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The Impact of Patent Transaction Behaviors on Firm Performance: An Empirical Analysis Based on Chinese Listed Companies

LIANG Tian

Doctor of Management

Supervisors:
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July, 2023

BUSINESS
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Marketing, Operations and General Management Department

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I declare that this thesis does not incorporate without acknowledgment any material previously submitted for a degree or diploma in any university and that to the best of my knowledge it does not contain any material previously published or written by another person except where due reference is made in the text.

Signed:  Date: 2023.7.1

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Abstract

In the era of knowledge economy, the role of patents has become increasingly prominent. Chinese patents have grown rapidly in recent years, but the increase of patent transactions has been relatively slow. It is necessary to reveal whether patent transactions have a positive effect on firm performance. Based on the patent transaction and financial data of Chinese listed companies, this thesis examines the relationship between patent transactions and firm performance through literature research, theoretical appraisal and empirical regression analysis.

This thesis constructed a conceptual model of patent transactions and firm performance by sorting out transfer and absorption theory, patent assignment and licensing theory, and firm performance theory, and proposed the research hypotheses from three dimensions: internal and external patent assignment, internal and external patent licensing, and invention and non-invention patents. On this basis, the patent assignment and licensing data of listed companies from 2006 to 2020, and financial data such as the Tobin's Q and operating revenue from 2008 to 2022 were collected. Linear regression analysis was used to test the hypotheses, with the robustness checking of the regression results. Strategies and suggestions for patent transactions are then put forward.

This thesis verified for the first time the significant and positive contribution of patent assignment and licensing to the performance of listed companies based on data regression analysis. We find that external patents, patent licenses and invention patents bring more significant impact to firm performance. Further research is needed in the future. In particular, more sophisticated transaction methods such as patent pledge and patent securitization could be considered while more in-depth analysis of listed companies by industry, asset size and equity structure could be conducted.

Keywords: firm performance, patent assignment, patent licensing, knowledge absorption theory

JEL: M21; O34

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Resumo

Na era da economia do conhecimento, o papel das patentes tornou-se cada vez mais proeminente. As patentes chinesas cresceram rapidamente nos últimos anos, mas o aumento das transa ções de patentes foi relativamente lento. É necessário comprrender se as transa ções de patentes têm um efeito positivo no desempenho da empresa. Com base nas transa ções de patentes e dados financeiros de empresas chinesas listadas, esta Tese examina a rela ção entre transa ções de patentes e desempenho da empresa por meio de pesquisa bibliogr á fica, avalia ção teórica e análise de regress ão emp í rica.

Esta Tese constrói um modelo conceptual de transa ções de patentes e desempenho da empresa, tomando no ções relativas a transferência e absor ção, atribui ção e licenciamento de patentes e din âmicas de desempenho empresarial. Prop õem-se hipóteses de pesquisa a partir de três dimens ões: patentes internas e externas, atribui ção de patentes interna e externas, licenciamento de patentes de inven ção e n ão-inven ção. Nesta base foram colectados os dados de concess ão e licenciamento de patentes de empresas listadas de 2006 a 2020 e dados financeiros, como o Q de Tobin e receita operacional de 2008 a 2022. A análise de regress ão linear foi utilizada para testar as hipóteses, com a verifica ção da robustez dos resultados da regress ão. Estratégias e sugest ões para transa ções de patentes s ão apresentadas.

Esta Tese verifica a contribui ção significativa e positiva da cess ão e licenciamento de patentes para o desempenho das empresas chinesas listadas com base na análise de regress ão de dados. Revelamos que patentes externas, licen ças de patentes e patentes de inven ção trazem um impacto significativo para o desempenho da empresa. Mais pesquisas s ão necessá rias no futuro. Em particular, métodos de transa ção mais sofisticados como securitiza ção de patentes poderiam ser considerados, enquanto an á lises mais aprofundadas de empresas listadas por sector, tamanho de activos e estrutura de patrim ônio poderiam ser realizadas.

Palavras-chave: desempenho da empresa, transfer ê ncia de patentes, licenciamento de patentes, absor ção do conhecimento

JEL: M21; O34

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摘 要

在知识经济时代，专利的作用日益凸显，中国专利在近年来快速增长，但专利交易的增长则相对缓慢，需要深入揭示专利交易对企业绩效是否有积极的促进作用？本文通过文献研究、理论演绎和实证回归分析，基于中国上市公司的专利交易数据和财务数据，对专利交易与企业绩效的关系进行研究。

本文通过对知识转移与吸收理论、专利许可与转让理论和企业绩效理论的梳理，构建专利交易与企业绩效的概念模型，从内部转让与外部转让，内部许可与外部许可，发明专利与实用新型专利、外观专利三个维度提出本文的研究假设。在此基础上，收集上市公司在 2006-2020 年的专利转让与许可数据，以及 2008-2022 年的托宾 Q、营业收入等财务数据，运用 SPSS 工具进行回归分析，对研究假设进行验证，并对回归分析进行稳健性检验。在此基础上，提出了专利交易的策略与建议。

本文基于数据回归分析证实了专利转让与许可对上司公司绩效的积极促进作用，其中外部专利、专利许可及发明专利会给企业带来更显著的绩效影响。本文研究中，还未考虑专利质押、专利证券化等更复杂的交易形式，同时还未对上市公司按照行业、资产规模、股权结构等进行更深入分析，需要在未来进行进一步研究。

关键词：企业绩效，专利转让，专利许可，知识吸收理论

JEL: M21; O34

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致 谢

值此论文定稿之际，回想攻读博士的这几年，有彷徨有兴奋有失落有激情，学术之路虽艰辛无比，但取得研究成果后的那份喜悦也是非千言万语能够说尽的。首先我要深深感谢导师 Sandro Mendonça、肖延高教授的亲切关怀和悉心指导，两位导师丰富的研究经验和广阔的国际视野使我能够跟踪最新的发展方向抓住研究中的关键和难点问题并始终站在相关领域研究的前沿。在论文选题、框架规划以及撰写修改过程中，两位导师给予了细心地指导和帮助，使我受益匪浅，论文的字里行间凝聚着他们大量的心血和汗水。两位导师也教会了我理性的思维方式、前沿的创新理念和科学的研究方法，是我在攻取博士学位期间最宝贵的财富。博士生涯即将结束，但师生情谊历久弥香。

感谢我的父母和所有家人给予我最无私的温暖和关怀，对我无微不至的照顾使我可以全身心的投入到博士论文的写作中，正是他们殷切希望给予了我无限的动力，激励我奋发进取，不断进步。在我求学的每一个阶段每当我要放弃的时候，都是他们给我鼓励劝我坚持到底，正是由于他们的支持，才使得我能够克服重重困难走到了今天。

最后，对支持、帮助、关心我的所有的老师、朋友、同学和家人表示深深的谢意。谨向百忙中抽出宝贵时间评审论文的各位专家、学者致谢！

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Chapter 1: Introduction

1.1 Research background

This section introduces the research background of this thesis from the advent of the era of the knowledge economy, the dynamics of Chinese patents, the status quo of patent assignment and licensing in China, and the industrialization and exploitation of Chinese patents, which then leads to the study of the relationship between patent transactions and firm performance.

1.1.1 Advent of the era of the knowledge economy

In the past few decades, knowledge has become increasingly relevant and been hailed as the source of growth and competitiveness of all economic sectors (Freeman & Louçã, 2001; Louçã & Mendonça, 2002). While changing the physical constraints and costs of information acquisition and dissemination, computer and communications technology has also changed how knowledge is produced and distributed and the interaction between factors of production, resulting in major changes in the structure of economic life. Hence the entry into an era of the knowledge economy. Knowledge is the primary foundation for economic expansion and growth (Unger, 2019). Human beings are now undergoing tremendous transformations from material resources to knowledge and from hardware to software. Similar to how machines once supplanted human and animal labor, knowledge has now become the primary foundation of industrial production, superseding the role of machines and factories. Almost all high added-value products embody elements of scientific knowledge (Caraça et al., 2009). All-round routines of knowledge production and usage may underpin the more general category of knowledge-intensive consumer services(Costa & Mendonça, 2019). with the proposal of China's Belt and Road initiative(B&RI), thus B&RI would revitalize cultural, intellectual and economic life in Central Asia and the Middle East with positive spillover effects with alleviating (Casta, 2009; Costa & Li, 2003). The global knowledge economy is developing rapidly. Knowledge represented by intellectual property or intellectual capital is on its way to gradually supplanting labor and capital as the major factor of production which to some extent takes the place of physical capital such as energy and natural resources (Crouzet et al., 2022), playing a key role in creating economic added value. Education, knowledge, technological advances and scientific research, on the other hand, are concrete means to increase the

efficiency and productivity of the workforce. With the rapid development of the global economy and continuous factor redistribution, modern society is becoming a knowledge society with knowledge production and utilization as core resources (Mao et al., 2020). According to UN estimates, knowledge economies account for at least 7% of global GDP and grow by at least 10% per year (Connell et al., 2015). Against the backdrop of the knowledge economy, R&D investment is an important way of sustaining knowledge output to achieve the knowledge economy cycle, and the knowledge economy in developing countries has contributed significantly to their economic growth and played a prominent role in maintaining high growth rates for decades (Mohamed et al., 2022). According to the total R&D expenditure released by the National Bureau of Statistics of China, as shown in Annex Figure 1, R&D expenditure of China has been growing steadily at a fast pace over the years. It jumped from 461.6 billion yuan in 2008 to 3087 billion yuan in 2022, up 668.76%, demonstrating a high growth rate. During 2008-2022, the growth of China's R&D investment far exceeded that of GDP in the same period, indicating the obvious characteristics of a knowledge economy in China's economic development and facilitating the rapid economic growth and the continuous increase in patents over the same period. As a direct result of R&D investment, the number of patents also grew continuously and rapidly over the same period.

As described by the OECD (Organization for Economic Co-operation and Development), knowledge-based growth is characterized by lower production cost and higher efficiency in the transmission, retrieval, and analysis of information (OECD, 1996). The most prominent feature of such knowledge-based economy is that knowledge is ubiquitous in economic activities as both input and output. Wealth creation in such a pattern of economic growth becomes increasingly dependent on the effective management, that is, the ability to organize, create, acquire, accumulate, spread and utilize information and knowledge. Knowledge is not only a major means to drive social progress, but also an integral part of all aspects of overall social development, resulting in the emergence of knowledge-intensive industries, which together with labor-intensive and capital-intensive industries constitute the typical features of modern economic development and play an increasingly important role. During recent years, knowledge-intensive industries have become the core of economic growth. The role and importance of knowledge in the economic process have undergone fundamental changes.

The typical characteristics of the knowledge economy include: rapid growth in services, the key role of information as a factor of production, continuous innovation to meet changing needs, and interaction within knowledge transmitted through expansive network connections around the globe (Hong, 1998). While the primary resource in the industrial economy was

land and capital respectively, that in the knowledge economy is information and knowledge. The knowledge economy has effects that are different from all previous types of economies, including the law of increasing returns, network effects, the exponential nature of growth, and positive feedback. Compared to the traditional economy, the knowledge economy embodies network externalities because it relies on information and knowledge that do not diminish in use, but instead can be shared and used to add value to knowledge (Dalkir, 2005). The distinctive characteristics of the knowledge economy demonstrate a deviation from the traditional law of diminishing marginal returns (Caraça et al., 2009; Foray, 2004). Typically, in economic activities, continued input leads to a decrease in output after a certain point. However, in the knowledge economy, because the marginal production cost of products and services can approach zero, the concept of diminishing returns is less applicable, and marginal returns can instead increase. Products and services in the knowledge economy are intangible and external in use, attracting more participants. With the increase of consumers and users, the value of products and services will further increase.

White et al. (2013) argued that open innovation is the foundation and core element of the expansion of the knowledge economy. The basis of a knowledge society is information and innovation. The creation, use and management of knowledge will generate competitiveness and productivity. In the knowledge economy, intangible assets such as knowledge and information management become the new key of productivity and competitiveness, while the creation, acquisition and effective development of knowledge within organizations become the core source of competitive edges. In the era of the knowledge economy, as intellectual capital becomes increasingly significant, organizations are increasingly reliant on knowledge. For most organizations, knowledge represents competitiveness and profitability, while intellectual capital plays a pivotal role in building edges and contributes to the long-term sustainable development of organizations.

