the Patent Law of China

The third amendment of the Patent Law of China was initiated in December 2008 and went into effect on October 1st 2009. This version is still in force. In this version, for the first time, it is confirmed the connection between the protection of intellectual property rights and economic development (Article 1, Patent Law of China, 2009[8]). Thus, in this version, the distribution of profits between co-applicants is stipulated in more detail. In addition, the fine for patent right infringement is increased from 50,000 RMB Yuan into one million RMB Yuan. This change aggravates the penalties for patent right infringement and increases the value of patent right as well.

Meanwhile, the standards for granting a patent also become stricter according to the current version of the Patent Law. This version defines the three criteria for granting a patent – novelty, inventiveness and practical applicability – in more detail. Moreover, the evaluation of any patent application should be based on the comparison against an existing technology, not only known in China, but also known outside China (Article 20, Patent Law of China, 2009). These changes significantly increase the difficulties of being granted patent rights in China.

After years of development, the Patent System of China has become increasingly developed and transparent. The establishment of the first three Intellectual Property (IP) Courts in Beijing, Shanghai and Guangzhou in 2014 indicates that the Patent System of China has gone into a new era. The specialized IP courts aim to improve the quality of judgments related to IP rights by giving quicker and better decisions on IP infringement cases than general courts (such as, civilian courts). The fourth amendment of Patent Law was initiated in 2014, and it is still pending. Considering the short history of the Patent System of China for only 33 years (1985 – 2018), its integrality and the degree of internationalization are very impressive.

[8] Patent Law of the People's Republic of China (2008 Amendment): `http://www.lawinfochina.com/display.aspx?id=7289&lib=law`. Last visited July 25th, 2018.

2.2 International Patent Applications

Because of the development of Patent System of China, more and more international applicants file their patents in China. International applicants seeking patent protection in China can choose to file applications through either Patent Cooperation Treaty (PCT) route or Paris Convention route. China joined the PCT in 1994, and before then SIPO accepted international patent applications through only Paris Convention route. Paris Convention allows applicants to file patent applications in any of the 177 Paris Convention contracting member countries within 12 months after the same application is filed in a local member country. Figure 2.1 shows the application process through Paris Convention route.

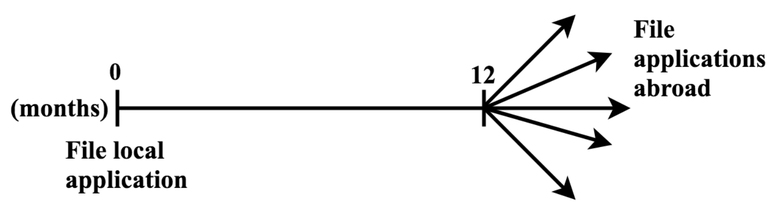

Figure 2.1: Patent Application through Paris Convention Route[9]

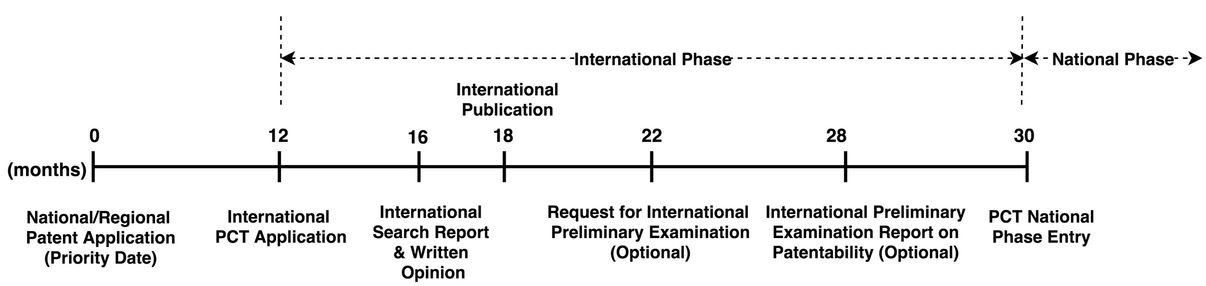

Figure 2.2: PCT Application Procedures [10]

[9]Source: http://www.wipo.int/pct/en/faqs/faqs.html. Last visited October 9th, 2018.
[10]Source: http://www.wipo.int/pct/en/faqs/faqs.html. Last visited July 25th, 2018.

Compare with the Paris Convention, PCT is more convenient if an applicant is seeking patent rights simultaneously in multiple foreign countries. A PCT application goes through the following process. The applicant first files an application with a local patent office in one of the PCT member countries. Within the next 12 months, the applicant should file the international application with WIPO, which is the PCT receiving office. Within 16 months after the first filing date, a worldwide patent office called "International Search Authority" will issue an international search report with a written opinion on the potential patentability of the application. Within 18 months after the first filing date, the application will be published. Next, the applicant can request for an international preliminary examination which will result in a report on the application's patentability, but this step is optional. Within 30 months after the first filing date, the application will enter into the national phase in the desired countries. Figure 2.2 shows the complete process of the PCT application described above.

2.3 Patent Examination Process

According to the Patent Law of China, the patent administrative department under the State Council, namely, SIPO is responsible for carrying out the examination of all patent applications. SIPO was founded in 1980 as the National Patent office, and was renamed in 1998. It is responsible for patent related work and for the coordination with foreign countries in the field of intellectual property.

As aforementioned, there are three kinds of patents in China, invention patents, utility patents and design patents. Among the three kinds of patents, the examination of invention patents takes most resources. While the other two kinds only require a preliminary examination, invention patent applications need to go through both a preliminary and a substantive examination. In this thesis, we will only focus on invention patent applications. The process of examining invention patent applications will be introduced in the following sections.

2.3.1 Preliminary Examination of Invention Patent Application

The preliminary examination is a procedure that automatically starts after an invention patent application is received at SIPO. Once the application passes the preliminary examination, it will be published. The main purposes of the preliminary examination are two folded. First, it checks whether an application is complete and fulfills all the formal requirements outlined by the Patent Law and its Implementation Regulations. Second, it classifies patent applications into relevant technology domain(s) and assigns them to examiners accordingly.

There are few things of a patent application that need to be checked during the preliminary examination. First, a patent application will be checked whether its main and related documents are submitted in conformity with the Patent Law of China and its Implementing Regulation. Second, if additional documents are requested, whether they have been submitted by the specified deadline. Finally, it will also be checked whether all the fees incurred have been paid on time.

After making sure all the formal requirements of a patent application are fulfilled, SIPO will categorize the application into certain technology domain(s) and assign it to examiners accordingly. SIPO uses International Patent Classification (IPC) to classify patent applications. IPC is an internationally accepted classification system for patent documents. It is a useful search tool for accessing to the technological and legal information contained in each patent. Moreover, it also serves as a basis for the industrial property statistics which permits the assessment of technological development in various areas. The format of IPC code is divided into five parts: Section, Class, Subclass, Main Group and Subgroup. This format indicates a hierarchical system of categorization in which each level is nested into another. Figure 2.3 shows the structure of the consistent of IPC code.

Table 2.1 shows the structure of an example of IPC code of A61K 6/05. A patent that is assigned this IPC code belongs to the domain A – Human Necessities – in general. Within the domain of Human Necessities, it belongs to the class of Medical or Veterinary Science; Hygiene, indicated by two digits 61. Its subclass, indicated by the letter K,

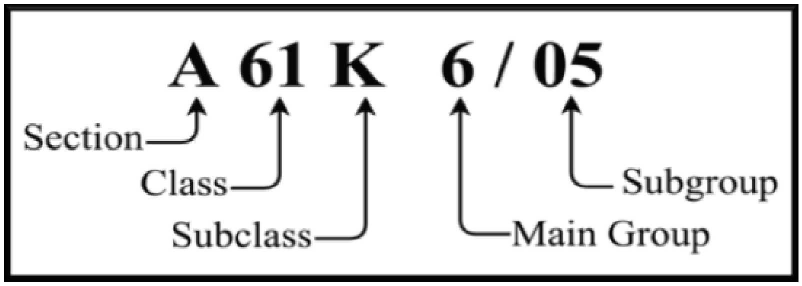

Figure 2.3: The Structure of IPC code

is Preparations for Medical, Dental, or Toilet Purposes. More specifically, within this subclass, it is categorized into the main group of Preparations for Dentistry, indicated by 6/00 (all main group level codes end with /00), and finally into the subgroup of Amalgams, indicated by 6/05.

Layout	IPC Code	Definition
Section	A	Human Necessities
Class	A61	Medical or Veterinary Science; Hygiene
Subclass	A61K	Preparations for Medical, Dental, or Toilet Purposes
Main Group	A61K 6/00	Preparations for Dentistry
Subgroup	A61K 6/05	Amalgams

Table 2.1: An IPC Layout Example for A61K 6/05

When assigning IPC code to a patent application, an examiner first assigns the patent a main IPC code which most adequately represents the invention information. Invention information includes the claims the applicant makes that define the range of protection, description of the technology filed for being patented and figures that illustrate the technology. It is basically the information that delineates the contributions of the current filed patent application built on prior art. A patent application can be assigned with multiple IPC codes if the application contains invention information that covers different technological domains at various levels (i.e., Section, Class, or Subclass, and so on).

After conducting the preliminary examination, SIPO will disclose patent applications that have not requested to be kept confidential. The publication date is usually 18 months after the filing date, which is a statutory period regulated by the Patent Law of China. Applicants may request an early publication for free to disclose the application earlier than 18 months after the application is filed.

2.3.2 Substantive Examination of Invention Patent Application

Within three years after filing a patent application, the applicant may request a substantive examination. During the substantive examination period, an application will be judged from the three aspects – novelty, inventiveness and practical applicability – of a qualified patent outlined in the Patent Law. At the end, a decision of granting or rejecting will be reached. The substantive examination is mostly initiated by applicants' request. If an applicant fails to submit the request within the first three years after filing the application, the application will be considered as withdrawn. However, SIPO may also initiate the substantive examination process for an invention patent application when it is deemed necessary (Article 35, Patent Law of China, 1985, 1992, 2000, 2008). The time that the substantive examination process takes varies, depending on the nature of the patent applications. The substantive examination fee for applications filed through PCT (with prior international search) is RMB 1200 Yuan, and RMB 2500 Yuan for the rest (with no prior international search).

Once the substantive examination process for a patent application starts, the examiner needs to review whether the application fulfills all the requirements for novelty, inventiveness and practical applicability. The examiner will first search prior art related to the application. China adopts the 'first-to-file' system, which means whoever files a patent application for an invention first will be considered as the potential owner of its patent right, regardless of the date of actual invention. A patent application is considered as novel if there has no similar technology filed as patent before the filing date of the current application.

Before examiners start to search for prior art, they first need to double check the assignment of IPC code(s) to the applications during the preliminary examination is correct. Then they use the IPC code(s) to determine the technical field(s) to be searched (Guidelines for Patent Examination of SIPO, Part II, Chapter 7, Article 5.3.2, 2010[11]). Next, they use expressions from the claims, such as the key words or chemical structural formulas, to narrow down the range of comparing documents (Guidelines for Patent Examination of SIPO, Part II, Chapter 7, Article 5.4.2, 2010). Sometimes, they also need to search other materials, such as non-patent literature (Guidelines for Patent Examination of SIPO, Part II, Chapter 7, Article 6.2.4, 2010) to make informed decisions on whether the technologies described in patent applications are novel. Once the application fulfills the novelty criterion, the examiners then decide its inventiveness and practical applicability.

Patent substantive examination focus on two parts of information, one is patent claims which limit the scope of requested patent right; the other includes the abstract, description and figures, which help to understand the technology. Examiners review the complete patent application file to evaluate the patentability and authorize patent rights requested by the claims. If an application does not conform to the three requirements of a qualified patent, the examiners will require the applicant to revise it within a specific time limit (usually four months). An application can go through up to two rounds of revision.

After the substantive examination, one of the following two results will be made: grant and rejection. If an application, after being revised if required by the examiners, fulfills all the requirements, it will receive a decision of grant. An authorized version of the granted patent will be published and open to the public. The applicant will receive a certificate of invention patent right and enjoys the patent right within the scope of the specified claims. The right will last for up to 20 years, or until the patent holder stops paying the

[11]Source: `http://www.cnipa.gov.cn/zhfwpt/zlsqzn/sczn2010eng.pdf`. Last visited November 29th, 2018.

annual fee. On the contrary, if an application does not fulfill the requirements of novelty, inventiveness and practical applicability, even after two rounds of revision, it will receive the decision of rejection. Moreover, if the patent application contains information against the law (for example, invention of addictive drug-device), endangers public benefits (for example, inventions that endanger public health) or seeks the patent right for items not patentable[12] will be directly rejected without any revision opportunities.