The knowledge owned by firms includes intellectual property represented by patents and trademarks, with each type of intellectual property classified by different criteria. For example, trademarks can be divided into value trademarks, defensive trademarks, cumulative trademarks, and associative trademarks (Xiao et al., 2021). It may also include knowledge in the formats of research reports, technical papers, or tacit knowledge. Knowledge such as patents and trademarks plays an increasingly important role in enterprises. Mendonça et al. (2004) propose trademarks as a complementary indicator in the portfolio of available empirical tools of innovation studies and industrial dynamics. Xiao et al. (2024) find that in-use trademarks (trademarks being used by firms), as well as unused trademarks

registered for a firm's current businesses, are positively related to firm value, By contrast, unused trademarks that are not registered for a firm's current businesses have no impact on firm value. The modern economy is a sign-rich reality and trademarks are intangible assets that economic actors can mobilize to differentiate themselves and their offerings in the marketplace (Castaldi & Mendonça, 2022). Firms can sort out these knowledge assets and sell them to others. For example, a firm can license patents or sell training programs, production process, technical know-how, and technical secrets. Identifying and extracting knowledge assets is the process of determining the assets owned by firms through sorting out knowledge assets by listing the patents and patentables of firms. After sorting out the knowledge, assets that no longer have competitive advantages are stripped after opportunity cost analysis by means of assignment, licensing and donating, which is also the initial form of patent assignment and licensing market.

In the context of the knowledge economy, innovation is increasingly becoming the original driving force for social and economic development, and technological innovation naturally entails the protection from the patent system. The patent system strikes a balance between public interest and individual interests through technology disclosure in exchange for the right to monopolize technology for a certain period of time, and strongly promotes continuous innovation. In turn, the importance of innovation and the inherent variability are presented as a great heterogeneity in the importance, value or quality of patents. The basic social value of intellectual property is to promote the production and dissemination of knowledge, because technological advances play a key role in powering economic growth. After patent documents enter the public domain, anyone can search for technological knowledge with patents. The public welfare is promoted with the spread and wide application of new knowledge during goods production and further knowledge generation. However, the rapid spread of knowledge can be at odds with private returns for the original innovators, as it may reduce their incentives to invest in creating new knowledge. While this could be true for the original creators, other private users can benefit from these knowledge spillovers, gaining access to valuable information without bearing the initial innovation costs. The intellectual property system represented by patents provides knowledge creators with a way to obtain gains. On the one hand, the inventor is granted the monopoly on an invention and its derivative rights and protected from unauthorized use of his/her technical knowledge. On the other hand, the disclosure of technical knowledge for public use can timely stimulate knowledge spillover and the transfer of technical knowledge in the whole economy.

The theory of the knowledge economy emphasizes the importance of knowledge,

information and proprietary technology as the basic resources of economic development. At the same time, people's general perception of knowledge has changed, and knowledge has become a special commodity for the intended purpose (Burgin, 2016). Intellectual property rights represented by patents have become the institutional guarantee for the development of the knowledge economy and the concrete form of the knowledge economy. The era of the knowledge economy has laid the economic and realistic foundation for patent assignment and licensing.

1.1.2 Patent trends in China

In the era of the knowledge economy, patents take on a bigger role as the monopoly effect of patent as formal technical knowledge protection device can secure the economic and competitive advantages of firms. Since the reform and opening up, China has gradually adopted a market-oriented approach to economic reform, and re-formulated and put into practice laws on patents. At present, China's patent system is relatively mature with the number of patents leading in the world.

1.1.2.1 Evolution of patent system

The *Patent Law of the People's Republic of China* has been revised four times since its implementation in 1985. It now has the basic characteristics of a mature law in terms of the form and content (Guo, 2021).

Establishment of the patent system. Developing countries and economies in transition like China need advanced technologies from developed countries to develop themselves. After the reform and opening-up kicked off in 1978, in order to promote economic development, the modern intellectual property concept was introduced to China. Institutional and ideological obstacles no longer existed for introducing investment from abroad. In order to meet the needs of reform and opening-up and attract foreign investment, it was necessary to effectively protect the technologies of foreign investors, and a patent system that protected and encouraged inventions came into being (X. Zhao, 2021). Drafted in 1979, the *Patent Law of the People's Republic of China* was implemented on April 1, 1985 which marked the beginning of a stage of exploration. Its main contents include three types of patents (invention, utility model and design), a protection term of 15 years for invention patents, objects that are not granted patent rights, patent publication and examination, patent rejection and reexamination, patent invalidation, and cases not regarded as patent infringement.

*First amendmen*t. The Patent Law was first amended against the background of China-U.S. trade negotiations, which was an externally driven stage. The negotiations starting from

1989 were related to the annual review of China's most-favored-nation status by the U.S. government. The focus of the negotiations was China's intellectual property protection. In 1991, the U.S. government put China on the Special 301 Blacklist and threatened China with trade sanctions. The Chinese government compromised in the end. On January 17, 1992, the two sides signed an MOU in Washington, D.C. which committed the Chinese government to amend the Patent Law. The U.S. government terminated the investigation according to Special 301 provisions under the U.S. Trade Act and removed China from the watch list. As promised, the Standing Committee of the National People's Congress of China passed the amendment on September 4, 1992 which entered into force on January 1, 1993. The major changes were: extending the protection term for invention patents to 20 years, adding patent protection for chemicals and medicines, and restricting the conditions for compulsory licensing.

Second amendment. In the 21st century, the IP system has become the basic system of the global market economy. The Patent Law was amended for the second time against the backdrop of China's accession to the WTO (World Trade Organization), which continued the externally driven process since the first amendment. In 2000, China further revised its Patent Law to better prepare for its accession to the WTO in 2001. In 2001, China took the Agreement on Trade-Related Aspects of Intellectual Property Rights (TRIPS) as part of its WTO obligations, benchmarking its IP standards against international rules. China successfully joined the WTO on November 12, 2001. As a result of the negotiations, China once again committed to review and amend the Patent Law. The Standing Committee of the National People's Congress of China passed the second amendment on August 25, 2000 which came into effect on July 1, 2001. In order to make the Patent Law conform to the TRIPS Agreement, the patentee is granted the right to prevent others from "selling" patented products or products directly obtained through patented methods. "Use or sell unknowingly" was removed from the list of non-infringing acts. A method for calculating infringement damages was specified for the first time. If the infringer's gains or infringement damages could not be determined, the penalty could go up to 500,000 yuan. A system of preliminary injunction was also set up.

Third amendment. On June 5, 2008, the State Council issued the *Outline of the National Intellectual Property Strategy*, which defined such contents as "establishing a comprehensive IP system", "promoting IP creation and utilization", "strengthening IP protection" and "preventing the abuse of intellectual property rights". The third revision of the Patent Law was neither out of external pressure nor in conformity with international treaties. It was an

effort to promote independent innovation and build an innovative country under China's new IP strategy, and an internally driven optimization. Clearly, the third revision of the Patent Law was intended to realize China's IP ambitions. Highlights in the 2008 amendment include: (1) promoting patent application; (2) encouraging patent development; (3) raising patentability requirements; (4) strengthening patent protection; (5) solving the problem of compulsory license; and (6) protecting genetic resources. The third amendment was passed in December 2008 and implemented in October 2009 (Zhong, 2019).

Fourth amendment. After three revisions, the legal system for patents was basically complete. However, new issues and problems occurred in the process of implementation, such as difficulty in proving infringement evidence, low compensation, and long duration of lawsuits. In the second half of 2014, China officially started to prepare for the fourth revision of the Patent Law, which continued the internally driven optimization since the third amendment. The fourth draft amendment was reviewed on December 23, 2018 and June 28, 2020. On October 17, 2020, the *Decision on Amending the Patent Law of the People's Republic of China* was approved by voting. The fourth amendment of the Patent Law entered into force on June 1, 2021. The fourth revision was done 12 years after the third one, which was the longest interval. It was the longest revision. The fourth amendment of the Patent Law mainly focused on the following aspects: increasing the compensation for patent infringement, with a statutory compensation of up to five million yuan; improving the burden of proof with patent infringers also bearing the burden of proof in the process of determining the amount of compensation; clarifying the joint liability of network service providers; improving the service invention system; improving patent administrative law enforcement; and extending the protection term of design patent to 15 years. This revision also established a patent open licence system, specified in Articles 50-52 of the Patent Law, that is, the patentee declares his/her willingness to license to the public, and clarifies the payment method and royalty rates to solve the problem of information asymmetry among patent licensing entities, thereby improving the transfer and transformation of Chinese patents. Open licensing, voluntary licensing, and compulsory licensing constitute China’s patent licensing system. The fourth revision of the Patent Law was mainly to strengthen the protection of the legitimate rights and interests of patentees, promote the exploitation and application of patents, and improve the patent granting system, which also indicated further improvement of China’s patent system.

Meanwhile, China became a member of the *Paris Convention for the Protection of Industrial Property* on March 19, 1985, recognizing the principle of national treatment and the right of priority. In terms of inventions and utility models, China joined the *Patent*

Cooperation Treaty (PCT) on August 2, 1998, becoming the receiving Office, International Searching Authority, and International Preliminary Examining Authority. On December 11, 2001, China officially became a member of the WTO and began to implement the TRIPS. The TRIPS agreement is the most extensive and binding international treaty and introduces the most-favored-nation principle. In respect of design patents, China acceded to the *Hague Agreement Concerning the International Registration of Industrial Designs* (1999 text) on February 5, 2022, which entered into force on May 5 of the same year, better facilitating domestic and foreign applicants to file design patent applications. With the introduction of a series of international treaties, China's legal system gradually caught up with the international level. The Patent Law is a reflection in China of the national treatment principle, the right of priority and the principle of most-favored-nation treatment in international protection treaties such as the *Paris Convention*, the *Patent Cooperation Treaty,* the TRIPS Agreement, and the *Hague Agreement Concerning the International Registration of Industrial Designs*. As one of the laws highly benchmarked with international laws in China, the Patent Law reflects the betterment of China's patent system, constantly innovates in line with the changes in social and economic development, and gradually moves towards internationalization. In recent years, the development of the patent system strongly encourages the internationalization of patent legislation, patent filing process, patent authorities, and patent information management and use (C. Tang, 2008).

Jin et al. (2022) believed that when the institutional threshold of intellectual property protection is met, introduction and outbound transfer of patents in developed cities will play a more significant role in driving local substantive innovation. The same is true for China as a whole. After more than three decades of evolution, China's patent system has been improved in all aspects and has basically met the corresponding system threshold. The role of patent transactions in promoting innovation and economic development will also become stronger as patent transactions increase.

1.1.2.2 Changes in the number of patents

Since the establishment of China's patent system, the number of patents has also been increasing rapidly, especially since the implementation of the *Outline of the National Intellectual Property Strategy* in 2008. In the last decade, China's patent applications have mushroomed. It became a leading power in patent applications, attracting wide attention from the academia, governments, and firms. As a major subject of technological innovation, firms are making increasingly significant contributions to China's reputation as major source of

patent filings. Nguyen and Doytch (2022) analyzed patents in the ICT sector of 43 economies around the world (including 26 developed economies and 17 emerging market economies from 1998 to 2016), and argued that the total amount of patents and economic growth have reciprocal causality. The rapid growth of Chinese patents also echoes the rapid growth of China's economy.

According to the statistics published by China National Intellectual Property Administration, as illustrated in Figure 1.1, the number of patent applications in China (including invention, utility models and design) increased from 828,300 in 2008 to 5,364,600 in 2022, a growth of 547.7%. Over the same period, the number of patent grants jumped from 412,000 to 4,323,400, that is, a growth of 949.4%, slightly faster than the increase of applications. The number of invention patent applications grew by 458.8% from 289,800 to 1,619,300, and the number of invention patent grants increased by 751.9% from 93,700 to 798,300. The latter grew slightly slower than the former over the same period. Compared with the total number of applications, the number of applications and grants of invention patents grew slightly slower, indicating that the applicants are more inclined to apply for utility models and designs which are easier to be granted, which is consistent with the national conditions of China as a developing country. At the same time, the actual number of invention patents still takes up a certain part of the total number of patents, indicating that China's patent system is now more recognized.

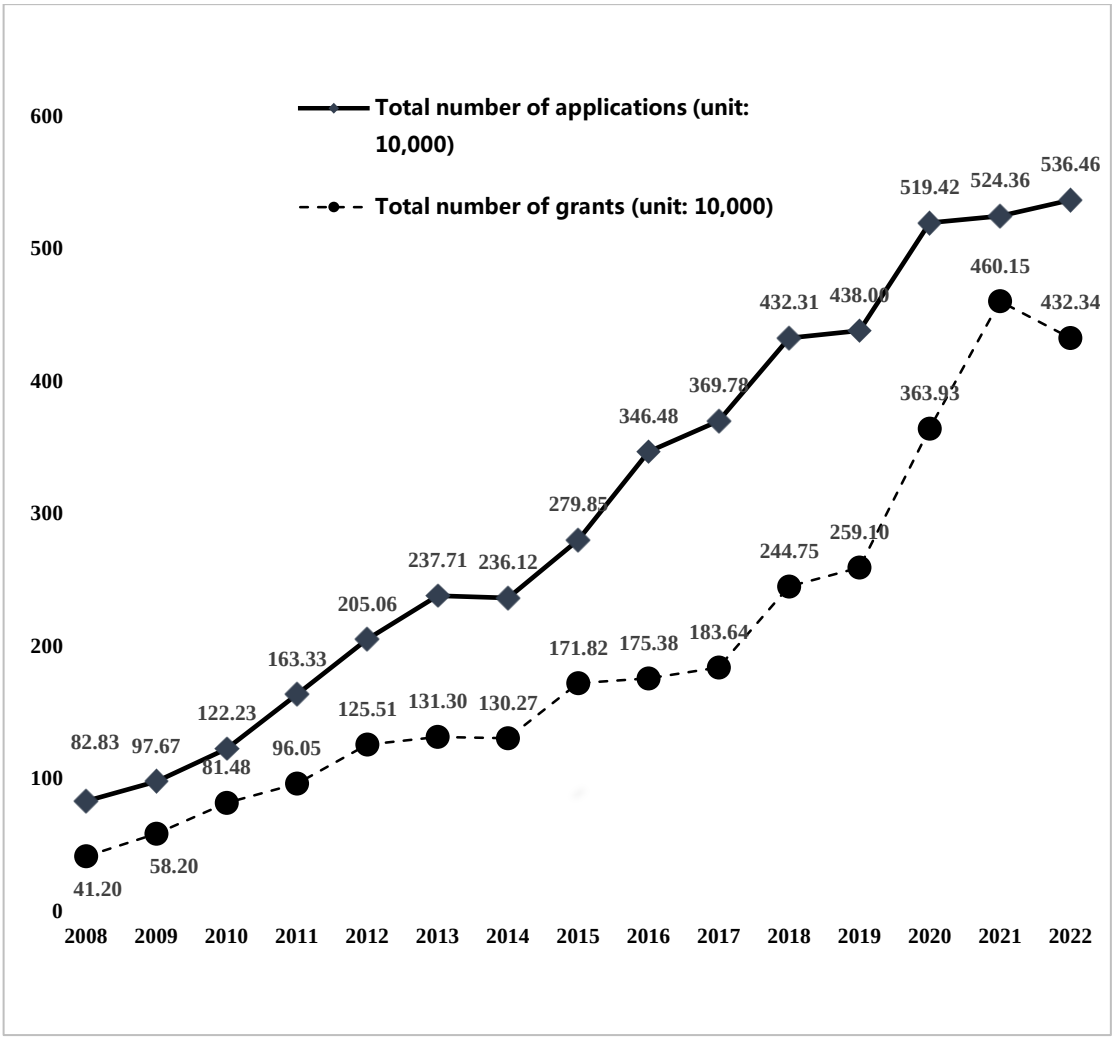

Figure 1.1 Patent applications and grants in China, 2008-2022

Source: https://www.cnipa.gov.cn/col/col61/index.html

According to the World Intellectual Property Indicators report released by the World Intellectual Property Organization (WIPO) in 2019, China submitted 58,990 international patent applications in 2019, surpassing the 57,840 of the United States for the first time and jumping to the first place, becoming the country with the largest number of international patent applications filed. According to the World Intellectual Property Index report released in 2022, by 2021 the number of valid patents in the world was about 16.5 million, of which 3.6 million were from China, accounting for 21.8%, followed by 3.3 million from the United States. This is the first time that China surpassed the United States to become the country with the largest number of valid patents. On the one hand, the yearly increment of valid patents against the backdrop of the rapid growth of patent applications and grants in China reflects a better policy environment and stronger awareness. On the other hand, the huge number of patents has also made patent transactions more viable in China. The ability to create, utilize and protect patents based on the "blowout" of firms' patent applications has had a positive

effect on firm performance in general, including the performance indicators of sales growth rate, ROE, and profitability (Y. G. Xiao et al., 2019). In addition, the slower growth of invention patents in recent years may be sending a message that China's patents have shifted from quantity growth to quality development. It can be predicted that high-quality patent assignment and licensing will bring better economic benefits to firms.

1.1.3 Patent assignment and licensing in China

Through patent assignment and licensing, inventors can stay motivated to innovate, and technology transferees can avoid R&D risks, quickly integrate internal resources, and improve innovation performance. Patent transactions represented by patent assignment and licensing are the link between innovation and application, and the current situation of patent assignment and licensing in China will be sorted out for the realistic basis of this research. According to the information disclosed in the annual reports of national technical market statistics, as shown in Annex Figure 2, the number of technology transfer agreements in China increased from 11,932 in 2008 to 34,317 in 2021, with an increase of 187.6%. In the same period, the value of technology transfer grew from 53.3 billion yuan to 324.7 billion yuan, with an increase of 509.2%. The value grew much faster than the number, with the average value of each technology transfer agreement surging from 4,463,500 yuan to 9,460,600 yuan. Thus, the market value of technology in technology transfer agreements was greatly enhanced.

As illustrated in Annex Figure 3, from 2008 to 2021, the number of patent license agreements in China increased from 1,918 to 8,189, up by 326.9%. During the same period, the turnover of patent licensing grew from 10.6 billion yuan to 95.8 billion yuan, a growth of 803.8%. On the one hand, the number of patent license agreements did not grow significantly, but showed some ups and downs, indicating that the business model of patent license in China had not been widely accepted by the market. On the other hand, China's patent licensing turnover increased significantly, reflecting that the technical value of patents had been recognized.

As shown in Annex Figure 4, from 2008 to 2021, the number of patent assignment agreements in China increased from 450 to 13,302, with a growth of 2856.0%, and the turnover of patent assignment from 6 billion yuan to 61.1 billion yuan, with a growth of 918.3%. As can be seen from Annex Figure 4, the number and turnover of patent assignments in China have both grown significantly, reflecting the great success of the patent assignment model. Since 2018, the number of patent assignment agreements in China has far exceeded that of patent license agreements, indicating that China's patent assignment model was more acceptable to the market than the patent license model. The latest data show that the number

of patent assignments and licenses in China reached 420,000 in 2021. Among them, the growth rate of the number of patent assignments and licenses related to green new energy and other "carbon neutrality and carbon peak" related industries was more than twice of the average (Pan, 2022).

However, there was a huge gap between the number of patent assignment and patent license agreements and the number of patent applications and grants. According to the data disclosed in the *2022 China Patent Survey Report*, in 2022, China's invention patent assignment ratio was 11.5% and licensing ratio was 12.1%, This might mean that China's patent assignment and licensing market was still in the early stage with much room for development in the future.

1.1.4 Industrialization and exploitation of China's patents

With the rapid growth of the number of patent applications, assignment and licensing in China, the industrialization and exploitation of patents now draw wider attention. To be more specific, firms now are more concerned with such issues as the practical application of patents, the actual industrialization of the huge number of patents, and the contribution of patents to economic development. The industrialization and exploitation of patents could tell how well patents are actually used, which is the most important way for patents to move from technology to market. Since 2015, the Strategic Planning Department of China National Intellectual Property Administration has been working with the Development Research Center and developed the annual *China Patent Investigation Report* with extensive data obtained through a large number of questionnaires. Data related to patent transfer and transformation, patent industrialization, and patent exploitation were disclosed in the report.

In the *2020 China Patent Investigation Report*, the patent transfer and transformation index was put forward for the first time, as a comprehensive indicator of patent transfer and transformation. It equals the weighted sum of standardized data of valid invention patent industrialization rate, license ratio, assignment ratio, percentage of patents used to invest as converted shares, and patent value. Similar to the Purchasing Managers' Index (PMI) in economic activities, the patent transfer and transformation index uses 50 as the dividing line between growth and contraction. An index above 50 indicates active patent transfer and transformation. An index below 50 indicates the contraction of such activities. The specific index of patent transfer and transformation was summarized from the *China Patent Investigation Report* published over the years from 2016 to 2022 as shown in Annex Figure 5. Patent transfer and transformation in China has been relatively active with an index of over 50 since 2019.

The concept of patent "transformation" originated from Article 16 of the *Law of the People's Republic of China on Promoting the Transformation of Scientific and Technological Achievements.* According to the law, the ways of transformation for technology holders include investing in the transformation themselves, assignment, licensing, working together with another in the implementation, and investing with their achievements as converted shares. The *China Patent Investigation Report* by the China National Intellectual Property Administration also published the patent industrialization rate from 2015 to 2022. As shown in Annex Figure 6, the rate was relatively stable during this period, exceeding 30% every year and presenting a growing trend. The patent industrialization rate = the number of patents used to make products which are then put into the market / the number of valid patents owned.

Patent exploitation refers to the patentee's behaviors of manufacturing, using, offering to sell, selling and importing for the purpose of production and operation, or to transfer the patent right to others. The *China Patent Investigation Report* also published the patent exploitation rate from 2015 to 2022 which in recent years has exceeded 50%. The patent exploitation rate = the number (valuation) of patents exploited / the total number of valid patents.

1.2 Research questions

In the era of the knowledge economy, intellectual property, typically represented by patents, plays an increasingly important role in economic growth and high-quality social development. In this context, the number of patent applications in China has also grown continuously and rapidly for many years, but the rapid increase of the number of patents in China has also raised many questions around the subsidies granted by governments at all levels for patent applications, which contributed to the surge in the past decade (Boeing & Mueller, 2015; Dang & Motohashi, 2015; X. Li, 2012). This subsidy policy has to some extent deviated from the original purpose of the patent system to protect technological innovation. At present, there is an increasing number of studies on the relationship between patent quantity and economic growth, regional development, regional innovation, and firm performance, but studies based on patent application data interfered by subsidy policies may lead to unjustified analysis results.

While the number of patent applications continues to grow at a high rate, the industrialization and implementation of patents are relatively weak. The primary form of patent industrialization and implementation is patent trading, with patent assignment and

licensing being the two most important methods. Currently, the growth of patent assignment and licensing has not kept pace with the rapid increase in patent applications. Both the number of patent transactions and the amount transacted have grown relatively slowly. On the other hand, policy subsidies for Chinese patents are mainly limited to the application phase. Due to the overall small number of transactions in the assignment and licensing phase, subsidies are seldom involved. Therefore, patent assignment and licensing are generally market-driven choices made by both parties in a patent transaction based on economic interests. To some extent, this excludes the interference of policy subsidies and provides more accurate basic research data. Analyzing changes in patent transaction data can more effectively assess the impact of such behavior on firm performance.

At the same time, current studies of patent transactions mainly focus on topics such as motives, strategies, and costs, while the impact of patent transactions on firm performance, especially on the performance of the recipient, has been less examined. The overall objective of this study is to explore the impact of patent transactions of Chinese listed companies on corporate performance. We obtained sufficient empirical samples through patent transaction data and financial data of the listed companies, and adopted empirical research methods to investigate the relationship between patent transactions and firm performance on the basis of data collection and descriptive analysis. Specifically, this study will answer the following two questions:

- Do patent assignment and licensing both have a positive impact on firm performance?
- Do invention and non-invention patents, internal and external patent transactions have different impacts on firm performance, and are there differences in the degree of this impact?

The results of the empirical study can not only test the positive role of patent transactions in firm performance, but also lead to suggestions for patent transactions based on the results of the empirical research, which will play a positive role in promoting the sustained high-quality economic development.

1.3 Research methods and framework

1.3.1 Research methods

Literature research. We reviewed relevant studies from China and abroad and identified the relationship between firms' patent transaction behaviors and performance from the perspectives the theory of knowledge, patent, and firm performance. A gap in the previous studies was also identified. This method provided the theoretical support for this study.

Theoretical deduction. Through the lens of the absorptive capacity theory, knowledge absorption is the main source for firms to maintain competitive advantages. A conceptual model of patent transactions based on the theoretical basis was constructed.

Statistics and econometrics (including descriptive analysis, exploratory factor analysis, confirmatory factor analysis, correlation analysis, and regression analysis). This method was used to analyze the influence of patent transaction behaviors on business performance. The computations were carried out with the help of SPSS software.

1.3.2 Research framework

This thesis comprises six chapters.

Chapter 1 is the introduction. By analyzing the knowledge economy, patent trends, the current status of patent licensing and assignment, and the industrialization of patents, this chapter describes the background, research problem, research design, and methods.

Chapter 2 is the literature review. It reviews and discusses relevant studies by delving into theories on knowledge, patent and firm performance. This chapter prepares the ground for this study and closes in on the research topic.

Chapter 3 is the model construction and research hypotheses. This chapter sets the dependent and independent variables and puts forward the research hypotheses by constructing the theoretical conceptual model from the three perspectives of transaction scope, methods, and types.

Chapter 4 is data collection and descriptive statistics. This chapter elaborates on the data sources of the empirical research in this thesis. The data collection mainly involves the collection of financial data and patent data. On the basis of data collection, this chapter also preliminarily sorts out and analyzes the data and gives descriptive statistics from various angles.

Chapter 5 is the empirical analysis. In this chapter, the regression analysis is carried out to study the impact of patent assignment and licensing of Chinese listed companies on firm performance, including market performance and financial performance. On this basis, corresponding suggestions are made from the perspective of the firm and the government, in the hope of contributing to the various systems of patent transactions in China, promoting patent transactions and driving economic development.

Chapter 6 is conclusions and prospects. This chapter summarizes the previous discussions, describes the main research conclusions, and identifies the limitations and possibilities for future research.