An application can also be withdrawn by the applicant any time after the application is filed so that the process of patent examination is terminated. As aforementioned, if an applicant does not request substantive examination within three years after filing the patent application, the application will be deemed as withdrawn. Applications that fail to enter the substantive examination process will be considered as open knowledge and available to anyone. An applicant can also withdraw an application during the substantive examination process by not responding to the examiners requests for revision. Therefore, once an application enters the substantive examination process, there are three possible outcomes for it, namely, grant, rejection or withdrawal.

Figure 2.4 shows the complete process of patent examination at SIPO. The process consists of the preliminary examination stage and the substantive examination stage, during each of which an application can be withdrawn thereby terminating the examination process before reaching the decisions of grant or rejection.

[12] Patent Law of China, Article 25 (2008 Amendment): For any of the following, no patent right shall be granted: 1) scientific discoveries; 2) rules and methods for mental activities; 3) methods for the diagnosis or the treatment of diseases; 4) animal and plant varieties; 5) substances obtained by means of nuclear transformation; and 6) the designs that are used primarily for the identification of patterns, colors or the combination of the two on printed works. For processes that produce the products listed in item 4), a patent may be granted in accordance with the provision of the law.

[13] Source: Liegsalz and Wagner (2013); the SIPO website: http://www.sipo.gov.cn/zhfwpt/zlsqzn/zlsqspcxjs/, last visited July 25th, 2018.

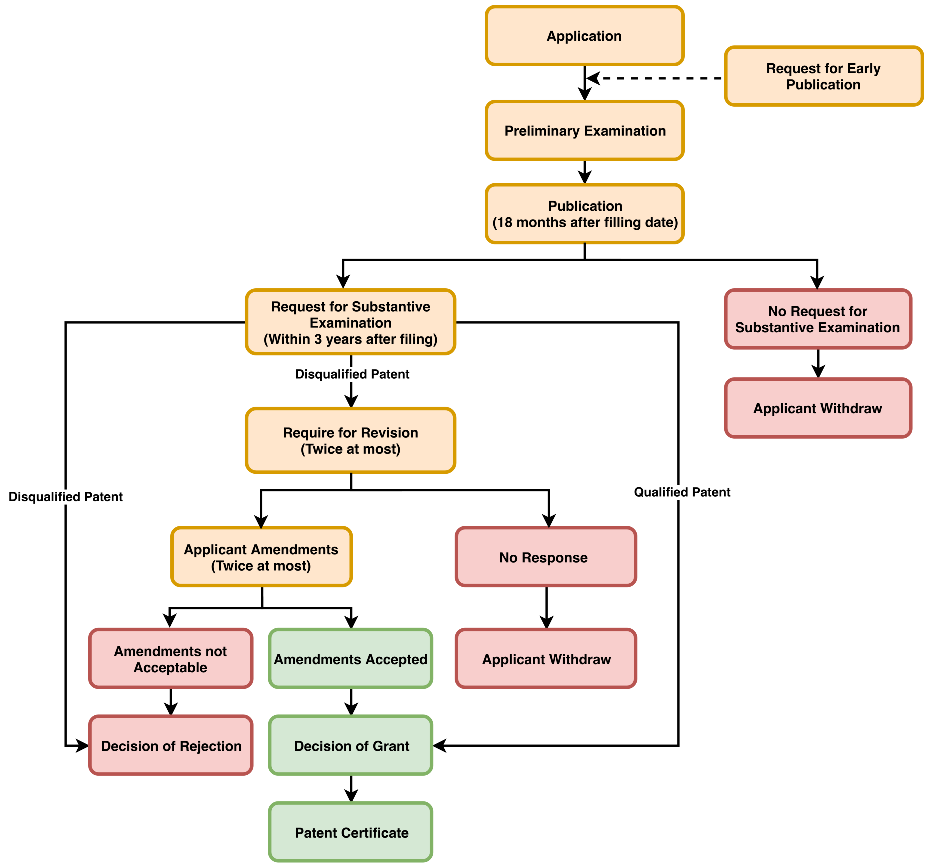

Figure 2.4: Process of Chinese Patent Examination for Invention Patent Application[13]

2.4 Statistic Description of Chinese Invention Patent

Ever since 1985 when the first version of the Patent Law of China was put in force, the Chinese Patent System has been continuously developing in the past three decades. Table 2.2 shows the annual statistic for invention patents at SIPO from 1985 to 2017. According to this table, the number of annual invention patent applications requested for substantive examination at SIPO exceeds 10,000 for the first time in 1993, and the number exceeds 100,000 in 2003. SIPO started to accepted PCT applications since 1994, and the number of PCT applications requested for substantive examination is higher than domestic patent applications from 1994 to 2001. In 2002, the number of Chinese domestic patent application requested for substantive examinations exceeds PCT applications and the gap increases year by year.

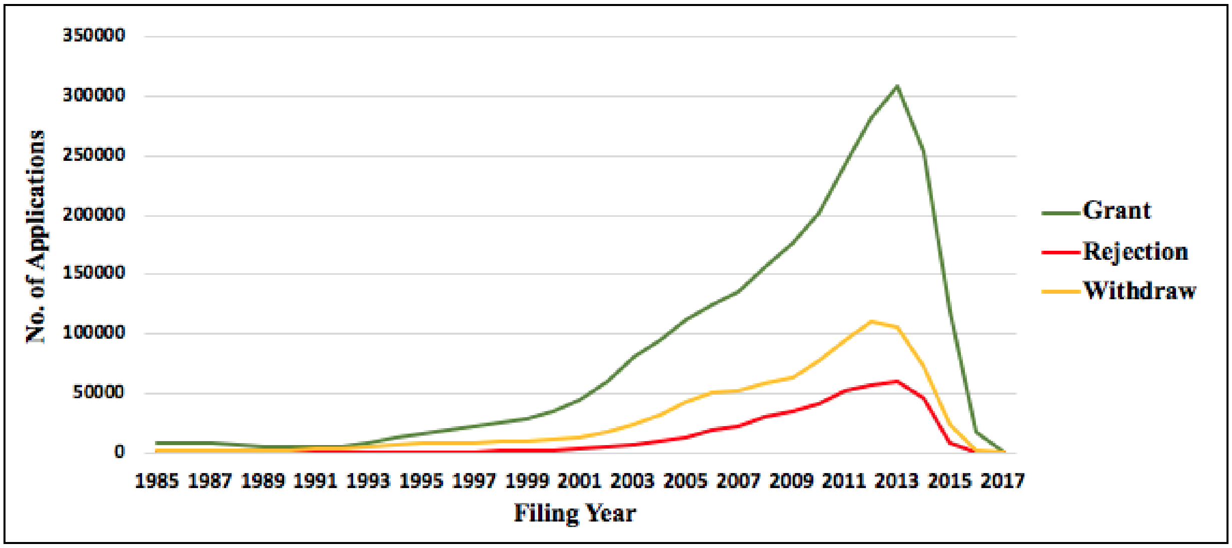

Figure 2.5: Annual Statistics of Patent Substantive Examination Outcomes for Invention Patents at SIPO (1985–2017)[14]

Figure 2.5 shows the annual number of patent examination results for invention patents at SIPO from 1985 to 2017. The number of granted patents exceeds rejected and withdrawn patents in 1994. Moreover, the number of withdrawn patents is always higher than rejected patents. Combined with Table 2.2, it shows the average duration of substantive examination for different results. We can see that the average rejection duration is always longer than grant duration since 1994. In general, the durations for all the three results are getting shorter year by year. This probably reflects the learning effects of SIPO. When the patent system first established in China, SIPO needed more time to adapt to the new system, hence, it took longer to reach decisions for patent applications. Since the first

[14]**Note:** There are drops after year 2013, this is because patent examination process usually takes more than three years at SIPO. Most of the applications which are submitted to SIPO after 2014 are still under examination without any decisions have been made.

amendment of the Patent Law in 1992, the Chinese patent examination system has been gradually improved.

Filing Year	Applications Entering Substantive Examination	Grant Share (%)	Avg. Grant Duration (months)	Rejection Share (%)	Avg. Rejection Duration (months)	Withdrawal Share (%)	Avg. Withdrawal Duration (months)	PCT Share (%)	Domestic Application Share (%)	Avg. Number of Claims
1985	9900	79.78	60.75	4.14	52.27	15.75	54.10	-	34.65	8.26
1986	9856	81.26	57.46	3.69	51.91	14.51	55.79	-	30.39	8.75
1987	9974	79.23	54.16	3.40	50.74	16.36	55.79	-	34.53	8.47
1988	8570	71.27	56.31	3.90	53.47	23.40	57.37	-	38.11	8.70
1989	7370	62.92	56.87	3.84	58.28	30.61	58.16	-	41.34	8.98
1990	7405	60.66	56.27	3.65	67.82	32.30	58.34	-	50.41	8.61
1991	7854	58.86	58.34	3.81	68.78	33.72	59.01	-	56.35	8.07
1992	9918	56.23	62.49	3.50	74.70	37.33	58.66	-	60.23	7.78
1993	14626	56.02	69.56	3.19	77.33	37.19	61.37	-	50.81	8.71
1994	19849	62.32	75.44	2.33	89.38	32.27	66.86	24.85	35.32	10.80
1995	23911	64.92	77.18	2.28	96.04	30.89	68.07	32.17	27.54	12.03
1996	29016	66.22	74.35	2.62	95.29	29.54	66.58	35.28	26.02	12.31
1997	32824	69.39	69.97	2.89	91.43	26.74	64.98	36.23	25.20	12.16
1998	36483	69.79	66.54	3.32	86.11	26.41	64.57	38.35	25.10	12.57
1999	40136	70.32	62.18	4.64	81.64	24.69	62.12	41.31	28.51	14.28
2000	49489	70.85	57.62	4.82	77.36	23.23	57.37	39.07	33.64	14.13
2001	61242	72.48	55.28	5.43	75.79	21.83	55.72	37.73	35.61	14.52
2002	82644	73.45	54.14	5.56	75.25	20.84	55.27	35.53	39.55	14.27
2003	111601	72.04	53.79	6.42	76.15	21.31	55.95	33.61	41.42	14.29
2004	136243	68.9	53.55	7.31	77.03	23.46	55.43	32.34	41.57	14.22
2005	168002	66.3	51.38	8.00	70.49	25.27	52.68	30.29	45.37	13.20
2006	195825	63.72	49.96	9.39	66.69	26.15	50.08	28.51	50.46	10.60
2007	212328	63.8	47.84	10.72	62.28	24.59	47.52	25.50	56.27	9.81
2008	245676	63.28	44.96	11.94	57.66	23.65	45.04	22.77	61.86	10.05
2009	279118	63.29	41.87	12.51	53.16	22.63	43.59	21.58	66.75	8.96
2010	327778	61.68	39.71	12.76	47.20	23.37	41.86	19.62	69.28	4.98
2011	406299	59.52	38.52	12.92	42.11	23.38	39.94	17.29	72.46	2.10
2012	496841	56.72	36.10	11.59	39.95	22.13	36.49	14.78	76.78	1.16
2013	604370	51.03	31.31	9.90	38.21	17.46	32.80	12.91	80.59	1.15
2014	792619	31.94	26.43	5.72	33.63	9.09	29.16	10.10	85.30	1.47
2015	941299	12.78	21.84	0.87	26.60	2.50	24.04	7.76	88.01	3.50
2016	966749	1.8	14.86	0.01	17.66	0.25	9.96	1.75	94.09	6.27
2017	570624	0.13	8.92	-	-	0.14	6.62	0.06	97.22	7.33
Total	6916439	37.95	49.25	6.08	61.59	13.37	50.04	13.76	75.96	9.17

Table 2.2: Statistics of Invention Patents at SIPO (1985–2017)

Chapter 3

Literature review and Hypotheses

3.1 Literature Review

There are two branches of research which are relevant to the technological diversity and patenting outcomes. One branch of literature focuses on theoretical studies of knowledge-based technological diversity and innovation outcomes, represented by Fleming (2001). This group of research defines innovation as a process of knowledge recombination (Nerkar, 2003; Yayavaram and Ahuja, 2008; Strumsky and Lobo, 2015). They argue that there's a non-linear relationship between technological diversity and innovation outcomes measured by the impact of grant patents (Fleming, 2001; Huang and Chen, 2010; Kim et al., 2016).

The other group of studies consists of practical research focusing on the patent examination processes at global major patent offices. They summarize a list of patent attributes, such as number of inventors, number of claims, applicant types, and so on, focusing on the relationships between those attributes and patent examination outcomes (Lerner, 1994; Popp et al., 2004; Van Zeebroeck, 2007; Xie and Giles, 2011; Liegsalz and Wagner, 2013). This group of research tries to find out how different factors influence patent examination outcomes – grant, rejection and withdrawal – differently (Harhoff and Wagner, 2009; Tong et al., 2018).

Notably, both streams of literature have found that the number of claims included in a patent have significant impacts on patent examination outcomes. However, so far no study has explained how these two patent attributes affect the outcomes together.

3.1.1 Innovation as Knowledge-based Technological Recombination

It is widely accepted that knowledge creation comes from recombination of existing knowledge (Fleming, 2001; Nerkar, 2003; Ahuja and Katila, 2004; Yayavaram and Ahuja, 2008). Also, knowledge recombination is a dynamic process whose output is implicitly considered as a technological innovation (Quintane et al., 2011). Innovation arises from diversity. Like the ecology where a variety of different species consist a community. And the diversity of ecology takes into account the variation in the complexity of the biological community including the number of niches and other ecological process (Odum, 1959; MacArthur, 1965; Wikipedia contributors, 2018). When regarding the science and technology discipline as a community, the knowledge components inside the community can be seen as different species. The diversity of the components influences the activities of knowledge combination, therefore affects the characteristics of the invention.

The technological knowledge components within a specific technology field available for recombination is finite (Ahuja and Katila, 2004), therefore, inventors still create new inventions by exploiting and exploring knowledge from history and other technology fields (Nerkar, 2003). Thus, technological components combined from other fields make the current technical community diverse. Furthermore, if the new and existing components combined in the invention are dominant equally, then breakthroughs are likely to come out, as it is difficult to categorize the outcome into any of the existing technological fields (Fleming, 2007).

However, the outcome of technological recombination is highly uncertain and unpredictable (Van de Ven, 1986; Fleming, 2001, 2007). When creating inventions, inventors explore combinations with both unfamiliar and familiar individual components. Learning from unfamiliar knowledge components takes time and efforts for inventors. Also, the inventing process is a trial and error process, whose outcomes are unpredictable. Even combining familiar components requires inventors to learn from previous efforts and find the best combination of those individual components; thus, it does not reduce invention uncertainty by combining familiar components (Fleming, 2001). Fleming (2007) concludes that combining new components and creating new combinations can lead to both breakthroughs and failures. Because both of the exploring processes create inventions from nothing and the outcomes are always unpredictable. Verhoeven et al. (2016) later define such new knowledge combination as 'novelty in knowledge origins'.

Since breakthroughs are barely achieved, we would like to ask, what kinds of technological combinations can reduce the innovation uncertainty and make invention creation process more successful? Fleming (2001) finds that refinement of previously used combinations, which is a knowledge exploration process, reduces uncertainty. It is because inventors can increase the awareness of the usefulness of specific combinatory relationships by using them more than once. Thus, it is easier to capture the optimal combinations between individual components throughout the refinement process and increase the certainty of inventing. For example, the evolution of the keyboard. Before the 'QWERTY' layout keyboard became dominant, inventor tried plenty combinations about the layout of keys, such as mixing numeric and letter keys in the same row or rearrange different orders of the letter keys like the Dvorak Simplified Keyboard (Fleming, 2001). Finally, inventors found that 'QWERTY' arrangement was the most efficient way of typing on a typewriter. Such refining of previous technological combinations generates new relationships between previously combined components and reduces the invention uncertainty (Alois, 1939; Silverman, 1999; Fleming, 2001).

3.1.2 Technological Diversity and Innovation Performance

Considering invention as a process of knowledge combination, researchers ask how diverse the combined technological components should be to receive good innovation performance? There are two groups of arguments on the relationships between technological diversity and innovation performance. The first group claims that the more diverse the combined technological components, the more innovative the resulting technologies. Refining existing technologies results in a high level of specialization, such in-depth exploitation might limit inventor's knowledge absorptive capacity (Cohen and Levinthal, 1990). Furthermore, an inventor who tends to use broader technological recombination across technological domains is more likely to generate inventions (Breschi et al., 2003; Gruber et al., 2013). Although this group of literature proposes an idea that there is a linear relationship between technological diversity and innovation performance, they do not illustrate to what extent technological diversity should be to get the desired innovation performance.

Unlike the first stream of literature that claims a linear relationship between technological diversity and innovation performance, the second group argues that the outcomes of technological recombination are always uncertain, thus, the relationship between technological diversity and innovation performance is non-linear (Fleming, 2001; Leten et al., 2007; Huang and Chen, 2010; Kim et al., 2016; Wang et al., 2016). Fleming (2001) explains that as inventing is a process of trial and error, combining new technological components can lead to both failure and breakthrough. This uncertainty makes the relationship between technological diversity and innovation outcomes a non-linear relationship. Leten et al. (2007) later use EPO granted patent data and find an inverted U-shaped relationship between technological diversity and innovation performance at the firm level. They confirm that there is an optimal technological diversity level for innovation performance. Moreover, firms with high levels of technological diversity can decrease their innovation performance. The reason is that although diverse technologies can offer opportunities for cross-domain integration, a high level of diversification can bring about risks of lacking sufficient capabilities and higher costs for coordination and integration (Leten et al., 2007).

3.1.3 Technological Diversity and Patent Examination Outcomes

During the patent examination process, applications are always grouped into different technology categories and then assigned to examiners specialized in relevant technology domains. Thus, technology classification codes assigned to patents are excellent indicators for technology domains they belong to. In addition, as all the patent applications are categorized into at least one technology domain using one technology classification code, researchers prefer to take advantages of technology classification codes to study the technological diversity of a patent (Strumsky and Lobo, 2015).

Lerner (1994) first develops a proxy to measure patent technology scope using the number of IPC codes assigned to a patent. If a patent is assigned with a specific IPC code, then the technology scope for this patent is narrow. On the other hand, if a patent has multiple IPC codes, the technical scope for the patent is broad.

Later on, researchers study how the number of IPC codes or technology classification codes[15] assigned to a patent affect patent examination outcomes. They assume that the greater number of IPC codes assigned to a patent indicates a more complex invention, thus, the more complex task for patent examination (Harhoff and Wagner, 2009; Van Zeebroeck, 2007; Liegsalz and Wagner, 2013). Patent examiners need to evaluate the patentability of the applications by comparing with prior art from different technical fields. Based on this assumption, researchers have hypothesized and empirically found that there is a linear relationship between the number of IPC classifications and examination duration, regardless of the decision types (Harhoff and Wagner, 2009; Liegsalz and Wagner, 2013; Tong et al., 2018).

Notably, Harhoff and Wagner (2009) use generality and originality to evaluate the tech-

[15]There are at least two types of technology classification codes studied previously. One is IPC codes, and the other is the United States Patent Classification (USPC) codes. IPC is a patent classification system which is accepted internationally. USPC is mainly used in the U.S. patent system since 1899 (https://en.wikipedia.org/wiki/United_States_Patent_Classification, last visited October 3rd, 2018.)

nological diversity using patent citation data. Generality refers to the extent to which a patent contains technologies that can be used in a wide range of technology areas. Originality refers to the extent to which a patent is generated from a broad set of technologies. They find that the higher generality, the shorter the duration for grant and longer for withdrawal and rejection, because high generality means a high value of the patent and applicants make more efforts to get grant results. Furthermore, the higher the originality of a patent application, the longer time is required to examine it (regardless of the outcomes), as it takes time for examiners to search and review from a large set of prior art. This suggests a linear relationship between patent technological diversity and patent examination durations.

Other than patent technological classifications, the number of patent claims can also affect the technological performance of a patent (Tong and Frame, 1994). Patent claims set the boundaries of patent rights (Harhoff and Wagner, 2006) as well as the technology scope of the invention (Lanjouw and Schankerman, 2004). Applicants intend to claim as much rights as possible to describe their inventions fully. However, patent examiners may require applicants to narrow the scope of patent protection and only keep the claims that cover patentable technologies. Thus, on the one hand, the higher number of claims indicate a broader scope of technology. On the other hand, it can also represent the complexity of patent examination process (Popp et al., 2004; Harhoff and Wagner, 2009; Liegsalz and Wagner, 2013), because examiners need time to review all the claims and make decisions on which ones should be kept. It is observed that a greater number of claims leads to a longer patent examination duration, regardless of the outcomes (Harhoff and Wagner, 2009; Liegsalz and Wagner, 2013).

3.1.4 Information Processing and Decision-making

Information processing is a process that a processor, such as a computer, takes in information and generate an output following specific procedures. Shannon (1949) first, from the cognitive psychology perspective, explains information processing as an approach to understand human thinking, which is related to how people deal with the same type of information as computers. In the information processing theory, the mind is treated as a computer, which is responsible for analyzing information gathered from the environment. After actively manipulating the information, there is an output generated which is stored in the memory for future usage (Gray, 2010). Human beings use the processed information to communicate with the environment or make decisions. Hence, researchers treat information processing as a crucial aspect for decision-making (Saaty, 1990; Wu and Cavusgil, 2006; Bettis-Outland, 2012).

Since information processing is an approach to dealing with information from the environment, information attributes can affect the process, thereby influencing the decision-making of the information processor. There are two information attributes that have been discussed. One is information ambiguity (Paul and Nazareth, 2010; Luippold and Kida, 2012; Bettis-Outland, 2012), the other is information complexity (Streufert, 1973; Iselin, 1989; Chewning Jr and Harrell, 1990; Hwang and Lin, 1999).

Information ambiguity arises from insufficiency and complexity of information (Luippold and Kida, 2012; Bettis-Outland, 2012). Information sufficiency refers to the information set that contains the necessary evidence for making a correct judgment. The more sufficient information, the more accurate the decision is. However, information sufficiency is different from information completeness; sometimes even if the information set contains complete data, the necessary evidence for accurate decision-making can still be lacking, as the complete information set does not necessarily represent all the relevant data for decision-making (Luippold and Kida, 2012). Thus, information insufficiency causes ambiguity in making decisions. For example, when hiring an employee, a fancy and complete resume does not guarantee the employment. Usually, the hiring manager also needs to assess whether the candidate's working experience is related to the job description or not. If the candidate's skill set does not fit the position, no matter how complete the resume is, the candidate still cannot be hired.

Information complexity is also considered as information overload, which means that the amount of information exceeds the decision maker's processing capability. Complex information requires an extensive information processing to extract the most relevant information for decision-making. Paul and Nazareth (2010) conduct experiments and find that the complexity of input information slows down the individual's decision-making process, as well as group decisions. Later, Chewning Jr and Harrell (1990) use a decision-making experiment to analyze the relationship between information overload and information usage during the decision-making process. They find an inverted U-shaped relationship between information usage and information load. When individuals are over-loaded with information, they tend to use only a small portion of it which is relevant to decision-making. This conclusion is based on the findings about information relevance and decision-making from Streufert (1973). Streufert (1973)'s study suggests that irrelevant information increases information searching, thus, slow down the decision-making process. Hence, increasing the proportion of relevant information within a constant information set can help decision makers to filter the noise contained in the information set and make proper decisions.

Our research builds on the previous research and contributes to understanding how technological diversity affects patent examination durations that lead to different outcomes (grant, rejection and withdrawal). We define technological diversity based on the existing theory of knowledge recombination. We also consider patent claims' effects on the examination process as the claims contain technological information of a patent and patent examiners make approval decisions mainly based on patent claims. Inspired by the modelling method used by Harhoff and Wagner (2006), we estimate competing risks hazard models (Fine and Gray, 1999) to find what factors can accelerate/decelerate the decision making process of patent examiners, incorporating the insights from the information processing literature.

3.2 Hypotheses

3.2.1 Technological Diversity of Patent Applications and the Duration of Examination

Technological novelty arises from a process of (re)combining existing and/or new technological components (Fleming, 2001; Fleming and Sorenson, 2001). Research has shown that which components (i.e., interdependent, distant, familiar, etc.) to combine has great implications for the resulting technologies (Fleming and Sorenson, 2001, 2004). One interesting finding is that the diversity of the combined technological components seems to have a non-linear relationship with impact or usefulness of resulting inventions (Leten et al., 2007; Miller et al., 2007; Sampson, 2007). For example, using a dataset of the patents from 1,644 companies from 1985 to 1996, Miller et al. (2007) find that combining interdivisional knowledge has the strongest positive effect on the impact of a patent than using intradivisional knowledge or extraorganizational knowledge. This non-linear relationship between technological diversity and innovation performance has also been found in other contexts. At the firm level, Leten et al. (2007) point out that a diversified technological knowledge base can offer opportunities for technological cross-fertilization, therefore more conducive to creative technological inventions, however, a highly diversified technological portfolio increases the costs to coordinate across and combine knowledge from different domains and thereby dampening the innovation performance of an organization. In a similar vein, Sampson (2007) examines the effects of firms' alliance partners on their innovation performance and find that a moderate level of technological diversity of a firm's R&D alliance partners contributes the most to the firm's innovation.