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Chapter 2: Literature Review

This chapter will survey the relevant literature on the theories related to knowledge, patent, and firm performance, identify the topics, debates and gaps, and lay a theoretical ground for the conceptual model and empirical research. The review of the theory of knowledge consists of foundation of the theory, classification of knowledge, knowledge-based theory of the firm and the theory of knowledge transfer and absorption. With regard to patents, the concept and role of patents, patent assignment, and patent licensing will be reviewed and analyzed. The firm performance will be analyzed from the perspectives of firm performance overview, firm performance indicators, and patents and firm performance.

2.1 Review of the perspective of the knowledge economy

Knowledge is the collection of all human knowledge of the world, and has always been at the heart of philosophical thinking. Since the Classical Greece, to define knowledge has been a lingering topic for philosophers and triggered many epistemological arguments. Most philosophers believe in the concept of objective reality, arguing that people can understand the objective reality through systematic or scientific observation and analysis. In this sense, knowledge represents objective truth. Based on the philosophers' understanding of knowledge as a foundation, as people's understanding of the world deepens, this concept has been further refined, and knowledge has been studied as a discipline, gradually giving rise to the theory of knowledge. This has led to a more profound comprehension of the concept, characteristics, and classification of knowledge.

2.1.1 Foundation of the knowledge-based perspectives

A good start for the study of the theory of knowledge is to delve into the concept of knowledge, conducting an analysis of its fundamental nature, and elucidating the scope and dimensions of knowledge research. Building upon this foundation, an examination of the characteristics of knowledge can be undertaken, exploring its core elements that set it apart from other theories. This comprehensive approach facilitates a holistic grasp of the theory of knowledge and, consequently, enables a more precise analysis of the knowledge-based theory of the firm.

2.1.1.1 Concept of knowledge

Different from the physical world which is an independently existing objectivity, knowledge is an abstract and ambiguous subjective concept that is gradually formed on the basis of the physical world. Scholars with varied understandings of knowledge have tried to define it from different perspectives other than philosophy. Plato, Aristotle, and Spinoza all had their own explanations of knowledge, arguing that knowledge is validated understanding. Marx held that knowledge derives from social practice which is the foundation of all knowledge and the standard for testing knowledge. In the field of information technology research, concepts such as information and data closely resemble knowledge. Effectively distinguishing between them is crucial for forming a valid understanding of knowledge. Therefore, some scholars have defined knowledge by distinguishing between knowledge, information and data. One view is that knowledge management deals with the various structured insights and descriptive information that people acquire and that if knowledge is different from data or information, there is nothing to discuss about knowledge management (Fahey & Prusak, 1998). Another prevailing view is that knowledge is obviously different from data or information, because data is the original figures and facts, information the processed data, and knowledge the authenticated information interrelated with different entities, and that new information may add, reorganize or change knowledge (Dretske, 1983; Machlup, 1980).

Nevertheless, every inference, from data to information to knowledge, changes along a certain dimension, such as context, usefulness, or interpretability. The key to effectively distinguish information from knowledge is absent in the content, structure, accuracy or practicability of assumed information or knowledge. Knowledge is the information owned by individuals and possesses a strong subjectivity. Therefore, Tuomi (1999) put forward a contradictory argument that the generally assumed hierarchy from data to knowledge should actually be reversed, that is, knowledge is a prerequisite for information which can be generated after objective materials are processed by people, and knowledge exists before data forms information. When knowledge is expressed and structured, it becomes information. When it is presented in fixed forms and standard explanations, it becomes data. Once processed in one's mind, information will be transformed into knowledge. Once expressed and presented in the form of text, graphics, words or other symbols, knowledge will become information. Based on this view of knowledge, a shared knowledge base is necessary for the spread of knowledge and for people to have the same understanding of data or information.

Other scholars have also studied knowledge from other angles. Huber (1991) posited that

knowledge increases the certainty of people's understanding of the world and is a belief that can enhance the ability of an entity to take effective actions. Schubert et al. (1998) described knowledge as the state or fact of knowing, and the cognition gained through experience or learning. Others defined knowledge as an object (Zack, 1998), emphasizing its object-oriented attributes and holding that knowledge can be regarded as something to be stored and controlled. Some considered knowledge as the foundation of cognition and the condition for gaining information (McQueen, 1998), according to which knowledge must be organized to promote the access to and retrieval of content and to have greater utility value. This view is an extension of the theory of knowledge as an object, with special emphasis on the accessibility of knowledge objects. Watson (1999) took a step further based on the view of knowledge capability by arguing that knowledge is not the ability of specific actions, but the ability to use and transform information. Through learning and experience accumulation, we can explain information and determine what information is needed in decision-making. Davenport and Prusak (2000) defined knowledge from its form, components, major functions, and repositories, which forms a relatively comprehensive picture of knowledge.

Maier (2007) defined knowledge based on previous studies: knowledge includes experience, communication or inference, and the cognitive expectation obtained through observation; whether this expectation is rational or irrational, individuals or organizations as participants can use such expectation to explain facts and generate activities, behaviors, and solutions. As a technical document, a patent represents a broad form of human experience and a rational cognitive expectation derived through the observation of objective phenomena and naturally belongs to the category of knowledge. This is the theoretical ground on which we build the research model. After sorting out the concept of knowledge, the next step is to analyze the characteristics of knowledge to give a full picture of knowledge.

2.1.1.2 Characteristics of knowledge

On the basis of knowledge definition, some have also examined the characteristics of knowledge in order to better distinguish it from other concepts. Chang et al. (2001) analyzed the economics of knowledge, and put forward several characteristics of knowledge: (1) The non-exclusivity of knowledge use. Knowledge can be simultaneously shared and used by multiple individuals. It embodies greater value and utility when shared by more people; (2) The marginal return of knowledge increases progressively. The more investment there is to improve resource efficiency, the more marginal returns will be obtained. This is clearly distinct from the diminishing marginal returns of most production factors, making it easier to

achieve excess returns by increasing investment in knowledge products; (3) The intangible loss of knowledge. As technology advances, the economic lifecycles of various technologies are becoming shorter and the depreciation of knowledge becomes increasingly apparent. This also indicates the need for continuous investment in knowledge and timely updates; and (4) Knowledge transfer has its own cost. Knowledge does not flow freely between different entities without incurring costs, and one of the primary costs is the expense associated with new entities absorbing and learning that knowledge. Due to variations in the complexity of knowledge, the transfer costs for general knowledge are typically lower than those for specialized knowledge. This highlights the clear distinctions between knowledge and tangible assets. The non-exclusivity of knowledge is a fundamental reason for the existence of patent systems. Its increasing marginal returns serve as a key backdrop to the knowledge economy. Its intangible loss plays a crucial role in defining one of the primary characteristics of patents - its valid period. The cost of transferring knowledge is a vital aspect of research in the field of patent transactions.

Song et al. (2010) conducted a study of the relations between knowledge characteristics, knowledge sharing and the innovation capability of firms, arguing that knowledge is tacit and decentralized and has certain value and that knowledge sharing would influence the innovation capabilities of firms. Yan and Jia (2002), based on the theory of knowledge, put forward the contents and ways of constructing and improving the knowledge sharing mechanism of firms, pointing out that the particularity of knowledge is mainly embodied in the progressive increase of marginal returns, externality, and the asymmetry of transactions. Chao (2000) summarized the characteristics of knowledge from the perspective of knowledge management, opining that knowledge characteristics include human nature, resources, technology and culture. Su (2009) analyzed the effect of knowledge characteristics on knowledge transfer efficiency, identifying taciturnity, complexity and specificity as the key factors of knowledge characteristics. Foray (2004), from the perspective of knowledge economy, believes that a knowledge-based economy refers to an economy with a high proportion of knowledge-intensive work and a greater share of intangible capital in the total stock of real capital than that of tangible capital.

As a result, knowledge possesses intrinsic value. Owners of knowledge can enhance their ability to reshape the physical world. Meanwhile, the shareable nature of knowledge enables its transfer between different entities, allowing for market transactions and facilitating its widespread dissemination. The fact that knowledge can be specific means that knowledge with a certain level of monopoly usually carries more significant value. Additionally, the

inherent asymmetry in knowledge transactions makes it prone to risks. Hence, in market transactions, there is a preference for utilizing knowledge through intellectual property rights, particularly patents. Intellectual property rights ensure the monopolistic nature of knowledge and its transparency reduces the risk of information asymmetry associated with knowledge transfer. Furthermore, because knowledge is dispersed, organizations need to acquire external knowledge to enrich their internal knowledge base. This approach maximizes the value of internal knowledge through the assimilation and incorporation of external knowledge. Knowledge can be categorized in various ways to better understand its different types. In the following section, we will review the literature on knowledge classification, taking into account the characteristics of patent knowledge.

2.1.2 Classification of knowledge

The classification of knowledge involves categorizing knowledge into various types based on its characteristics. Knowledge classification helps gain a deeper understanding of knowledge and enables firms to recognize and manage different types of knowledge more effectively. This, in turn, facilitates the enhanced utilization of knowledge to improve business performance. Nonaka (1994), based on whether knowledge can be easily concretized and made explicit, clarified two dimensions of knowledge: tacit and explicit. Tacit knowledge is rooted in the actions and experiences of individuals or organizations. Formed by individuals or organizations through long-term accumulation, it primarily depends on knowledge holders. It is subjective and discretionary in nature, making it generally difficult to be accurately described. Examples of tacit knowledge include personal insights, inspirations, and visual perceptions. Tacit knowledge is difficult to be formalized accurately in language or words. Even if it is expressed, the recipient often finds it hard to accurately comprehend and absorb. As a consequence, it is difficult to share it with others. The efficiency and accuracy of knowledge sharing generally needs to be enhanced through face-to-face contact, personal experience and insight, which indicates marked situationality. Tacit knowledge contains both cognitive and technical elements. The former refers to individual psychological models composed of psychological intentions, beliefs, and opinions. Technical elements include specific processes, skills, and technical know-how suited for specific environments. Because most tacit knowledge relies on the knowledge subject rather than other physical medium, tacit knowledge takes up a larger proportion and generally has higher value.

Explicit knowledge is known knowledge that can be recorded, expressed, sorted, and transmitted in symbols and/or natural language, so it is easier to be clearly expressed than tacit knowledge, and easy to learn, imitate, recreate and communicate. For instance, the user

manual for electronic products contains knowledge about the correct operation of the products. Explicit knowledge could be carried in words, images, videos, audio, and other forms. As a result, the recipient can acquire the knowledge more easily, hence better communication of the knowledge. Therefore, explicit knowledge is the manifestation and effectiveness of implicit knowledge, and implicit knowledge is the origin and foundation of explicit knowledge (Zheng Hao et al., 2016[ ]). (H. Zheng & Zhang, 2016).

Technology, as an important type of knowledge, naturally includes explicit and tacit technical knowledge. Tacit technical knowledge can also be "coded" into explicit technical knowledge. This coding process standardizes and refines tacit technical knowledge, making it easy to be stored, understood, communicated, shared, and transmitted. Patents are an important means of transforming tacit technical knowledge into explicit technical knowledge. Ma (2011) analyzed the difference between explicit and tacit technical knowledge and concluded that there is a difference in the state, that is, explicit technical knowledge is "coded, formatted and structured", while implicit technical knowledge is "uncoded, unformatted and unstructured". B. L. Song and Li (2011) examined the generation and obtainment of technical knowledge and pointed out that explicit technology includes technical literature, technical standards and patents that are of high economic value, and that purchasing is the most effective way to acquire external explicit knowledge. Therefore, as a kind of explicit technical knowledge, patents can be used by firms to acquire external technologies through patent assignment and licensing and cultivate technological capabilities by absorbing and transforming such technologies into internal tacit knowledge through learning. This also lays a theoretical foundation for this thesis to examine patent assignment and licensing through the lens of knowledge.

Although classifying knowledge as either tacit or explicit has been widely accepted and cited, some scholars also tried to classify by other dimensions to gain a better understanding of knowledge as shown in Table 2.1. Quinn et al. (1996) studied how organizational capability exceeded the sum of individuals, and argued that professional knowledge needed to be fully utilized to become the professional knowledge of the organizations. As a result, they put forward a four-level hierarchy of the professional knowledge of an organization in order of increasing importance. The first level, cognitive knowledge (know what), is the basic knowledge of a field that professionals have acquired through extensive learning and training, which is essential for business success, but usually far from enough. The second level, advanced skills (know how), transform knowledge learned into effective execution, and are applied to complex practical problems. These skills are the most widely used to create value.

The third level is high-level understanding (know why). Professionals can solve bigger and more complex problems and create extraordinary value through in-depth understanding of the causality of things. Such knowledge will ultimately become trained intuition. The fourth level is self-motivated creativity (care why), which consists of will, motivation, and effective adaptability. Teams with such knowledge generally outperform those with more physical or financial resources. Wiig (1988) classified knowledge into three levels: public knowledge, expertise, and personal knowledge. Public knowledge is the knowledge found in the public domain with the most recipients, which can be acquired through textbooks and taught in classrooms. Expertise is the knowledge shared among experts with limited recipients, and experts have developed the means to exchange with others. Individual knowledge resides within each person's mind but cannot be directly shared with others. Therefore, patents, as a form of specialized technical knowledge, can only be shared among experts in specific technical domains, falling within the realm of expert knowledge.