We argue that such a non-linear relationship also exists at the patent level in the process of patent examination: technological diversity of a patent application has an inverted-U shaped relationship with the duration of patent examination. Patent examination is a process of evaluating the patentability of each patent application, which ultimately leads to a decision. During this process, an examiner evaluates the quality of a patent application using its technological information and makes the decision to either accept or reject it based on certain criteria. In China, the three criteria are novelty, inventiveness, and practical applicability (Article 22, Patent Law of China, 1985).

In this study, we argue that patents' technological diversity can influence the speed of examiners' decision-making. If a patent application has a low level of technological diversity, it means that the invention resides mainly in a few technological domains. The elements combined in this application are likely drawn from a pool that can yield only very limited number of potential combinations. Therefore, this application has a higher risk of having been seen or being similar to a previous invention. In this case, the examiner will have ambiguous information to evaluate its novelty and inventiveness. He/she will have to compare the current application against many published others. He/she might also have to return the application and require the applicant(s) to make it clearer on how it is different from others, following the rule used in China that all patent applications must be given at least one chance for revision before being rejected. Hence, the patent examination process will be extended. On the other hand, if a patent application has a higher level of technological diversity, it means that it draws on many different technological domains (but with a clear focus on one domain) and combine elements from those diverse domains together. The number of potential combinations that can be derived from many technological domains are much greater than that from only a few domains. Consequently, the chances that a patent application drawing on many technological domains has been seen or is similar to others are much lower. Moreover, such an invention is less likely to be regarded as obvious by the experts skilled in any of these domains, thereby fulfilling the criterion of inventiveness more easily. The examiner, therefore, will experience less ambiguity about the novelty and inventiveness of the patent application. The examination process can be shortened, because the examiner will only need to evaluate its practical applicability.

The relationship between technological diversity of a patent application and the duration of examination is not linear. A patent application with a very high level of technological diversity contains elements distributed evenly in many technological domains (for example, lack a clear focus on any domain). Such an application might take the examiner long time to make the decision. Although high technological diversity increases the novelty and inventiveness of a patent application and reduces the time that the examiner takes to determine its novelty, it does not necessarily accelerate the patent examination process. The examiners still need to dive into those different technological domains and investigate whether the proposed invention is feasible and practical. An application that combines a variety of technologies is likely to exceed the expertise of the assigned examiners, who then will need to spend time studying by themselves or asking others for help to make an informed judgment. His/her workload to examine the application will to a large extent increases. Thus, we expect that, when a patents technological diversity is very high, the examination duration will increase. Based on the analysis above, we reach to our first hypothesis:

Hypothesis 1: Technological diversity of a patent application has an inverted-U-shaped relationship with the duration of patent examination. The duration that leads to a decision, either grant or rejection, is the shortest when a patent application has a moderate level of technological diversity.

3.2.2 The Moderating Effect of Claims

Patent claims contain crucial information about how patent applications are different from existing technologies, and they define the boundaries of rights patents enjoy once granted. Patent examiners use claims as a source of information to classify applications into various technological fields and evaluate the patentability of the applications. Their decisions to a large extent rely on claims. They base their decisions (at least partially) on whether the claimed rights can be supported by the description of the inventions applied to be patented. According to the Guidelines for Patent Examination of SIPO (Part II, Chapter 2, Article 3.2, 2010), patent claims should be supported by the description, clear and concise.

It is inconclusive in the literature what quality of a patent its claims can demonstrate

(Harhoff and Wagner, 2009). Some scholars have used the number of claims to capture the complexity of a patent application (Harhoff and Wagner, 2009). Others have used the length of the principal claim as a proxy of novelty of a patent application (Tong et al., 2018). Still others have used the number of claims to measure the value of the property rights granted to a patent (Lanjouw and Schankerman, 2004).

In this study, we use the number of claims to capture the quality of writing of a patent application, in another word, the degree to which the claims clearly and concisely describe the invention. SIPO charges RMB 150 Yuan for each of the additional claims when the number of claims exceeds 10. It means that the application costs for patents with more than 10 claims are higher than those with less than 10 claims. We construct a dummy variable indicating whether a patent application contains any paid claims. Since the applications with more than 10 claims incur higher costs, we assume that the underlying technological inventions in those applications are very important to the applicants, who are eager to have those technologies protected with IP rights as soon as possible. Therefore, applicants are more likely to invest more efforts in the applications with more than 10 claims to ensure they get through the examination process fast. As a result, these applications tend to be written more clearly with less ambiguity or confusion.

Clear writing style of patent applications contain less ambiguous information that requires patent examiners to spend a lot of time processing. When a patent application is well written, it is easier for examiners to evaluate its novelty, inventiveness and practical applicability. Specifically, for well written applications with too low technological diversity, examiners can use claims to narrow down the prior art to compare with; similarly, for well written applications with too high technological diversity, examiners can also use claims to direct their effort to find relevant information to evaluate practical applicability. The ambiguity inherent in the applications with too low or too high technological diversity therefore can be attenuated if they are well written. This leads to our second hypothesis:

Hypothesis 2: The number of claims moderates the relationships between patent technological diversity and examination duration. For the patent applications that have more than 10 claims, the effect of technological diversity on the duration of examination is weaker.

Chapter 4

Methods

4.1 Data

We collect the bibliographic data of all invention patent applications published between 1985 and the end of 2017 from SIPO[16]. After removing the duplicated records, we obtain a dataset of 6,916,439 patent invention applications grouped into 35 technology areas by the main IPC code (Schmoch, 2008).

We choose the applications in the field of pharmaceuticals that have entered the stage of substantive examination as our research sample. The reasons that we choose pharmaceutical applications are twofold. First, pharmaceutical products highly rely on complex scientific and technological knowledge (Brusoni et al., 2005). Patenting activity is an essential source of technological advantage in the pharmaceutical industry. Second, pharmaceutical manufacturers need patent rights to protect their profits. All pharmaceutical products including patented or generic ones can be put into the market as long as they have the listing approvals from China Food and Drug Administration (CFDA). Therefore, in order to get a monopolistic market share and prevent others' imitation, pharmaceutical

[16] China Intellectual Property Right Net website: `http://english.cnipr.com/`. Last visited October 9th, 2018.

manufacturers need and prefer to obtain patent rights even before they put the products into the market. Thus, they should want to understand patent examination process better in order to get patent rights as soon as possible.

We include only the applications that have entered substantive examination into our risk set, because we believe that the starting date of substantive examination should be the starting point of the duration until the final decisions are made, not the application date. According to the Patent Law of China, the applicants must make a request of substantive examination within three years after the application date; otherwise, the applications would be regarded as withdrawn. This means that applications do not enter substantive examination automatically, and that only those having experienced substantive examination can ultimately receive decisions of grant or rejection from SIPO. Given our research question, it is more appropriate to only include those applications that have entered substantive examination stage, as only they are at the 'risk' of being granted or rejected. We are also aware that while applications are under substantive examination, the applicants can still withdraw them, therefore, withdrawal should also be one of the potential outcomes following substantive examination. Even though withdrawal of patent applications is not our focus, as this is the decision of applicants rather than patent examiners, we still include it into our competing risk hazard rate model to avoid biases when we test our hypotheses (see below for more details).

Our final sample includes 283,884 patent applications (with the main IPC code as A61K, but excluding A61K-008, see Schmoch (2008)). Out of these applications, 92,812 are granted, 19,630 are rejected, 47,305 are withdrawn and 124,137 are still pending at the end of our observation period (December 31st, 2017).

4.2 Analysis

4.2.1 Survival analysis

The pending applications at the end of our observation period represent right-censored cases (Tuma, 1984). Without including them in the sample, the results would be biased. Including the right-censored cases into our sample, we cannot use ordinary least square regression to model the examination duration. Instead, we use survival analysis.

Survival analysis is used to analyze the expected duration of time starting from when research objects enter the risk set until the event of interest occurs to them (for example, exit the risk set). A basic concept is survival function defined as:

$$S(t) = P(T > t), \quad t > 0 \tag{4.1}$$

where T is a random variable that represents the duration, beginning at t_0 (for example, the time when a research object enters the risk set), until an event occurs (for example, the object experiences the transition from (origin) state k to (destination) state j and exits the risk set). Survival function defines the probability of that the duration until an event occurs is at least t, and that the event occurs later than t (Broström, 2012). From this perspective, survival analysis essentially analyzes the transition rate, namely the probability of the change of state from k to j in a very short period of time from t to $t+ \Delta t$. As Δt is increasingly closer to 0, the transition rate can be written as:

$$r(t) = \lim_{\Delta t \to 0} \frac{P(t \leq T < t + \Delta t | T \geq t)}{\Delta t}, \quad t > 0 \tag{4.2}$$

In this study, we are interested in the rates of grant and rejection but include the rate of withdrawal in the data analysis. When a patent application enters substantive examination, it can face any of the three outcomes, and it will experience only one of them

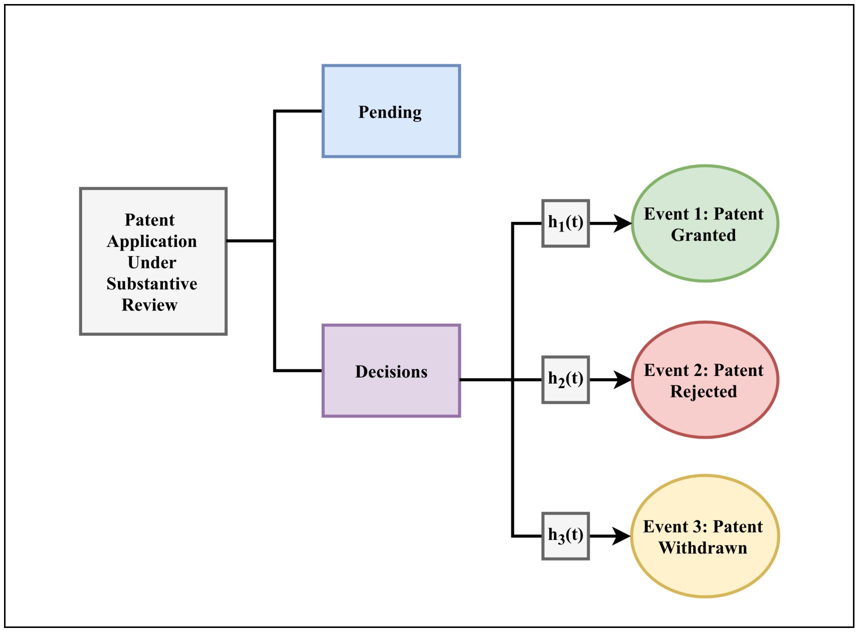

Figure 4.1: Competing Outcomes for Patent Applications under Substantive Examination

if any. In other words, the three outcomes are competing with one another. The process that a patent application goes through once the substantive examination is requested (until December 31st, 2017) is shown in Figure 4.1.

We use exponential hazard rate model to find out how the transition rates are dependent on a set of covariates. Specifically, we are interested how patents' technological diversity and its interaction with the number of claims affect the transition rates to grant or rejection. The higher the transition rates, the sooner the application receives a decision (Hansen, 1999). The exponential hazard rate model assumes that the duration variable T can be described by an exponential distribution (Blossfeld et al., 2012) and takes the following form:

$$r(t)_i = r(t)_i^* \cdot exp(\beta_1 D_i^2 + \beta_2 D_i + \beta_3 D_i^2 C_i + \beta_4 D_i C_i) \tag{4.3}$$

where $r(t)_i$ is the rate of decision of patent application i, t is the duration from the beginning of substantive examination until the decision is made about i, and $r(t)^*_i$ is the rate of decision including the effects of all control variables. The effects of the independent variables are shown in the rest of the equation. D_i represents the level of technological diversity of patent application i, C_i indicates whether the patent application i contains more than 10 claims. Hypothesis 1 is supported if $\beta_1 < 0$, and hypothesis 2 is supported if $\beta_3 > 0$.

4.2.2 Imputation of Missing Dates

To conduct survival analysis, it is important to identify the time point when each research object enters and exits the risk set. In this study, the entering time of each application into the risk set is the starting date of substantive examination and the exiting time is the date a decision (grant or rejection) is made or the date when it is withdrawn. Some of the records in our data do not have complete information about those dates, mostly those applications that filed in late 1980s and early 1990s when data collection was yet standardized. We take several measures to impute the missing dates.

We impute missing substantive examination dates for applications with decision dates or with the legal status of under substantive examination[17] from application dates and publication dates following the steps below. First, if both the application date and the publication date are available, we consider the publication date first, because the publication date is closer to substantive examination date than the application date. If the publication date is earlier than the decision date (the date of grant, rejection or withdrawal), we use the publication date as the substantive examination date. If the publication date is later than the decision date (which is likely to be an error, as it is rare, if not unlikely), we set the substantive examination date as 18 months after the application date, because substantive examination usually starts after an application is published 18 months after

[17]We do not impute missing substantive examination date for withdrawn applications because they could be withdrawn before or after substantive examination was requested. As a result, we cannot conclude whether those applications have actually entered the stage of substantive examination.

the filing date. Second, if only the application date is available, we also use the application date plus 18 months as the substantive examination date.

We impute missing grant dates if we can infer that applications have been granted patent rights. There are three possible situations. First, if an application has a waive date, it means it has been granted. According to Patent Law of China, if applicants of granted applications do not pay due fees within 2 months after receiving the notification of grant, it is regarded that they waive the patent rights. In this case, we use the date two months before the waive date as the grant date. Second, if there is a decision-made date (appears in early applications before 1993), as well as a termination date (when the owner stops paying renewal fee or when the patent reaches the maximum protection period specified in the law) or a waive date, this application is likely to have been granted patent rights. In this case, we use the decision-made date as the grant date. Third, if there is only a termination date, the situation can be more complicated. If a substantive examination date is available, we use the date plus 12 months as the grant date. It is because it normally takes 6 to 18 months after the substantive examination starts and we use 12 months as it is the mid-point of the range. If the substantive examination date is not available, but the publication date is, then we use the publication date plus 12 months as the grant date (as we have set the substantive examination date as the publication date for those cases). Fourth, if neither the substantive examination date nor the publication date is available, we set the grant date at 30 months after the application date (the substantive examination date is set at 18 months after application date and the grant date is 12 months after the imputed substantive examination date).

Finally, we impute missing rejection dates for the applications that can be inferred having been rejected. These cases do not have the grant date, withdrawal date, waive date, or termination date, but the decision-made date. We then code the decision-made date as the rejection date.

4.3 Variables

4.3.1 Dependent Variables

Our dependent variable is the duration of patent examination in months. The starting date is the date when an application enters substantive examination. The end date is the date when an application is granted with patent rights, is rejected or is withdrawn by the applicant(s).

4.3.2 Independent variables

Technological diversity. We keep the first four digits of the IPC code assigned to each application. The first four digits include the section, class and subclass of a specific IPC category. We calculate technological diversity of a patent application as following:

$$Technological\ Diversity = 1 - \Sigma_i \left(\frac{number\ of\ IPC_i}{total\ number\ of\ IPC}\right)^2 \tag{4.4}$$

where IPC_i represents each unique IPC code assigned to an application. This index takes into account not only the number of unique IPC's, but also the distribution of the assigned IPC's. The higher the index, the more diversified technological elements are combined in an invention.

Paid claims. We create this variable based on the total number of claims for each application. It is a dummy variable that indicates weather a patent application contains more than 10 claims. According to Chinese Patent Fees Schedule published by SIPO[18], applicants must pay, when filing the application, RMB150 Yuan for each additional claim when the number exceeds 10. We use this variable to interact with technological diversity

[18] According to SIPO website: http://english.sipo.gov.cn/application/howtopct/200804/t20080416_380500.html. Last visited August 9th, 2018.

to examine its moderating effect on the relationship between technological diversity and the duration of patent examination.

4.3.3 Control Variables

We include following control variables that might have significant effects on the duration of patent examination.

The number of assigned IPC (No. of IPC). We control for the number of IPC being assigned to an application. Prior research has used this variable as a proxy for the complexity of examining an application and found that it can slow down the process of examination at both EPO and SIPO (Harhoff and Wagner, 2009; Tong et al., 2018). Since this variable as a skewed distribution, we include the logarithm form of this variable in our data analysis in order to avoid the biases brought about by outliers.

Application assigned with one IPC (Single IPC). There are significant number of applications that have assigned with only one IPC. In case there are some significant unobservable differences between them and others, we include a dummy variable indicating whether an application has only one IPC code into the analysis in order to reduce the potential biases.

Application with one claim (Single claim). For the same reason mentioned above, we also include another dummy variable indicating whether an application only has one claim. We create a dummy variable to control the applications with only one claim.

Application filed by a business-academic alliance (Business X Academic). We identified those applications that are filed by business companies together with academic institutes, such as universities or research institutes. Some studies have found that the alliance with academic institutes can help firms to generate more inventions and increase their innovativeness in biotechnology than those firms without such linkages (George et al., 2002). This is because the collaboration between business companies and academic institutes can pool scientific talents and business talents together and facilitate knowledge sharing. The resulting patent applications might be more innovative and of higher quality, therefore faster to be granted and less likely to be rejected.

Application filed by one applicant (Single applicant). We control for the effect of single applicant, be it is an organization or an individual. A single applicant enjoys full patent rights if the application is granted but also assumes all the costs incurred by the R&D activities and the patent application process. A single applicant has limited resources (compared with multiple applicants), which might have implications for the quality of the patent application, which in turn can affect the duration of examination process.

The number of inventors (Total inventors). The inventors do not necessarily the same as the applicants of a patent. An inventor is an individual who contributes his/her knowledge and expertise to an inventionn to be patented. It is widely accepted that innovation arises from the combinations of existing knowledge elements stored in organizational knowledge repositories (Yayavaram and Ahuja, 2008; Nerkar, 2003). Knowledge workers are one type of knowledge repositories. A group of inventors working together can facilitate the combinations of different knowledge elements possessed by each of them. The more inventors combining their knowledge, the more likely the innovativeness of the resulting technological invention is high. We therefore expect the number of inventors might affect the duration of patent examination. In our analysis, we include the logarithm form of this variable due to its skewed distribution.

Application of an invention invented by one person (Single inventor). Given that there are many applications that involve only one inventor (about 46%), we include a dummy variable to control for the effect of single inventor.

Application filed by individuals (Individual applicant). In our dataset, we can distinguish two different types of applicants. One is organizational applicant and the other is individual applicant. It is less likely that individuals file patens for strategic reasons than organizations. Hence, they may not care about the results of patent examination as much as organizations. The investment into the invention is also likely different. All these can potentially affect the duration of examination process.

Application filed through PCT (PCT application). Following Tong et al. (2018), we create a dummy variable to indicate whether an application is filed through the PCT route. Most (not all) of such applications are filed by foreign companies from overseas. Due to the institutional delays (for example, time spent on looking for agents and on translation documents) and the lack of knowledge about China's patent system, those applications might experience longer waiting time before they receive a decision.

Application filed through the Paris Convention (Paris Convention application). Filing through the Paris Convention route is another way to obtain patent rights in China. It takes a different process than the PCT route (for details, please refer to Section 2.2). We include a dummy variable indicating whether an application is filed through the Paris Convention route. Since an application can be filed through PCT, or Paris Convention route, or directly with SIPO, the estimated parameters of *PCT application* and *Paris Convention application* essentially show the differences between these two application routes with the direct filing (for example, the route taken by most Chinese applicants)

Application represented by patent agency (Patent agency). We include a dummy variable to indicate if an application is represented by a patent agency. According to the Chinese Patent Law, domestic applicants have the rights to decide whether to use patent agencies. The establishment of the patent agency system accompanied the development of the patent system in China. Patent agencies are organizations aiming to provide professional service to patent applicants. They are responsible to help applicants to write effective applications and to respond to patent examiners' requests in a timely manner. Therefore, we expect that a patent application represented by a patent agency will wait shorter before it receives a decision from SIPO.

Chinese priority right. We separate international and domestic rights of priority. If an application has been filed in other countries before being filed in China, it has a right of priority of 12 months starting from the first filing date. It means that if granted, the patented technology will be protected starting from the first filing date, rather than the date of application in China. The effect of international priority can be controlled for by

PCT application and Paris Convention application, as most of those applications enjoy international rights of priority. Domestic applications can also have rights of priority if applicants file subsequent applications on the same subjects within 12 months after the first applications. The protection will start from the first filing date if patent rights are granted. It is often a strategic decision made by applicants when they want to get the ongoing inventions protected as early as possible. These inventions might be very important for the applicants or so challenging that the R&D will take long. Given the potential strategic importance of applications with national priority rights, the dummy variable indicating whether an application has national priority right might have a significant effect on the duration of examination. Therefore, we include it in our analysis.

Application with a request for early publication (Early publication request). We include a dummy variable indicating whether an application is requested to be published early. According to Chinese Patent Law, all applications will be published 18 months after the application date on the condition that they passed the preliminary examination, thereby entering the pool of prior art for subsequent applications. The substantive examination usually starts after applications are published. Early publication can trigger early start of substantive examination. Early publication can be initiated only by applicants request on the application date. Applicants request early publication often to block competitors and/or to get the inventions protected as soon as possible (especially when the technology is easily copied or improved by others). These applications might have some characteristics that affect the length of examination duration.

Divisional application. According to the Implementation Regulation of Chinese Patent Law, one patent application should contain only one invention. When a patent application contains two or more inventions, the applicant will be requested to separate them and to file an individual application for each of them. This is called divisional applications. We expect that being requested to file a divisional application might increase the examination duration as it breaks the process. Thus, we create a dummy variable to indicate whether an application is a divisional application.

Annual applications. At the system level, we control for the workload of Chinese patent system measured by the number of filed applications per year from 1985 to 2017. We include the logarithm form of this variable in the analysis due to its highly skewed distribution.

Legal periods. Finally, we include historical time period dummies to control for fluctuations in the environment surrounding the Chinese patent system as a result of historical, institutional and organizational shifts, which can affect the examination duration. We divide the time between April 1st, 1985 and December 31st, 2017 into five periods. The first three periods are corresponding to the effective duration of the first three versions of Patent Law: the first period is from April 1st, 1985 to December 31st, 1992, the second is from January 1st, 1993 to June 30th, 2001, and the third is from July 1st, 2001 to September 30th, 2009. We further divide the period after the fourth version of Patent Law became effective (on October 1st, 2009) into two periods: before and after March 14th, 2011. The reason is on March 14th, 2011, the Chinese government released the 12th Five-Year (2011 – 2015) Plan for the National Economic and Social Development[19], in which it proposed a goal of having 3.3 granted patents per 10,000 people. This was the first time the government included number of granted patents per 10,000 people as an index of national capability of invention and innovation. We expect this will not only cause a drastic increase of the number of patent applications, but might also influence the patent examination process. We include four time period dummies in our models, except for the first period that serves as the reference category.

The definitions of all variables included in our statistic models and descriptive statistics are presented in Table 4.1.

[19]Source,http://www.lse.ac.uk/GranthamInstitute/wp-content/uploads/2018/04/1314.pdf. Last visited October 9th, 2018.

Variables	Definition	Mean	S.D.	Min.	Max.
Dependent Variables					
Grant duration	Duration from substantive examination date to grant date	25.10	14.90	0.23	190.6
Rejection duration	Duration from substantive examination to rejection date	37.21	17.62	4.14	185.95
Withdrawal duration	Duratrion from substantive examination to withdrawal date	26.86	12.73	0.23	143.8
Independent Variables					
Technological diversity	Calculation of technology diversity index for the patent application	0.40	0.18	0	0.89
Paid claims	Whether number of claims is greater than ten (0/1)	0.09	0.29	0	1
Control Variables					
No. of IPC	Number of IPC classifications assigned to the patent application	4.28	2.82	1	93
Single IPC classification	Whether the application assigned to one IPC classification (0/1)	0.06	0.24	0	1
Single claim	Whether the application contains one claim (0/1)	0.54	0.50	0	1
Business X academic	Whether business and academic applicats cooperated (0/1)	0.01	0.10	0	1
Single applicant	Whether the application has one applicant (0/1)	0.94	0.24	0	1
Total inventors	Number of total inventers in the application	2.67	2.30	1	52
Single inventor	Whether the application has one inventor	0.46	0.50	0	1
Individual applicant	Whether the applicant is an individual (0/1)	0.42	0.49	0	1
PCT application	Whether an international patent files through PCT route (0/1)	0.13	0.34	0	1
Paris Convention application	Whether an international patent files through Paris Convention route (0/1)	0.03	0.17	0	1
Chinese priority right	Whether the application has a Chinese priority right (0/1)	0.02	0.13	0	1
Early publication request	Whether the duration from application date to publication date is less than 18 months (0/1)	0.68	0.47	0	1
Divisional application	Whether the application is a divisional application (0/1)	0.03	0.16	0	1
Patent agency	Whether a patent agency is used in the application (0/1)	0.64	0.48	0	1
Annual applications	Number of patent applications in each year	21559	13581	168	42232
Legal period V2	Whether the application files during 1993.01.01 to 2001.06.30 (0/1)	0.07	0.26	0	1
Legal period V3	Whether the application files during 2001.07.01 to 2009.09.30 (0/1)	0.25	0.43	0	1
Legal period V4	Whether the application files durinf 2009.10.01 to 2011.03.13 (0/1)	0.06	0.23	0	1
Legal period V5	Whether the application files during 2011.03.14 to 2017.12.31 (0/1)	0.62	0.49	0	1

Table 4.1: Variable Definitions and Descriptive Statistics

Chapter 5

Results

5.1 Descriptive Analysis

Table 5.1 shows the descriptive statistic of Chinese pharmaceutical invention patent applications from 1985 to 2017. It shows a few interesting patterns. First, the number of pharmaceutical invention patent applications that enter into the substantive examination process in general increases over years, especially after 2010, the increase is almost exponential. Second, the proportion of Chinese applications fluctuates over time. When the patent system was just established, most of the applications were filed from overseas, only about 30% were domestic. It may suggest that the understanding of intellectual property rights were lacking in China at that time and most of inventors did not know how to protect their and others' intellectual property rights by filing patent applications. The percentage slowly increases as China's patent system is developed until 1993 when the second version of Patent Law took effect. After that, the percentage starts to decrease until 1999. The decrease might be caused by the China's joining in PCT in 1994 and large number of foreign applications flooded in through PCT. The percentage has been increasing since 1999, reaching 99.72% at the end of 2017. This trend is coincident with the surge of the number of Chinese applications in the last two decades. Third, the average technological diversity of the applications each year gradually increases over time and stabilized in the range of 0.35 – 0.43 after 2000. It might mean that the technologies in the pharmaceutical industry grow increasingly more complex, but stop at a medium level, which seems to provide support to our hypothesis 1.