Table 2.1 Representative knowledge classifications

Author	Classifying criteria
Machlup (1962)	1. Practical knowledge 2. Intellectual knowledge 3. Small talk or pastime knowledge 4. Spiritual knowledge, 5. Unwanted knowledge
Quinn et al. (1996)	1. Cognitive knowledge (know what) 2. Advanced skills (know how) 3. System understanding (know why) 4. Self-motivated creativity (care why)
Heideloff and Baitsch (1998)	1. Fact knowledge (about things) 2. Episodic knowledge (about events) 3. Procedural knowledge (about relationships)
Wiig (1988)	1. Public knowledge 2. Expertise 3. Personal knowledge
Sveiby (1997)	1. Factual knowledge 2. Skills 3. Experience 4. Value judgment 5. Social networks
Baecker (1998)	1. Product knowledge 2. Societal knowledge 3. Leadership knowledge 4. Expert knowledge 5. Milieu knowledge

The classifications above however are not the golden standard. Different classification of knowledge may overlap, while the same knowledge can be classified and studied in a different manner based on the purpose of analysis. The patents studied in this thesis are commodifiable knowledge based on explicit technical knowledge. In the subsequent text,

when referring to knowledge or knowledge commodities, it primarily pertains to this type of explicit knowledge. Nevertheless, the process of converting patent knowledge into the firm's own knowledge also involves some technical know-how and experience, which need to be digested and absorbed by the firm in order to be transformed into competitive advantages. This in turn shows that patent knowledge has the characteristics of tacit knowledge. After the overview of the theory of knowledge, we will combine the knowledge with the firms, the object of study, to review the knowledge-based theory of the firm.

2.1.3 Knowledge-based theory of the firm

Firms are the key force binding economy and technology, and also the most important players in the patent transaction market. Patents usually need to be transformed into economic growth points and real productivity through firms. Investigating the knowledge-based theory of the firm may help reveal the logic behind this economic phenomenon. Firm is a collection of knowledge, which can be manifested as the technical knowledge, institutional knowledge, and management knowledge of the firm. This attribute and its continuous accumulation form the unique competitive advantage of a firm in the market.

2.1.3.1 Source of firm knowledge

The knowledge-based theory of the firm emerged from the strategic management research (Cole, 1998; Nonaka & Takeuchi, 1995; Spender, 1996), asserting that knowledge plays an increasingly crucial role in the business process and is considered an essential factor to be taken into account when firms formulate their strategies. This perspective was first proposed by Penrose (1959) and expanded by other scholars through the Resource-Based View (Barney, 1991; Conner, 1991; Wernerfelt, 1984). The theory holds that products and services provided by firms depend on not only the combination and application of tangible resources by the firm, but also the firm's proprietary knowledge, such as technical operation manuals, production processes, and technical secrets. Since 1990s, with the advancement of knowledge and practice in the post-industrial era, it has been widely recognized that knowledge has gradually superseded land, machine and capital as the key resource for the development of firms (Drucker, 1993). In the domain of knowledge management, many scholars hold that the application of knowledge is an important means to reduce complexities faced by the organization, and that knowledge is the key factor that distinguishes successful entrepreneurs from their competitors (Dierickx & Cool, 1989). Darroch (2005) pointed out that knowledge itself is a resource, arguing that effective management of knowledge can enable personnel within the company to maximally utilize its value, and that knowledge provides coordination

and management skills for internal personnel of the firms and plays an important supporting role when knowledge resources are transformed into firm capabilities which support firms' sustained development. Since knowledge-based resources are usually difficult to imitate and have a complex mechanism of action, the knowledge-based theory of the firm holds that these knowledge assets may produce long-term sustainable competitive advantages which are key for firms to maintain their edges. The ability of a company to effectively apply existing knowledge to create new knowledge and take actions constitutes the basis for gaining competitive advantage from knowledge-based resources. Creating new knowledge is an important form of innovation.

The innovation process carries substantial market, technological, and business model risks. The dynamic nature of markets and fleeting opportunities pose formidable challenges for many firms. Furthermore, this process is often associated with elevated human resource, equipment, and financial costs, which are typically beyond the capacity of most firms. Consequently, this situation presents a challenge to the ongoing development of firms. As a result, an increasing number of firms use external knowledge to innovate products or processes to maintain their dominant position in the competition. External knowledge can help firms decide to constantly identify market opportunities and quickly innovate with new technologies, thus reducing the huge risk associated with innovation. Teece (1998) held that the main process of firm knowledge management can be divided into creating internal knowledge, acquiring external knowledge, storing knowledge, updating knowledge, and sharing knowledge internally and externally. Earl (2001) pointed out that if firms pay more attention to the creation, sharing, application, and protection of knowledge, their performance can be improved. In this sense, knowledge management is consistent with the resource-based view, that is, to develop an ability that is hard to be imitated by others.

The knowledge of firms comes from internal and external sources. Internal knowledge mainly includes employee knowledge, team knowledge and organizational knowledge that can be effectively mastered by firms. External knowledge cannot be mastered by firms in a short period of time. In order to fill the internal knowledge gap and update the internal knowledge, firms should also find out what important knowledge the organization needs from the external environment. Generally, firms mainly acquire knowledge from channels such as suppliers, distributors, consulting firms, research institutions, industry experts, industry associations, and industry forums and exhibitions. In patent transactions, for the recipient, it is obvious that the source of firms' knowledge is external knowledge, not the knowledge that has been internalized. How the external knowledge transforms into firms' internal knowledge

and forms the competitive advantage of the firm is an important factor to be considered in patent transactions.

2.1.3.2 Firm knowledge management

After a firm acquires knowledge, it is essential to effectively manage that knowledge to maximize its value. This process is known as knowledge management. With the advent of the knowledge economy era, the quantity, quality, value, and significance of knowledge have been steadily increasing in economic activities. Knowledge now plays an ever-expanding role in business operations, making effective knowledge management increasingly important and a focus of attention for many firms. Knowledge management involves the management of both internal and external knowledge by a firm, covering the entire process of knowledge selection, acquisition, assimilation, sharing, and application. Its core focus is on the flow of knowledge. As a result of the intersection between management and information science, many scholars have conducted research in this field.

Leidner (2000) posited that knowledge management constitutes a management activity of a firm, aiming to optimize the efficiency and efficacy of knowledge. Gold and Malhotra (2001) delved into systematic issues pertaining to knowledge management in organizations and held that the foundational organizational capabilities or prerequisites for effective knowledge management encompass a knowledge infrastructure comprising technology, structure, and culture, coupled with a knowledge flow architecture encompassing knowledge acquisition, transformation, application, and protection. They conducted empirical modeling and analysis through surveys of over 300 executives to support their findings. Consequently, it is imperative to augment the development of both knowledge infrastructure and process architecture in corporate knowledge management. This necessitates fostering synergy and alignment between the two facets to bolster knowledge management capabilities. Shin et al. (2009) compared three major schools of thought regarding knowledge, conceptualizing knowledge as situated in cognition, processes, and objects, respectively. They assessed the impact of these conceptualizations on knowledge management, highlighting that knowledge management is a process of knowledge flowing from its origin to its destination, where knowledge is seen as a valuable resource that can create value. H. Huang (2012) argued that corporate knowledge management constitutes a cognitive behavior subject to performance evaluation. It exerts either a positive or negative influence on a firm’s competitive edge or innovation capabilities. A favorable impact serves as validation that the firm has effectively undertaken knowledge management, thereby optimizing the leveraging potential of

knowledge.

Davenport (1997) proposed that the knowledge management process comprises behaviors such as knowledge identification, acquisition, innovation, and reconstruction. Building upon this foundation, Tranfield et al. (2003) asserted that knowledge management is a management activity consisting of three distinct stages: Discovery, Realization, and Nurture, and incorporated these perspectives into a generalized knowledge management model. By introducing the concepts of radical and incremental innovation within products and processes, the three high-level stages are further expanded into eight generic knowledge management routines: Search, Capture, Articulate, Contextualize, Apply, Evaluate, Support and Re-innovate. It is believed that for successful organizational knowledge management within the context of innovation, attention must be paid to all eight generic routines, as well as the influencers and barriers operating within the internal and external facets of knowledge management. Consequently, the overall knowledge management process encompasses three major dimensions: acquisition, transformation, and recreation. Tailoring management to each of these dimensions by considering the specific circumstances of the firm facilitates the improvement of knowledge management processes and enhances knowledge management performance.

Furthermore, scholars have conducted research on knowledge management in specialized technical domains. For example, in the field of Internet of Things (IoT), knowledge management is achieved through the use of SQL databases, NoSQL databases, and graph databases (Azad et al., 2019). In the field of robotics, knowledge management is facilitated by employing the Plan-Do-Check-Act (PDCA) method, which integrates other quality tools and know-how within robots (Barbosa et al., 2020). In the context of IoT, knowledge management extends to resource allocation methods and the use of algorithms (Ghanbari et al., 2019). The emergence of these new technological approaches and tools has the potential to further enhance the knowledge management performance of relevant firms.

Chuang (2004) held that knowledge management is an organizational capability and empirically investigated the relationship between knowledge management capability and competitive advantage, concluding that knowledge management capability reflects a firm’s ability to create, organize, transfer, and utilize knowledge resources. There is a significant correlation between knowledge management capability and competitive advantage. Therefore, strengthening knowledge management, improving knowledge circulation efficiency, and absorptive capacity are key factors in enhancing a firm’s innovation capabilities and maintaining a competitive edge. Next, we will review the relevant theories regarding the

connection between knowledge and competitive advantages.

2.1.3.3 Knowledge and competitive advantage of firms

According to Prahalad and Hamel (1990) who defined the core competencies of firms from three aspects, a core competency should be hard for rivals to imitate. A competitor might acquire some of the technologies that constitute the core competency, but it will find it harder to copy the comprehensive pattern of internal coordination and learning which is exactly the internal knowledge of the firm. Simply put, knowledge is an important aspect of the core competency of the firm. Senge (1990) argued that firms can quickly acquire new knowledge, transform such knowledge into their internal knowledge, and develop the skills of applying the knowledge in the market, which can become the source of their sustainable competitive advantage. Yao and Xi (2001) examined the relationship between firms' knowledge accumulation and competitive advantage, arguing that when firms possess differential knowledge advantage which the competitors find difficult to imitate, they will also gain certain resource advantage in production, development, and competition. Rui and Fang (2003) opined that the competitive advantage of firms comes from the specific knowledge. They believed this specific knowledge represents the unique capability of firms to assimilate and integrate diverse external knowledge with their specific circumstances. Through knowledge innovation, they transform it into internal knowledge that surpasses external knowledge, ultimately creating Schumpeterian rents for the company. C. H. Tang (2003) noted that knowledge is the core essence of the dynamic capabilities of firms, and that the dynamic mechanism of knowledge formation, that is, how firms continuously and dynamically acquire external knowledge and transform it, underpins the sustainable competitive advantage of firms.

In a rapidly evolving technology-based market environment, technology is constantly being iterated, concurrently giving rise to numerous market opportunities. A central challenge for firms is how to use the acquired knowledge to respond to innovative market opportunities that arise over time (Davis et al., 2009). The most dominant features of this environment are constant change and excessive competition, which require firms to match their knowledge with emerging opportunities in areas such as new product development and market entry in order to adapt to the quickly changing market environment (Roy et al., 2018). Knowledge, when applied to the design or improvement of new products or services and subsequently introduced as market-adaptive offerings, helps firms surpass competitors and maintain sustained competitive advantages (Ceylan, 2013). The design and improvement of new

products or services is innovation that holds the key to achieving and maintaining a firm's competitive advantage (Bayraktar et al., 2016). Davis et al. (2009) held that the collection of knowledge elements owned by a firm constitutes the firm's knowledge base. These knowledge elements encompass both well-defined explicit knowledge, such as technical manuals, operating procedures, and production processes, as well as tacit knowledge, including the technical secrets and operational expertise possessed by the employees, and innovation is the reorganization of knowledge elements in the knowledge base, especially when breakthrough technologies enter the market (Mendonça et al., 2022; Metzger et al., 2023; Silva et al., 2023). Boh et al. (2014) posited that a high level of knowledge breadth and depth will play a strong role in promoting innovation, and that the acquisition of external knowledge through knowledge transfer can both broaden the breadth and deepen the depth of firms' knowledge, which will enhance the competitive advantage of the firms. Xiao et al. (2013) developed a theoretical framework for understanding the technology strategy of latecomer firms and predicting its outcomes which demonstrates that knowledge can have varying impacts on industries with different levels of technological intensity. In patent transactions, patents as external knowledge need to be transferred and absorbed in order to form the firm's own knowledge which needs to be internalized to form the competitive advantage. Therefore, the theory of knowledge transfer and absorption will be reviewed in the following sections.

2.1.4 Knowledge transfer and absorption theory

Knowledge is a fluid factor of production. It is only when knowledge transfer and absorption extend beyond the boundaries of the firm that it can genuinely contribute to the advancement of innovation activities, thereby making knowledge a core competitive advantage. Because knowledge is an intangible asset, its transfer and absorption are different from the tangible asset, which explains the particularity of patent assignment and licensing. The recipient needs to absorb the transferred knowledge before transforming it into the recipient's own knowledge for future use. Acquiring complementary knowledge can contribute to better performance of the firms by stimulating innovation. Firms can couple with existing knowledge by acquiring external knowledge, in which knowledge from different domains complements each other through interaction and feedback, increasing the value or effectiveness compared to using their own knowledge alone and thus increasing the likelihood of innovation success (Makri et al., 2010). The key to achieving complementary coupling of knowledge lies in the acquisition of externally transferred knowledge by the firm and its subsequent absorption. External transferred knowledge serves as the foundation, and knowledge absorption is an essential

stage in this process.

2.1.4.1 Value realization of knowledge

Similar to market economies, knowledge markets may also experience market failures that disrupt normal knowledge transactions. Knowledge incompleteness, asymmetry and specificity could lead to inefficient operation of the knowledge market (Davenport & Prusak, 2000). Efforts should be made to overcome such failures in knowledge transactions to effectively promote the development of the knowledge market, which in turn maximizes the mutual benefits of both parties to the knowledge transaction. In knowledge transactions, knowledge owners charge fees for and inform knowledge seekers of their knowledge, and owners change the exclusivity of knowledge through knowledge transfer to obtain economic benefits. Knowledge transactions have certain prerequisites, which form the foundational conditions for knowledge to be exchanged. Due to the intangible nature of knowledge, it cannot be directly possessed like tangible assets. Determining the boundaries of knowledge is far more challenging than establishing the boundaries of ordinary goods. Knowledge to be traded must have clear and distinct rights boundaries to avoid unnecessary disputes during transactions. Scarcity refers to the condition where the knowledge to be traded is in a state that knowledge seekers want but have not yet obtained. Since knowledge can be freely accessed by any entity due to its non-exclusivity, the knowledge being traded must possess a certain degree of scarcity to have value. It is this scarcity that motivates knowledge seekers to pay for access to knowledge. Furthermore, knowledge needs legal protection through governmental authority to ensure there is a proper legal basis for its use rights and disposal rights. Patent granting needs to meet the requirements of novelty and creativity. There is no same technical solution protected by two patent rights. Moreover, the scope of protection is clearly defined through the claims in the patent documents. Therefore, patent granting meets the requirements of clear boundaries and scarcity, and patent rights are a form of property rights protected by the authority. Thus, patents satisfy the prerequisites for knowledge transactions and represent a key focus of knowledge transactions. This Thesis examines knowledge transactions from the perspective of patent transactions.

Asymmetry is both a characteristic and the prerequisite of knowledge transactions. The seeker's lack or incomplete understanding of the knowledge owned by the knowledge owner makes the transaction necessary. Reducing this asymmetry is also the foundation for the successful execution of knowledge transactions. Prior to knowledge transactions, knowledge seekers typically search for the knowledge they lack and its owners based on their specific

knowledge needs. The search for transaction partners and transaction objects is a process of identifying knowledge asymmetry. During the transaction, as knowledge seekers gradually acquire knowledge about the transaction partners and objects, this information asymmetry diminishes, transitioning toward information symmetry. Generally, it is only when this information asymmetry has been minimized as much as possible that knowledge seekers initiate knowledge transaction activities. Information asymmetry can lead to opportunistic behavior, where the party with information advantage tends to selectively disclose incomplete or inaccurate information to benefit themselves. Given that information asymmetry is more pronounced in knowledge transactions, opportunistic behavior is more prevalent in these transactions compared to general transactions. Thus, in knowledge transactions, knowledge seekers can choose trading objects that can disclose more knowledge information such as patents, so as to reduce the influence of information asymmetry on knowledge transactions. Patents not only allow for the quick identification of patent owners through patent records but also provide detailed information about the specific content of the transaction object through patent claims, specifications, and accompanying drawings. In patent transactions, the monopolistic nature of patents can prevent knowledge products from losing their trading value due to the disclosure of the patent's contents to potential seekers. At the same time, the exclusivity of patents can also prevent the buyers from suffering losses if the former patentee still uses the patent after the transaction. Therefore, patents are a suitable knowledge transaction object. Knowledge ownership does not prevent others from using it, so knowledge also has the characteristic of public goods, which leads to the externalities in knowledge transactions. Patent, as an exclusive right different from trade secrets, technical secrets, and operational experience, can effectively avoid the public goods characteristic of knowledge, thus solving the externality issue in knowledge transactions. Therefore, knowledge transactions are carried out preferably through patents to improve the trading efficiency.

2.1.4.2 Knowledge transfer theory

The key to innovation in product, services, production process, or business model all lies in knowledge, and acquiring new externally generated knowledge is essential for the development of knowledge within SMEs (Saad et al., 2017). Acquiring and absorbing new external knowledge is a process of knowledge transfer. Knowledge transfer is a process in which one entity is affected by the experience of another (Argote & Ingram, 2000), whose essence is the process by which the recipient internalizes the knowledge from the transferor as their own knowledge. In the process of development of a firm, internal innovation and

innovation based on external knowledge transfer are two different paths, and the latter can play a bigger role in expanding the firm's horizon and capabilities. Knowledge transfer can occur at staff training, staff turnover, reverse engineering, technology transfer, patents, and scientific publications (Galbraith, 1990) , which indicates that patents are an important means of knowledge transfer. The study of knowledge transfer first started with technology transfer, when Teece (1977) looked at the technology transfer of multinational corporations across different countries, arguing that it can accumulate cross-border technical knowledge and facilitate effective flow of knowledge. Novel knowledge, especially that outside the company, may be an important driving force for organizational change and improvement, promoting innovation of the companies through organizational change and developing competitive advantages ultimately. Gupta and Govindarajan (1991) thought that multinational corporations can be regarded as a network of capital, products, and knowledge transactions among different countries and regions. Multinational corporations exist primarily because they have stronger ability to transfer and utilize knowledge and facilitate the flow of knowledge across different countries and regions.

Scholars have defined the scope of knowledge transfer from different angles, and arrived at three different views: mutual learning, mutual communication, and dynamic process. Verkasolo and Lappalainen (1998) believed that knowledge transfer is a process of interaction and learning between knowledge providers and recipients, and that both sides need to have the willingness to learn from each other, which is the foundation for successful knowledge transfer. Singley and Anderson (1989) held that knowledge transfer is a process maintained through various communication channels and that communication is the key to gradually concretize intangible knowledge, thereby achieving the effective transfer of knowledge. Lahti and Beyerlein (2000) considered knowledge transfer to be a dynamic process that occurs within a company or between different companies and includes transmission and dissemination behaviors. Built upon the research of knowledge transfer scope, Garud and Nayyar (1994) studied the difficulty level of knowledge transfer which is also the difficulty level for the knowledge seekers to internalize the knowledge, arguing that the difficulty of inter-temporal knowledge transfer is correlated to that of knowledge transfer to the organization while the difficulty of knowledge transfer is positively correlated to strategic value.

After studying the process of knowledge transfer, some scholars have also proposed the theoretical model related to knowledge transfer based on its process. Nonaka (1994) examined the dynamic theory of organizational knowledge creation, and put forward the

spiral model. The explicit and tacit knowledge within an organization are mutually transformed through four stages: socialization, externalization, combination, and externalization. These four modes together make up a dynamic circular process of knowledge transfer, namely the SECI knowledge spiral model. The transfer and transformation of knowledge between individuals and between individuals and organizations are realized through this model, which ultimately generates new knowledge. On the basis of the SECI model, Nonaka and Konno (1998) further put forward the concept of "ba", including origination ba, interaction ba, cyber ba, and exercising ba corresponding to the four stages of the SECI model of socialization, externalization, combination, and internalization. The SECI model looks at the knowledge transformation mechanism of the organization itself, representing a relatively static perspective on knowledge transfer from within the organization. In contrast, ba focuses on how to promote knowledge innovation by creating the environment, representing a more dynamic perspective on knowledge transfer. Gilbert and Cordeyhayes (1996) summarized the process of knowledge transfer into a five-stage model of acquisition, communication, application, acceptance and internalization. The whole process is a dynamic learning one by the knowledge seeker. It also reveals the general patterns of knowledge transfer processes. In the five-stage model, internalization is a crucial stage in knowledge transfer and a key indicator determining the effectiveness of knowledge transfer. It is also a process of knowledge integration and reconstruction within the organization. Only after internalization by the knowledge seekers can the transferred knowledge be fully absorbed, thereby becoming part of the internal knowledge of the organization.

At the same time, an increasing number of scholars believed that organizations that can transfer knowledge from one unit to another are more efficient than those unable to do so (Almeida & Kogut, 1999; Hansen, 2002). The enhanced organizational efficiency also promotes firm performance. As a consequence, the actual results of knowledge transfer are generally embodied in the performance changes of the recipient. There have been many studies of the impact of knowledge transfer on the performance of the recipient of knowledge. Andrews and Delahaye (2000) argued that mutual knowledge transfer between individuals in an organization can enhance the learning ability of individuals and organizations, thereby realizing the knowledge sharing within the organization and improving the performance of individuals and organizations in their work, demonstrating the positive effects of knowledge transfer on firm performance. Zhou et al. (2007) found that the individual contextual performance of R&D team members influences team performance via the mediating variable of knowledge transfer effectiveness, so knowledge transfer can ultimately lead to better team

performance. Kang (2015) noted that the influence of knowledge transfer on performance is realized through the interaction with absorptive capacity and that knowledge transfer performance is positively correlated with absorptive capacity. Yang and Guo (2018) held that there was a significant positive correlation between international knowledge transfer and international entrepreneurial performance and that the cross-border transfer of knowledge could improve innovation performance. Wu and Ji (2013) conducted an empirical study of small and medium-sized enterprises in Chongqing, and concluded that tacit transfer of internal knowledge of firms was conducive to better innovation performance and that adopting measures to promote the internal knowledge transfer of firms will result in better innovation performance. Wan (2018) posited that the innovation effect of firms is greatly improved in the process of most of the knowledge transfer cases, signifying a U-shaped relationship between the two. At the initial stages, the innovation effectiveness increases with the growth of knowledge transfer. However, after reaching a certain peak, the innovation effectiveness declines as knowledge transfer continues to increase. Jiang et al. (2013) considered that the effective transfer of knowledge within the cluster can drive cluster innovation, and the diversity of knowledge can promote the technology upgrade of the cluster enterprise. Hameed et al. (2021) argued that external knowledge has a positive impact on firms' innovation performance as it can more easily stimulate innovation, and that it is important for firms to cite external knowledge and technology in the innovation process to improve their innovation performance, which highlights the important value of external knowledge (Medase & Abdul-Basit, 2020). Technology transfer contributes to higher innovation quality and performance, enabling firms to maintain a competitive advantage (Yu et al., 2019). During the knowledge transfer process, different types of knowledge transfer exhibit variations in success rates. Akhavan et al. (2014) from the perspective of knowledge characteristics, found that tacit knowledge and knowledge with higher complexity entail more constraints in knowledge transfer, requiring more demanding conditions from recipients, resulting in a lower success rate of knowledge transfer. Therefore, prior to engaging in knowledge transfer, knowledge seekers need to conduct a targeted analysis of the characteristics of the knowledge to be transferred and make preparations across various aspects to maximize the success rate of knowledge transfer.