Figure 5.1 shows the distribution of the three examination decisions. It shows that the durations for grant decisions are mainly between 10 and 25 months, while the ones for rejection are usually longer, which range from 20 to 36 months. Figure 5.2 shows the distribution of the average durations for different decisions by year. In general, the average durations for all the three decisions have a downward trend. It is noteworthy that the durations for grant seem to decline the fastest, especially after 1993, and since then the rejection pendency has been longer than those for grant.

Filing Year	Applications Entering Substantive Examination	Grant Share (%)	Rejection Share (%)	Withdrawal Share (%)	Domestic Application Share (%)	Avg. Number of Claims	Avg. Technological Diversity
1985	188	72.34	7.98	19.15	30.32	7.93	0.14
1986	168	64.88	4.76	27.98	37.50	9.04	0.13
1987	196	63.27	5.61	28.57	45.41	7.94	0.07
1988	235	47.23	6.81	43.40	48.94	8.75	0.08
1989	216	43.52	4.63	47.69	55.56	9.05	0.10
1990	282	41.49	5.32	46.45	58.51	8.11	0.08
1991	347	44.96	6.05	45.82	59.08	8.06	0.09
1992	576	36.98	5.21	54.86	74.48	6.29	0.08
1993	1755	39.26	5.19	49.34	81.94	5.79	0.07
1994	1788	45.81	3.36	47.04	67.39	7.83	0.09
1995	1848	50.49	3.63	44.32	59.63	9.12	0.09
1996	2147	54.54	4.75	38.89	55.57	10.56	0.09
1997	2323	57.90	5.25	35.47	53.03	10.73	0.09
1998	2528	60.64	6.01	32.87	48.30	12.08	0.09
1999	2865	60.91	6.88	31.90	47.12	12.84	0.21
2000	3406	60.25	9.13	29.33	51.41	12.61	0.35
2001	3787	60.71	10.56	28.31	56.17	12.56	0.37
2002	5351	61.58	11.75	25.96	57.91	13.60	0.38
2003	7033	60.66	12.60	26.29	64.20	12.90	0.38
2004	7843	57.25	12.79	29.22	66.94	13.57	0.39
2005	10256	55.25	12.42	31.32	73.39	10.89	0.40
2006	10310	52.61	12.10	33.02	72.29	7.24	0.38
2007	9600	52.41	12.85	32.63	73.81	6.65	0.39
2008	10077	53.58	13.23	30.47	76.27	8.62	0.39
2009	10436	56.30	13.65	25.79	75.89	8.47	0.40
2010	11339	55.15	11.92	27.09	77.13	4.01	0.41
2011	13176	57.89	11.15	23.44	80.73	2.21	0.41
2012	17606	51.91	12.90	22.95	87.08	1.23	0.43
2013	22030	47.69	10.81	19.06	89.59	1.12	0.42
2014	35409	14.68	4.04	7.18	93.54	1.46	0.43
2015	42232	1.88	0.14	0.54	95.01	3.18	0.43
2016	32963	0.58	0.02	0.40	98.90	4.49	0.43
2017	13568	0.07	-	0.11	99.76	5.72	0.42
Total	283884	48.02	7.68	29.90	67.05	8.02	0.26

Table 5.1: Statistic of Pharmaceutical Invention Patents at SIPO (1985 – 2017)

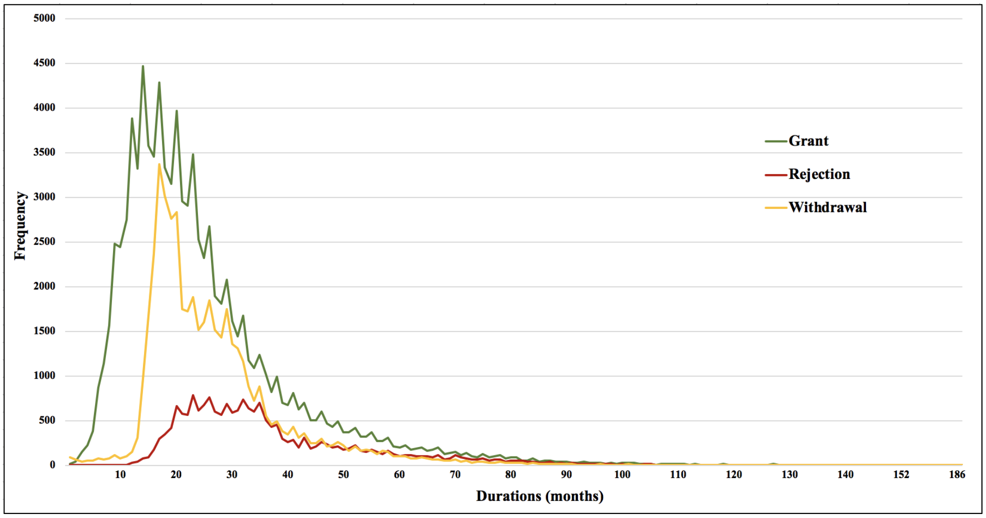

Figure 5.1: Pooled Patent Substantive Examination Durations

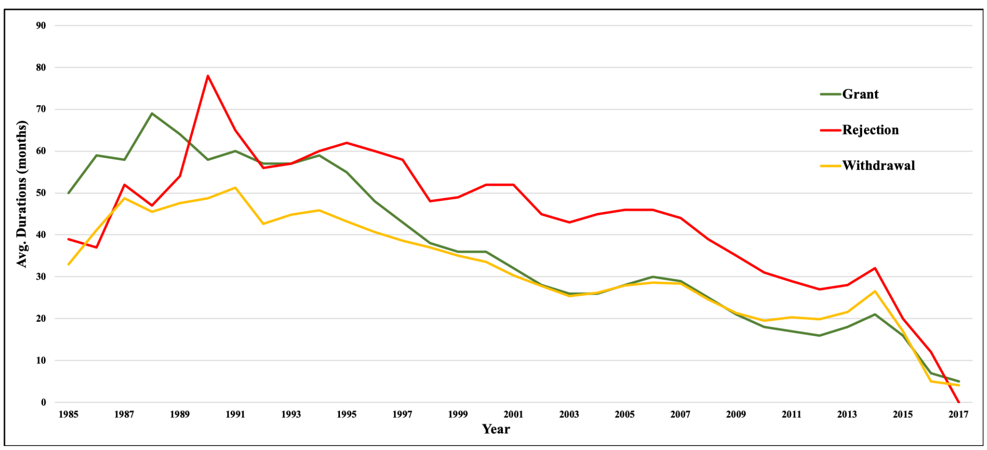

Figure 5.2: Average Durations of Patent Substantive Examination by Filing Year

5.2 Plot of Survivor Functions

Figure 5.3 is a plot of survivor functions for the three competing events – grant, rejection and withdrawal. The horizontal axis represents the duration since patent applications enter the substantive examination process; and the vertical axis represents the proportion of applications. We can see that, at the origin point, the proportion of pending applications (i.e., survivors) is 100%. It decreases while the proportion of applications that experience a decision (i.e., deaths) increases. The proportion of granted application starts to increase quickly after around 12 months and levels off after around 84 months at about 55%. It means that applications start to be granted with patent rights 12 months after they enter the substantive examination. The proportion of the granted increases as the waiting time increases, but most of the applications being granted with patent rights receive the decision before 84 months since the starting of the substantive examination. After 84 months, it is rarely that an application will be granted with patent rights in pharmaceuticals. The trend is to a large extent similar for the other two events. The proportion of rejected applications increases after 24 months and levels off after 108 months at about 13%. It means that, in general, to reject an application takes longer than to grant, and that the proportion of the rejected is much lower than that of the granted. Finally, the proportion of the withdrawn increases after 20 months and keeps constant after 96 months at 30%.

In sum, Figure 5.3 suggests that most of the patent applications in the pharmaceuticals are ultimately granted, followed by the proportion of the withdrawn, and then the rejected. The duration for the rejection seems to be the longest. It might be because patent examiners are required to give applicants up to two chances to revise their applications before making the rejection decisions. Finally, the proportion of pending cases drops to 0 after about 144 months under the substantive examination, meaning that by then all applications should have experienced one of the three events.

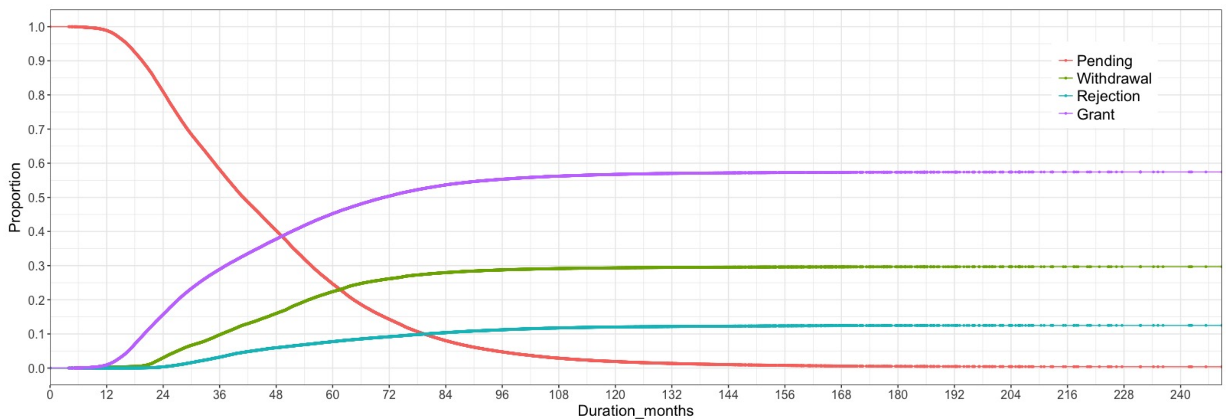

Figure 5.3: Survival Plot of Competing Events[20]

5.3 Results of Competing Risks Hazard Rate Models

Table 5.2 presents the correlation matrix of all the variables included in our analysis. The correlations are in general quite low among variables. It suggests that our results are not likely subject to any multicollinearity problem.

Tables 5.3 shows the estimated parameters of the competing risks hazard rate models for the effects of covariates on the rates of three outcomes following patent examination grant, rejection and withdrawal. Models 1 to 3 are on the rate of grant, Models 4 to 6 are on the rate of rejection, and Model 7 is on the rate of withdrawal. In Model 1 and Model 4, we include only the control variables. In Model 2 and Model 5, we add technological diversity and its squared term to test Hypothesis 1. In Model 3 and Model 6, we add the dummy variable of paid claims and its interactions with technological diversity (including both linear and squared terms) to test Hypothesis 2. Model 7 presents the full model for the rate of withdrawal as a comparison with the other two outcomes that we are interested in. The interpretation of the coefficients is intuitive. A positive coefficient means that an

[20]Survival plot is generated from R programming with package 'ggplot2'.

increase in the corresponding variable is associated with a shorter examination duration, which is equivalent to a faster decision-making process and a higher rate of the event in question. Likewise, a negative coefficient indicates that an increase in the corresponding variable slows down the decision-making process, and thus a lower rate of the event.