2.1.4.3 Knowledge absorptive capacity

Knowledge absorption is a dynamic and organic process of knowledge being transferred by the source to the recipient. For firms, it is a cognitive process in which they transform, digest,

and renew knowledge internally on the basis of acquiring and understanding external knowledge, creating conditions for enhancing firm performance. Firms need to recognize and assimilate new external knowledge, and apply it for commercial purposes during its operation and development, which is an ability first defined by Cohen and Levinthal (1990) as knowledge absorptive capacity who held that such absorptive capacity determines the accumulation and digestion of external knowledge through expanding internal knowledge, thus offering intelligent support for firm innovation and facilitating the use of these knowledge reserves to achieve better firm performance. Spraggon and Bodolica (2012) argued that transferred knowledge is only as effective when the organization understands it, and that such understanding process is the knowledge absorptive capacity which is the key to the success of knowledge transfer. Ziam et al. (2013) considered that absorptive capacity is the ability of an organization to make full use of external knowledge and that the stronger an organization's knowledge absorptive capacity, the better it can fully utilize external knowledge. Zahra and George (2002) adapted the concept through literature review and constructed a new absorption process by examining knowledge absorptive capacity from a dynamic perspective. They argued that knowledge absorptive capacity includes four stages: acquiring, internalizing, transforming, and exploiting knowledge. The capacities of these four stages have certain differences and commonalities among different firms, but are obviously different in the specific ways in which firms develop and use them. This variability provides a basis for firms to develop different competitive advantages. The ability to acquire, internalize, transform, and exploit knowledge corresponds to the four different stages of knowledge absorption, representing specific manifestations of a firm's knowledge absorptive capacity and influencing its performance. Knowledge acquisition is the first stage. It refers to an organization's identification and acquisition of external knowledge vital to its operation and is also the prerequisite for knowledge absorption. The process of knowledge acquisition is mainly influenced by three factors: intensity, speed, and direction. The type of products or services typically offered by a company determines the direction of its knowledge acquisition. The more firms invest in the intensity and speed of acquiring knowledge, the faster the knowledge is absorbed. Clearly, increasing the intensity of knowledge acquisition generally accelerates the speed of knowledge acquisition. However, firms have limited ability to achieve this speed, because the learning cycle cannot be shortened easily, and that some resources needed by firms to acquire knowledge cannot be integrated quickly (Clark & Fujimoto, 1991). On the other hand, the direction of firms' knowledge accumulation will also affect their path to acquire external knowledge, which indicates that it is necessary to have

expertise in different fields and accumulated knowledge within the company in order to successfully introduce external technology (Rocha, 1999).

The second stage, internalizing knowledge, refers to the process in which firms, after acquiring the knowledge, analyze, process, explain, and understand external knowledge (Kim, 1997; Szulanski, 1996). After acquiring knowledge, it needs to be internalized to effectively transform it into the knowledge that the firm requires. There have been studies of the possible difficulties in the process of internalizing knowledge by firms, resulting in a deeper understanding of the process and rules of internalizing knowledge. Those ideas and findings beyond the scope of the firm's vision are easily overlooked, because firms cannot easily understand them, thus unable to internalize the corresponding knowledge (Rosenkopf & Nerkar, 2001). Therefore, the knowledge internalized by the firm is primarily knowledge closely related to its core business. The knowledge acquired from outside may be obviously different from the research methods or ways of operation used by the firm, which, as a result, might delay the understanding of the knowledge because firms cannot understand based on the existing knowledge or experience (Leonard, 1995). External knowledge is also specific to the situation or background, which often makes outsiders unable to comprehend (Szulanski, 1996). This is also a result of the costs of transfer of knowledge. When the value of external knowledge also depends on the complementary assets the recipient might not be able to acquire, the understanding and absorption of external knowledge becomes particularly difficult (Teece, 1981). Nevertheless, understanding which is the prerequisite for knowledge absorption can promote knowledge absorption and enable firms to manage and assimilate external knowledge. In patent licensing, the licensor and the licensee generally hold regular or occasional meetings, training, and other exchange activities, and a great deal of informal information is shared between the partners, which is in line with the concept of "absorptive capacity" for the effective implementation of foreign technology licensing (Martinez et al., 2012). Lichtenthaler and Muethel (2012) analyzed the interdependencies between deliberate and experiential learning by the licensee in the development of a dynamic technology licensing capability by investigating the role of dedicated employees and prior licensing experience in the development of a firm's perceived, acquired, and transformed technology capabilities through three-year lagged data of 79 firms, and concluded that there is an interdependence between deliberate and experiential learning when the licensee develops its technological capabilities, which is a multidimensional and critical trade-off. Compared to the experiential learning of the licensee, this deliberate learning is the process by which firms internalize external knowledge.

Transforming knowledge, the third stage, refers to a firm's ability to develop and improve processes about the knowledge which help to combine existing knowledge with newly acquired and absorbed knowledge. Once knowledge is internalized, the crucial aspect of knowledge absorption lies in its transformation into valuable knowledge for firms. Knowledge transformation occurs when an idea is perceived and novel knowledge is generated in two kinds of paradoxical knowledge, that is, the existing and newly acquired knowledge (Koestler, 1964). Therefore, in different types of knowledge, the ability of firms to identify two apparently uncoordinated information sets and then to combine them to form a new pattern represents a kind of transformation ability. Knowledge transformation equips firms with a spectrum of knowledge, including their existing, newly acquired, and absorbed knowledge, as well as the fresh insights born from the amalgamation of these knowledge types, which consequently expands a company's horizons and capabilities, fostering the discovery of new business opportunities and at the same time changing the way companies view themselves and the competitive landscape. The study of strategic transformation by Christensen (1998) highlighted the importance of new knowledge as an important driver for strategic reform to redefine the company, industry and competitive strategy. In the study of entrepreneurship and firm growth, scholars have advanced similar arguments, contending that entrepreneurial spirit and the transformation of new knowledge during the process of firms' growth also play indispensable and crucial roles (Zahra et al., 2000). In conclusion, the process of knowledge transformation helps to open the black box of the research about organizational and strategic transformation.

The fourth stage is knowledge exploitation. Exploiting knowledge involves integrating the transformed knowledge with the actual products or services of the firm to enhance its performance. It is also the purpose of knowledge absorption. Cohen and Levinthal (1990) emphasized the importance of knowledge exploitation. It is an organizational capability, whose basis is that firms can improve and utilize the existing capabilities. The key is that firms have due mechanisms. They may accidentally exploit knowledge without such mechanisms. However, these mechanisms might enable companies to keep effectively exploiting knowledge for a longer term. The utilization of knowledge reflects the ability of firms to collect and incorporate knowledge into their operations and actual products and services (VanDenBosch et al., 1999). It requires searching the knowledge that has been formed and used internally, thus developing the experience path for knowledge exploitation (Lyles & Schwenk, 1992). Knowledge exploitation will bring about continuous innovation of products, systems, processes, knowledge, or new organizational forms (Spender, 1996). While

bringing about these changes, it naturally leads to a significant improvement in the firm performance. In the process of exploiting knowledge, firms acquire knowledge from markets, competitors, and customers, and then use it to incubate new capabilities which ultimately drive firm performance.

Todorova and Durisin (2007) further examined the process of knowledge absorption proposed by Zahra and George (2002), and proposed that the cognitive process of knowledge value should be introduced before knowledge acquisition as the basis of knowledge absorption. At the same time, the process of internalizing and transforming knowledge is not completely fixed and can be carried out in the reverse direction. knowledge absorption can be repeated back and forth between internalization and transformation. In this way, external knowledge can be successfully incorporated into the organizational knowledge system, which prepares for the exploitation. After receiving external knowledge, firms need a certain lag time to absorb it in order to generate value. This also underscores that the process of internalizing and transforming knowledge is not instantaneous but rather a dynamic and gradual progression. After acquiring external knowledge, firms require some time lag for absorption to generate value. This lag time represents the period for firms to digest external knowledge. Generally, tacit knowledge, knowledge with higher complexity, and knowledge significantly different from firms' existing knowledge require a longer lag time. Additionally, this lag time reflects the firm's learning capability, with stronger learning capabilities resulting in shorter lag times. Wang et al. (2014) conducted an empirical study of the time required for Chinese firms to learn from their licensed technology, and the results of their analysis showed that the recipient firms needed an average of 5.8 years to do this, while the knowledge absorptive capacity and willingness of the licensee, the age of the firm, the scale of technology licensing, and the age of the licensed technology can shorten the learning time of the licensed technology, which also indicates the important role of knowledge absorption for the licensee in patent transactions. It is the key factor to determine whether the patented technology's utility can be realized through the transaction and to what extent it can be realized.

Scholars also examined the process of knowledge absorption from the perspective of technological capability evolution, emphasizing that knowledge absorption process is not entirely a passive learning process but a process of utilizing external knowledge to form new technological capabilities. Y. Xiao (2006) introduced a model for the evolution of a firm's technological capabilities following the absorption of tacit knowledge which comprises several stages, including technology selection, technology acquisition, technology digestion,

technology improvement, and the creation of new technology. These stages correspond to the different phases of knowledge absorption. It posits that a firm's technological capabilities progress from absorption towards the stage of technology creation, ultimately leading to improved firm performance (Xiao, 2006). Evidently, this form of technology creation represents an advanced phase of knowledge absorption and serves as the ultimate objective for many knowledge-seekers.

A firm's knowledge absorptive capacity is also directly related to its performance, and is critical to external knowledge which could only be effectively transformed after being absorbed, and such knowledge can improve the innovativeness of a firm's products and other corporate outputs (Su et al., 2013). Zou et al. (2019) found that knowledge of new technologies often harbors more business opportunities of which the commercializing is a direct manifestation of innovation performance, and that the absorptive capacity of an organization plays a positive role in enhancing innovation performance by facilitating the commercialization of new technologies. Tseng et al. (2011) found a significant positive relationship between absorptive capacity and firm innovation performance. Specifically, firms share, integrate, apply, and create internal knowledge with external knowledge to integrate knowledge, which facilitates innovation and innovation results and then has a significant impact on firm innovation performance (Tsai & Hsu, 2014). Zhao et al. (2019) examined the impact of knowledge embeddedness on the synergistic effect of knowledge in collaborative networks in which deeper embeddedness results in greater synergy, and argued that the key to improving absorptive capacity lies in the integration and application of external knowledge.

In conclusion, knowledge absorption is a dynamic process. Knowledge products are more capable than physical assets of supporting firms to adapt to dynamic technological and market competitive environments, enabling firms to gain a competitive edge in the midst of uncertainty (Xiao & Wei, 2011). Through the absorption of external knowledge and its integration with internal knowledge, firms establish new knowledge reservoirs. This expansion of their knowledge horizons and capabilities enables easier application of knowledge to their operational processes, products, or services, resulting in enhanced technological competencies and innovation performance. Moreover, firms consistently update their existing knowledge and refine their current technological understanding following the acquisition of external knowledge. This iterative process contributes to the evolution of their technological capabilities, enabling the delivery of more competitive products or services and ultimately leading to improved firm performance. This underscores the purpose of firms engaging in patent transactions and serves as the theoretical foundation for the research

hypotheses presented in this thesis.

2.2 The role of patents and patent institutions

As a form of knowledge and typical intellectual property, patents have been extensively and deeply studied since its inception. There has been much in-depth analysis of its concept and role, which also prepares the theoretical ground for the research on patent transactions. Against the larger background of the knowledge economy, in order to reduce costs and improve efficiency, an increasing number of companies are gradually adapting their innovation strategies to develop partnerships with others (Wei et al., 2019). Relationships between innovative firms include formal relationships characterized by stable cooperation and informal exchanges and contacts (Lu et al., 2019). Such cooperative relations are usually bonded through patents for technological knowledge transfer. As a result, the two ways of cooperation of patent assignment and licensing also become more frequent.

2.2.1 Concept and role of patent

2.2.1.1 Essence of patent

Patents have a long history and represents a significant form of knowledge monopoly rights. The earliest patents only granted legal monopoly to specific products, rather than protecting technical inventions from being copied. One of the early examples of technology-related patents is a patent for a ship designed by Brunelleschi for transporting marble to the Arno River. The patent was issued by the government of Florence in 1421. After that, the Venetian Patent Statute was established in 1474. From the 15th through 17th centuries, the British royal family also granted various patent monopolies. The publication of the technical contents of modern patents requires a technical model or written description. Such a system could date back to the 18th century. It was first established in Britain, then in the United States, and later in France. Many other European countries also introduced the patent system in the 19th century. In the 20th century, the modern patent system had already been popularized across different countries in the world, and the signing of TRIPS has ensured that all WTO members have at least a minimum level of patent protection. China's current patent system was established in 1980s, and the *Patent Law of the People's Republic of China* came into effect in 1985 followed by four revisions in 1992, 2000, 2008, and 2020. The last revision was implemented from June 1, 2021.

Over the past three decades, with the advent of the knowledge economy, the most

common assets of firms have shifted from tangible to intangible assets including a diverse array of types, such as intellectual property rights, research and development, software, skills, organizational know-how and technology, and brand promotion. Among them, the intellectual property rights represented by patents are the most typical, which also play an increasingly important role in the knowledge economy. A study based on the OECD countries by Nikzad (2013) showed that firms invested equally in innovation-related intangible and knowledge assets and tangible assets (such as machinery, equipment, and buildings), which indicated the importance of knowledge assets. 'place-based intangibles' give thrust to context sensitive economic arrangements and social relations, These features present opportunities for equitable market participation, particularly in face of high-tech modes of specialisation (Castald & Mendonça, 2015). Firms need patents, which come with a certain duration of monopoly rights, to effectively protect their intangible assets because of low marginal cost and the fact that such assets generated from technology research and development are easy to replicate and spread. Without such protection, other producers or competitors can copy the innovation without bearing the sunk costs from R&D activities. Infringement and imitation will undermine the profits generated by the R&D and innovation of firms, thus reducing the returns on innovation and the motivation to innovate. With the development of globalization, encouraging innovation has become a key issue for policy makers when developing laws and establishing mechanisms to protect innovation investment so as to drive sustained economic growth. Countries generally protect innovation through establishing and improving the patent system.