Variables	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
1. Technological Diversity																				
2. Paid Claims	-0.185																			
3. No. of IPC (logged)	0.273	-0.066																		
4. Single IPC	-0.582	0.146	-0.559																	
5. Single Claim	0.141	-0.344	-0.001	-0.120																
6. Business X Acidemic	-0.002	0.051	0.005	0.011	-0.019															
7. Single Applicant	0.017	-0.047	-0.004	-0.030	0.049	0.096														
8. Total Inventors (logged)	-0.036	0.145	0.039	0.023	-0.062	-0.090	-0.170													
9. Single Inventor	0.069	-0.178	-0.028	-0.045	0.080	0.132	0.183	-0.873												
10. Individual Applicant	0.069	-0.225	-0.047	-0.038	0.105	0.071	-0.040	-0.483	0.471											
11. PCT Application	-0.244	0.545	-0.134	0.201	-0.122	-0.265	-0.068	0.188	-0.233	-0.296										
12. Paris Convention Application	-0.083	0.173	-0.009	0.075	-0.066	-0.183	-0.016	0.072	-0.097	-0.133	-0.070									
13. Chinese Priority Right	0.014	0.012	0.038	-0.015	-0.023	-0.014	-0.024	0.044	-0.035	-0.029	-0.047	-0.021								
14. Early Publication Request	0.175	-0.354	0.109	-0.166	0.148	0.335	0.082	-0.112	0.142	0.176	-0.561	-0.121	0.062							
15. Divisional Application	0.021	0.060	0.069	-0.027	0.019	-0.123	-0.020	0.055	-0.062	-0.087	-0.064	0.614	0.016	-0.221						
16. Patent Agency	-0.125	0.205	-0.052	0.120	-0.132	-0.185	-0.058	0.287	-0.290	-0.283	0.295	0.135	0.025	-0.098	0.063					
17. No. of Annual Application (logged)	0.349	-0.287	0.267	-0.381	0.452	0.783	0.086	-0.082	0.123	0.068	-0.233	-0.253	-0.009	0.291	-0.102	-0.220				
18. Patent Law V2	-0.354	0.203	-0.314	0.396	-0.214	-0.354	-0.030	-0.016	-0.011	0.020	0.160	0.133	-0.013	-0.194	0.033	0.119	-0.590			
19. Patent Law V3	-0.015	0.243	0.023	-0.005	-0.397	-0.724	-0.064	0.072	-0.101	-0.060	0.190	0.073	0.020	-0.233	0.094	0.114	-0.395	-0.159		
20. Patent Law V4	0.013	-0.038	0.059	-0.026	-0.059	-0.314	-0.043	0.073	-0.075	-0.056	0.038	0.022	0.011	-0.043	0.040	0.027	-0.099	-0.069	-0.141	
21. Patent Law V5	0.224	-0.312	0.143	-0.229	0.507	-0.033	0.096	-0.090	0.132	0.071	-0.265	-0.183	-0.014	0.335	-0.123	-0.185	0.783	-0.354	-0.724	-0.314

Table 5.2: Correlation Matrix

Note: N = 283, 884

Variables	Grant			Rejection			Withdrawal
	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6	Model 7
No. of IPC (logged)	0.014	0.014	0.021	0.139 ***	0.130 ***	0.123 ***	0.066 ***
	(0.014)	(0.014)	(0.015)	(0.022)	(0.022)	(0.022)	(0.019)
Single IPC	-0.346 ***	-0.262 ***	-0.239 ***	0.065	0.040	0.034	0.133 ***
	(0.054)	(0.051)	(0.050)	(0.048)	(0.053)	(0.052)	(0.034)
Single claim	1.190 ***	1.190 ***	1.250 ***	0.467 ***	0.469 ***	0.546 ***	0.507 ***
	(0.092)	(0.092)	(0.092)	(0.042)	(0.042)	(0.045)	(0.031)
Business * academic	0.115 *	0.114 *	0.111 *	-0.184 *	-0.182 *	-0.193 *	-0.310 ***
	(0.050)	(0.050)	(0.050)	(0.087)	(0.087)	(0.087)	(0.059)
Single applicant	0.095 ***	0.096 ***	0.091 ***	-0.028	-0.031	-0.035	-0.235 ***
	(0.026)	(0.026)	(0.027)	(0.040)	(0.040)	(0.040)	(0.032)
Total inventers (logged)	0.119 ***	0.118 ***	0.121 ***	-0.001	0.003	0.001	-0.089 ***
	(0.017)	(0.017)	(0.017)	(0.025)	(0.025)	(0.025)	(0.020)
Single Inventer	-0.257 ***	-0.259 ***	-0.251 ***	-0.084 *	-0.084 *	-0.082 *	0.051
	(0.026)	(0.026)	(0.026)	(0.041)	(0.041)	(0.041)	(0.031)
Individual applicant	0.035 +	0.032	0.037 +	-0.095 **	-0.100 **	-0.095 **	-0.064 *
	(0.021)	(0.021)	(0.021)	(0.030)	(0.031)	(0.031)	(0.026)
PCT application	-0.604 ***	-0.579 ***	-0.725 ***	0.009	0.017	-0.088 +	0.350 ***
	(0.060)	(0.060)	(0.069)	(0.048)	(0.049)	(0.049)	(0.038)
Paris Convention application	-0.610 ***	-0.590 ***	-0.706 ***	-0.496 ***	-0.494 ***	-0.558 ***	-0.041
	(0.089)	(0.089)	(0.092)	(0.147)	(0.147)	(0.143)	(0.090)
Patent agency	0.575 ***	0.577 ***	0.581 ***	0.442 ***	0.446 ***	0.461 ***	-0.794 ***
	(0.022)	(0.022)	(0.022)	(0.030)	(0.030)	(0.030)	(0.023)
Chinese priority right	0.453 ***	0.455 ***	0.432 ***	0.064	0.064	0.015	-0.280 ***
	(0.049)	(0.049)	(0.049)	(0.074)	(0.075)	(0.076)	(0.066)
Early publication request	0.483 ***	0.480 ***	0.479 ***	0.082 *	0.080 +	0.096 *	-0.119 **
	(0.044)	(0.044)	(0.044)	(0.042)	(0.041)	(0.042)	(0.038)
Divisional application	-1.380 ***	-1.390 ***	-1.340 ***	0.089	0.089	0.114	-0.226 *
	(0.165)	(0.165)	(0.161)	(0.141)	(0.141)	(0.139)	(0.106)
Annual applications (logged)	-1.700 ***	-1.700 ***	-1.730 ***	-0.627 ***	-0.630 ***	-0.638 ***	-0.828 ***
	(0.085)	(0.084)	(0.084)	(0.081)	(0.081)	(0.081)	(0.081)
Legal period V2	4.440 ***	4.430 ***	4.450 ***	1.200 ***	1.200 ***	1.220 ***	1.520 ***
	(0.279)	(0.279)	(0.281)	(0.211)	(0.211)	(0.211)	(0.274)
Legal period V3	6.360 ***	6.330 ***	6.370 ***	2.890 ***	2.890 ***	2.930 ***	2.320 ***
	(0.341)	(0.341)	(0.343)	(0.307)	(0.308)	(0.309)	(0.344)
Legal period V4	6.400 ***	6.370 ***	6.470 ***	2.840 ***	2.850 ***	2.920 ***	2.170 ***
	(0.364)	(0.364)	(0.364)	(0.321)	(0.322)	(0.324)	(0.356)
Legal period V5	5.310 ***	5.290 ***	5.340 ***	2.370 ***	2.380 ***	2.430 ***	1.420 ***
	(0.430)	(0.431)	(0.431)	(0.374)	(0.375)	(0.376)	(0.411)
Technological diversity		0.594 ***	0.996 ***		0.428 *	0.305	-0.221
		(0.152)	(0.186)		(0.194)	(0.213)	(0.159)
Technological diversity^2		-0.691 ***	-1.100 ***		-0.929 ***	-0.748 *	0.287
		(0.201)	(0.234)		(0.279)	(0.307)	(0.231)
Paid claims			0.436 ***			0.236 ***	-0.004
			(0.075)			(0.062)	(0.041)
Technological diversity * Paid claims			-1.090 **			0.665 +	0.362
			(0.343)			(0.371)	(0.280)
Technological diversity^2 * Paid claims			1.150 *			-1.050 +	-0.497
			(0.495)			(0.629)	(0.447)
$\Delta\chi^2$ $(\Delta d.f.)$	-	279.8(2) ***	100.7(3) ***	-	18.1(2) ***	3.4(3)	-
No. of observations	283884	283884	283884	283884	283884	283884	283884
No. of events	92812	92812	92812	19630	19630	19630	47305

Table 5.3: Results from Fine-Gray Competing Risks Regression Models

Notes: Standard errors are reported in parentheses. + p <0.10, * p <0.05, ** p <0.01, *** p <0.001.

Model 2 of Table 5.3 shows that technological diversity has statistically significant effect on the rate of grant. Both the linear and the squared terms of technological diversity are highly significant ($p < 0.001$). The squared term is negative (coef. = -0.691), indicating that the technological diversity has an inverted-U-shaped relationship to the rate of grant. It means that a moderate level of technological diversity can help patent applications to get granted sooner. Figure 5.4 visualizes this non-linear relationship. It shows that the optimal level of technological diversity is about 0.45. As the level of technological diversity increases from 0 to 0.45, the rate of grant increases by 13%[21]. As the level of technological diversity further increases, the rate of grant decreases. When the level of technological diversity reaches 0.89, which is the maximum value of our sample, the rate of grant is almost the same as when the level of technological diversity is 0. This provides support for Hypothesis 1.

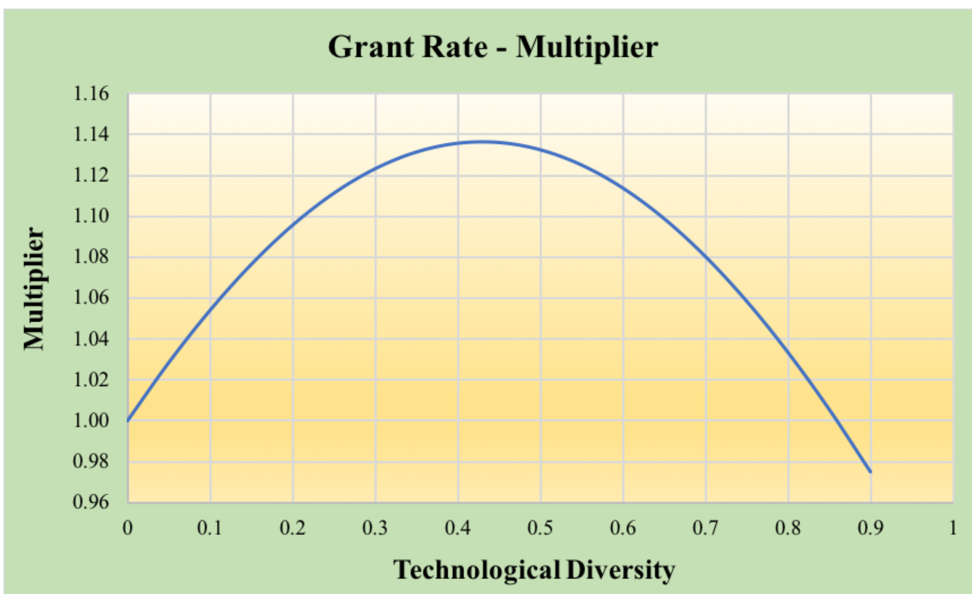

Figure 5.4: Relationship between Grant Rate and Technological Diversity

[21]It is calculated by setting all continuous variables at mean, all dummy variables at 0, except for *Single applicant* is set at 1. All interpretations of parameters in the rest of the results section are calculated in the same way.

We find similar results for the rate of rejection. In Model 5, the coefficient of the squared term of technological diversity is -0.929 and statistically significant ($p < 0.001$). It suggests that technological diversity has an inverted-U-shaped relationship with the rate of rejection, which is shown in Figure 5.5. As the level of technological diversity increases, the rate of rejection first increases and then decreases. The peak point is when the level of technological diversity is around 0.25, at which the rate of rejection increases by 5% compared with the cases when the level of technological diversity is 0. After reaching the peak point, the rate of rejection drops fast, and when the level of technological diversity reaches the maximum value, the rate of rejection decreases by about 30%. This result provides further support for Hypothesis 1. Technological diversity has inverted-U-shaped relationship with both the rates of grant and rejection; therefore, Hypothesis 1 is fully supported.

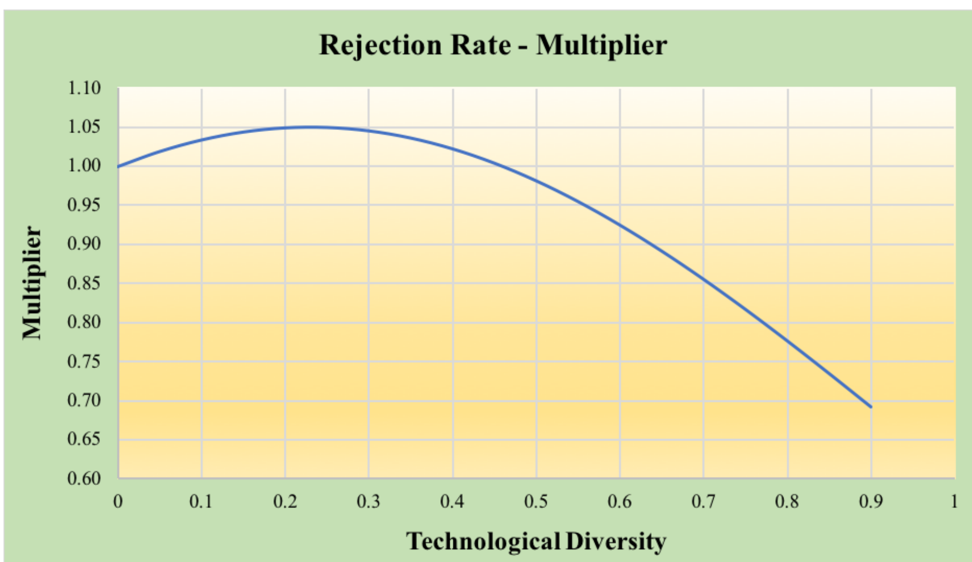

Figure 5.5: Relationship between Rejection Rate and Technological Diversity

Model 3 shows the moderating effects of paid claims on the relationship between technological diversity and the rate of grant. Both interaction terms are significant. The coefficient of the interaction between paid claims and the squared term of technological diversity is 1.150 ($p < 0.05$). It suggests that when patent applications have more than 10 claims, the effect of technological diversity is significantly weakened (i.e., the curvature of the relationship between technological diversity and the rate of grant is reduced, or less curved). This is clearly shown in Figure 5.6. For applications with more than 10 claims, technological diversity almost has no effect. As the level of technological diversity increases, the rate of grant monotonically and slowly decreases, but only by less than 5% when it reaches the maximum value. It seems that the effect of paid claims is so strong that it can override that of technological diversity. However, for applications with less than 10 claims, the effect of technological diversity persists. It still has an inverted-U-shaped relationship with the rate of grant, and the effect seems to be even stronger. The peak point is still at when the level of technological diversity is about 0.45, at which the rate of grant increases by about 25%, compared with that when the level of technological diversity is 0. This provides support for Hypothesis 2.

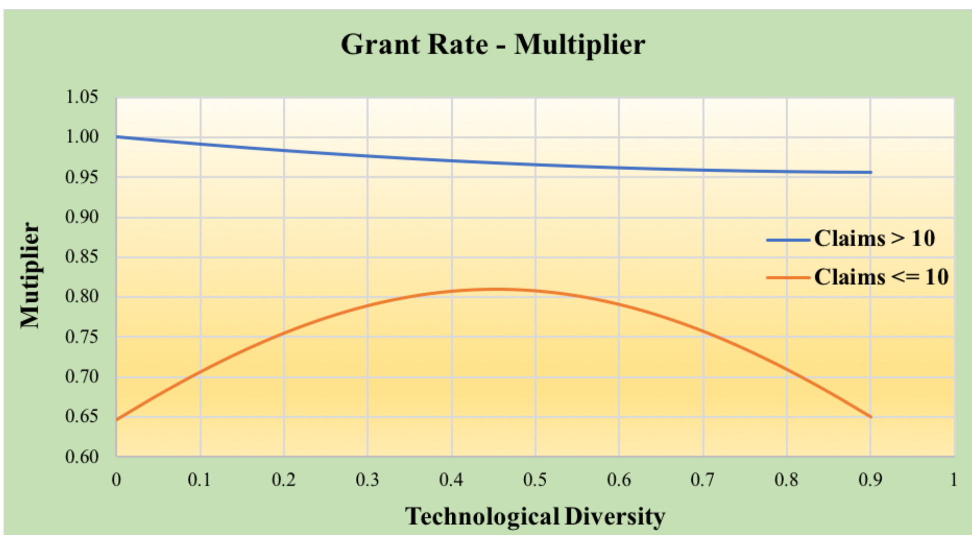

Figure 5.6: Moderating Effects of the Number of Claims on Grant Rate

It is noteworthy that the main effect of paid claims is positive (coef. = 0.436, p <

0.001)[22]. This suggests that applications with more than 10 claims wait shorter to be granted than those with less than 10 claims. This result seems to be consistent with our assumption that patent applications with more than 10 claims contain technologies that are more important to the applicants and therefore tend to be better written and less confusing, which can help them go through the examination process faster.

In terms of the rate of rejection, we do not find significant moderating effects of paid claims. In Model 6, the coefficients of the two interaction terms are only marginally significant ($p < 0.1$), whereas the squared term of technological diversity remains negative and significant (coef. = -0.748, $p < 0.05$). It suggests that the relationship between technological diversity and the rate of rejection is not moderated by paid claims. Our Hypothesis 2 is therefore only partially supported. Furthermore, similar to the rate of grant, paid claims has a positive main effect on the rate of rejection. This means that better written applications can in general accelerate patent examination process and reach the decision faster, be it grant or rejection.

As a comparison, we include the full model for the rate of withdrawal. The results are shown in Model 7. Interestingly, neither technological diversity nor paid claims has significant effect on the rate of withdrawal. This is probably understandable, as withdrawal is a decision made by applicants, which might follow very different logics than the decisions made by patent examiners. The applicant-driven decision can be much more complicated to make; it might involve factors such as strategic considerations, power structures within applicant organizations, and quality of communication among applicants, inventors, and with examiners.

[22]We also estimate the models without the interaction terms, the effect of paid claims is positive and significant for both grant (coef. = 0.284, $p < 0.001$) and rejection (coef. = 0.288, $p < 0.001$).

5.4 Effects of Control Variables

Other than the effects of independent variables, we also find some interesting results of the control variables. First, we find that the type of patent applicants can influence grant, rejection and withdrawal durations. For applications filed by individual applicants, it takes longer time to receive the decision of rejections or to be withdrawn. For those filed by business-academic collaborating applicants, the decision of grants is accelerated and the other two decisions are decelerated. These results are consistent with Tong et al. (2018)'s study using SIPO data. Second, we find that international patent applications in general experience different examination durations compared with Chinese domestic applications. Specifically, both PCT applications and applications through Paris Convention route have longer durations for grant decisions. These results are also found in the studies using EPO data and SIPO data (Harhoff and Wagner, 2009; Tong et al., 2018). Moreover, we also find some results that are different from prior studies. For instance, PCT applications get withdrawn sooner. This may be due to the high costs involved in the PCT application process. International applicants pay not only the patent examination fees to SIPO, but also other costs such as international delivery fees and the costs of using agencies. If the costs exceed the benefits, applicants will quickly make decisions to withdraw their applications. Third, we find that patent filing strategies can affect patent examination process as well. For example, if the applicants file applications with the help of patent agencies, they will enjoy faster decision-making, and less likely to withdraw their applications. Early publication request will accelerate the patent examination processes for both grants and rejections. If the applicants choose to file divisional applications, the patent examination duration for grants will be longer as dividing a new application from the original one suspends the examination process.

In summary, our Hypothesis 1 is supported by the competing risks hazard rate models. Hypothesis 2, however, is only partially supported. We do find a moderating effect of paid claims, but only on the rate of grant, and not on the rate of rejection. Other than the effects of our key covariates, we also find some other interesting findings, some of which are consistent with the prior research, while others are different. The differences between our results and those of prior research entail future research on patent examination durations.

Chapter 6

Summary and Discussions

6.1 Summary of the Findings

Patent examination is a crucial process to evaluate the patentability of technological inventions. Studying and understanding what affects the duration of patent examination can offer important insights for both patent applicants and patent system designers. This topic has attracted some research attention recently. There has been studies with a focus on world's major patent offices, such as USPTO (Xie and Giles, 2011), EPO (Harhoff and Wagner, 2009) and SIPO (Tong et al., 2018). Most of these studies aim to find out what factors can affect patent examination durations. They strive to depict a comprehensive picture and include many factors such as attributes of applications, applicants, application strategies and the surrounding environment. These studies are an excellent starting point that informs us what can affect patent examination durations. However, we still lack a deeper understanding of how patent examination duration is affected. In this study, we take a step into that direction. We focus on one important feature of patent application – technological diversity – and develop a theory about how it affects pendencies for both grant and rejection decisions, by itself and in conjunction with the number of claims. Our empirical analysis in general supports our theory.

Using 283,884 pharmaceutical invention patent applications filed in China from 1985 to 2017, we find that there is an inverted-U-shaped relationship between patent technological diversity and duration of patent examination regardless of the decision. This supports our Hypothesis 1. The finding suggests that a moderate level of technological diversity can help to accelerate decision-making in the process of patent examination, whereas a low or a high level of technological diversity slows down the process. Our explanation is that when technological diversity is moderate, it is less ambiguous for examiners to evaluate the novelty and inventiveness of patent applications without too much work needed to evaluate their practical applicability. This holds true for both outcomes of grant and rejection. However, the effects of technological diversity also differ for the two outcomes in a subtle way. The grant pendency is the shortest when technological diversity is about 0.45 (which is close to the mid-point of the data range), and it is about the same when the technological diversity is 0 or 0.89 (the highest value in the sample). The rejection pendency, however, is the shortest when technological diversity is about 0.25, but it is not much different from when technological diversity is 0; it starts to increase as technological diversity exceeds 0.25. This might be because for applications that are ultimately rejected, the time saved by unambiguous novelty and inventiveness is canceled out by the time spent on applicants' revisions. Thus, the level of technological diversity of applications to be rejected mostly reflects the amount of work that examiners need to do to evaluate their practical applicability.

Moreover, we find that the effect of technological diversity on examination duration is weakened when applications have more than 10 claims, but only for the decision of grant, not for the decision of rejection. Our Hypothesis 2 is therefore only partially supported. Based on our assumption that applications with more than 10 claims tend to be written more clearly with less confusion, we proposed the mechanism that when applications are well written, examiners will not need to rely on the level of technological diversity to infer the novelty and inventiveness of the invention, therefore weakening the effect of technological diversity on examination duration. However, this mechanism does not apply for rejection. Being better written do not substitute the effect of technological diversity for rejection. Paid claims and technological diversity have separate effects on the rate of rejection, both are significant. This result is surprising and currently we do not have a reasonable explanation. We hope future research can solve this puzzle.

This study complements prior studies that have focused on patent grant rate at SIPO (Yasong and Connor, 2008; Liegsalz and Wagner, 2013) by empirically analyzing three competing outcomes following the substantive patent examination simultaneously. Compared with prior studies that have studied these three outcomes (Harhoff and Wagner, 2009; Tong et al., 2018), this study zooms into two key features technological diversity and the number of claims of patent applications, develops and tests a theory of how they can affect the pendencies for different outcomes.

6.2 Practical Implications

The results of our research can offer strategic insights for both patent applicants and patent administrations. For patent applicants, in order to have their applications to be granted faster, it would be helpful to anchor their inventions in several technological fields but with a clear focus on one or two of them in order to reach a moderate level of technological diversity. Furthermore, a well-crafted application (indicated by whether applications include paid claims) can help to shorten the examination duration, so much so that it can override the effect of technological diversity. On the other hand, if applicants want to extend the patent examination process (for example, to delay being rejected), it might be helpful to have a complicated application that involves many different technological elements. Moreover, applicants can also get insights from other factors identified in our results that influence examination process. For example, collaborating with academic institutes can help accelerate grants and decelerate rejections; and using agency can help accelerate the decision-making process in general.

For patent administrations, it is evident that when the number of applications increases in the system, it will extend the examination process for each application, due to the limited capacity of examiners. Recruiting more qualified examiners is definite an option to reduce applications' processing time. Moreover, based on our results that more technologically complex application increases the workload for examiners, thereby delaying the decisions, we propose two suggestions to improve the examination efficiency. First, the number of patent examiners assigned to each application should be based on the complexity of the application. Second, examiners from different disciplines should form examination groups to better handle applications involving technologies in different fields.

6.3 Limitations and Future Research

Our research has a few limitations, each of which can lead to a potentially fruitful direction for future research. First, we cannot include all the factors that might have influence on patent examination processes, given the limited information available in our data. For example, it is conceivable that patent examiners' experience may affect the examination duration; however, this information is not available to us. Our understanding of patent examination process will be further deepened if other researchers can collect more data on other potential factors - such as the characteristics of examiners, the network structure of the knowledge elements combined in an application (based on how they were paired in the past), and the knowledge and relational structure of inventor teams - and develop and test theories on how they can affect the patent examination process.

Second, our results are based only on pharmaceutical patent data at SIPO, therefore it is still an open question that how well they can be generalized into other contexts, such as other industries and other countries. Our understanding will benefit from future research that compare our results with those found in other contexts.

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