Patent, an often important precursor to a commercialized innovation (Higham et al., 2021), is the right granted by the government to inventors to exclude others from using or selling related technologies. It is a monopoly. Successful innovators can benefit from innovation, gain excess returns, and inspire future investors to continuously innovate and engage in R&D efforts after disclosing the technology in exchange for monopoly protection. This monopoly right is embodied in the patent's scope of protection which is mainly specified in the claims of the patent document. Chu (2009) held that in an environment of continuous innovation, the scope of protection of the patent will determine the level of imitation prevention and the boundary of subsequent innovation. In general, patents typically seek a broader scope of protection during the filing process to more effectively prevent imitation. Patent protection urges firms to develop new products or services with market prospects in order to better maintain their competitive advantage through exercising the monopoly rights. Patents can prevent imitation and keep the value and rareness of innovation through legal protection. In

the absence of such legal protection, any potential advantage would soon disappear after being copied or imitated by competitors. The government grants the patent right in an effort to ensure the protection without which the competitive market will not be able to provide enough incentives for the private sector to promote research and development. New theories and technologies born from these R&D activities are important sources of long-term economic growth. Maskus (2004) elaborated upon the three purposes of patent granting: (1) patents are the legal means to provide inventors and companies with exclusive right and market share to compensate their investment costs and patentees can use this to gain excess returns; (2) the disclosure of details of the technical features of new inventions can increase public knowledge; and (3) patents can provide legal support for international technology transfer of new inventions, which facilitates the patentees in expanding international market or carrying out technological transfer across countries.

2.2.1.2 Role of patents

Patents provide detailed information about inventions and innovations, which generally includes: patent applicant, application time, technical summary, claims, instructions and drawings. Patents have consistently served as a crucial source of new technological information. This type of technical data is a result of the government's substantial investment in patent examinations over an extended period. It forms the fundamental basis for subsequent technological research and development by the public. Additionally, patents are employed to describe innovation processes and their outcomes. In recent years, patents have gained increasing prominence in the analysis of innovation processes and their results. Patent statistics are now widely utilized as instruments for measuring technological innovation.

The value and technical attributes of the patent make it a tool to measure technological innovation. Patent value refers to the economic returns a patentee can obtain through the patent in the market environment. Such returns can be generated both through the direct implementation of patents and through the assignment or licensing of patents. Lanjouw and Schankerman (2004) conducted a study of patent value based on the panel data of U.S. manufacturing firms from 1980 to 1993, holding that there are four main quantitative indicators affecting the patent value: forward citations, backward citations, claims, and patent family size. The number of forward and backward citations both indicate the contribution of an innovation to the research, hence obvious value characteristics. The forward citation count refers to the number of background patents required for the development of a particular patent, while the backward citation count represents how many subsequent research patents are based

on the given patent. The number of claims indicates a wider innovation scope, better protection, and higher value. The patent family size indicates the potential value a patent can generate in multiple regions and is directly correlated to the expected value from protecting an innovation. Y. Deng (2005) analyzed the maintenance data of patents for 1994-1996 of the European Patent Office, and concluded that the median value of actual patent value in Britain, France, and Germany was 11,682, 12,376, and 27,657 USD respectively. Especially in traditional industries such as pharmaceuticals or mobile communications where the technical research and development face high barriers and have low success rates, yet they are easily replicable, underscoring the need for protection through patents, patents play a key role in securing a firm's position and protecting profit flows (Li et al., 2021). S. L. Zheng and Song (2012) delved into the main influencing factors of patent value from patent characteristics, patentee characteristics, and characteristics of R&D activities. They put forward the framework of influencing factors of patent value as shown in Figure 2.1. Some scholars have developed a patent value assessment system based on technology, law, and market (Lv, 2014; Wan & Zhu, 2008; Xu & Cheng, 2014). As illustrated in Figure 2.2, the technical value refers to the novelty, creativity, and practicality of the patented technology. The legal value refers to the scope of protection of claims, the number of claims, and the stability of rights. The market value refers to the marketability of the patent such as market prospect and scale. Patent is a kind of explicit knowledge, and firms gain economic benefits by absorbing patented knowledge. The economic value of the patent is playing a role in the process. Patents will have economic value after being acquired through market means.

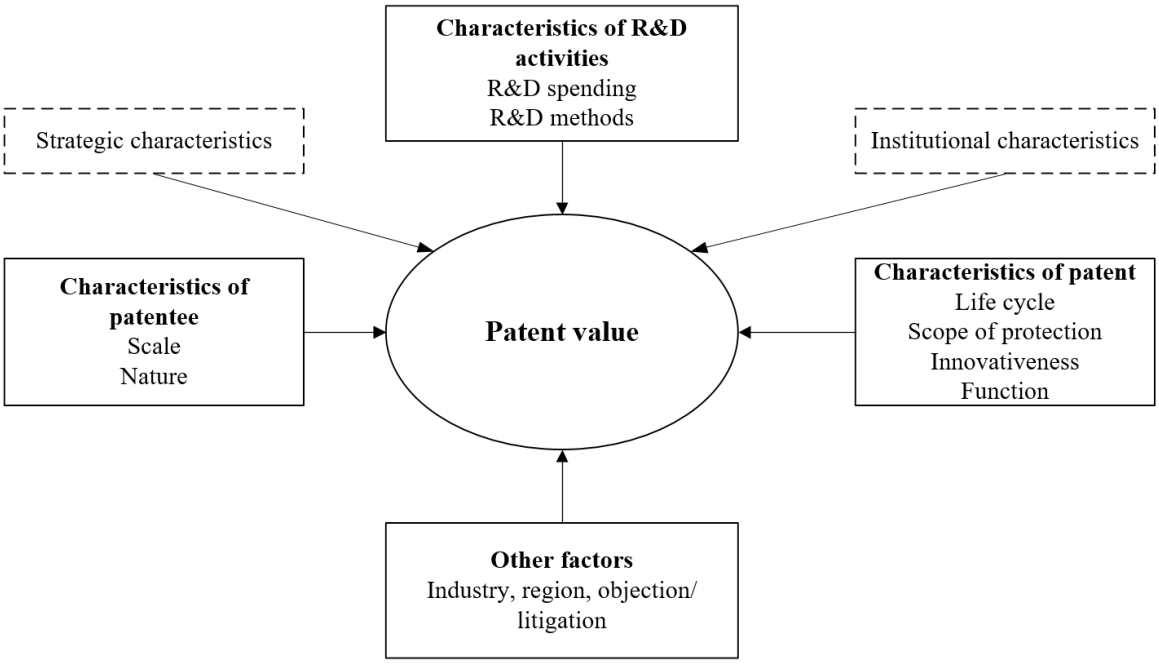

Figure 2.1 Influencing factors of patent value - comprehensive framework

Source: S. L. Zheng and Song (2012)

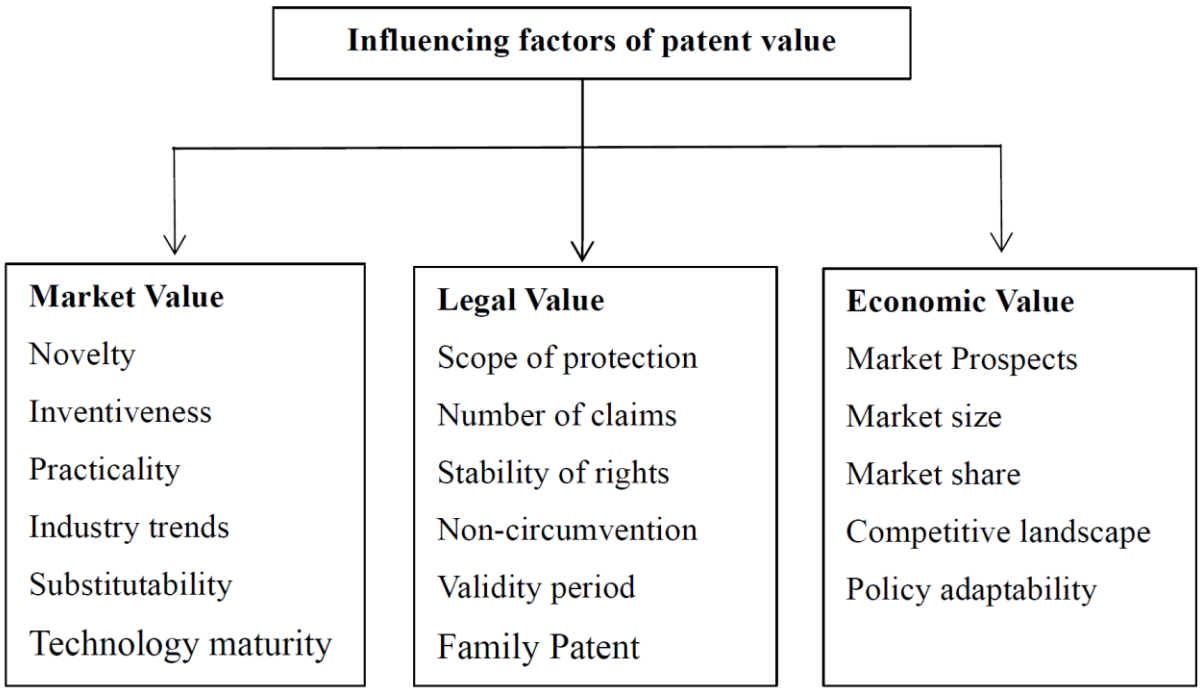

Figure 2.2 Influencing factors of patent value

Source: Wan and Zhu (2008); Xu and Cheng (2014); Lv (2014)

Patents, as a form of technical documentation, are intricately linked to innovation. Scholars have expounded the relationship between patent and technological innovation from different angles. Schmookler (1962) analyzed the patent data of the railway, agriculture, paper-making, and oil refining industries of the U.S. from 1836 to 1957, arguing that the change of industry and technology is the decisive factor of patent innovation, and that the number of patents can measure the level of technological innovation and indicates the technological changes. Griliches (1990) investigated the patent data as an economic indicator, and analyzed the time sequence of the relationship between patents and R&D expenditures, holding that patent data is a unique indicator for studying technological changes. Schmoch (1997) argued that the study of the relationship between science and technology is an important topic, and that patent as a quantitative indicator can effectively support the study, thus promoting technological innovation.

There are also studies that looked at the role of patents from other angles. Lach (1995) studied 20 U.S. manufacturing firms from 1958 to 1983, and considered that the number of patents was positively correlated with the improvement of productivity, and that the elasticity of knowledge output measured by stock patents was about 0.3. Allred and Park (2007) collected and analyzed the data of 706 firms, and concluded that patents or patent assignment promoted technological exchanges and quick returns and had a positive impact on the

investment in innovation of firms. Hall and Harhoff (2012) argued that knowledge-intensive firms face many problems related to intangible assets, and that patents can alleviate these problems by helping to clarify the ownership of some intangible assets and to obtain financing from venture capital. In addition to protecting innovation, patents have other functions, such as bargaining with competitors through cross-licensing, preventing competitors from gaining more advantages, and serving as a tool to measure the performance of scientists and engineers within firms. Given its multifaceted roles, patents are assuming an ever-growing significance in contemporary economic activities and the operational activities of firms.

2.2.2 Patent assignment

Patent assignment is the right of the patentee to dispose of the patent they own Patent assignment is a legal way for a patentee to assign the patent right to the assignee who then acquires the patent right and the right to exploit the patent. The original patentee no longer has the right to exploit the patent. It is a permanent assignment. Because of the intangibility of patent right, patent assignment generally needs to go through registration procedures before taking effect so as to avoid patent dispute. Patent assignment is an important means for the assignee to acquire external technology, and for the patentee to recover R&D costs and obtain returns on R&D efforts, laying a solid foundation for subsequent higher level and more diverse R&D. It transfers the intellectual property to assignees who can better utilize it, saving early R&D costs and avoiding potential risks from technology and market uncertainties, thus realizing the efficient circulation and optimal allocation of innovation resources. In the process of reorganization for merger or bankruptcy of firms, the core value of mergers and acquisitions involving technology and R&D capabilities lies in the intellectual property, knowledge, R&D, and design process (C. Huang & Sharif, 2015). Patent assignment is most common in this process which often involves the one-time assignment of a large number of patents. Patent assignment is the most common in the reorganization for merger or bankruptcy of firms. For example, Kodak assigned more than 1100 patents related to digital images to Intellectual Ventures, a patent portfolio company and RPX Corporation, a patent risk advisory firm, in its bankruptcy reorganization proceedings, with a deal valued at 525 million USD. As a result, Kodak emerged from bankruptcy protection in 2013 and ushered in a new stage of development (Caviggioli & Ughetto, 2013; Harris, 2014).

Some studies have also examined patent assignment based on the characteristics of patents. Serrano (2006) studied patent assignment through its statistical data, finding that nearly 20% of U.S. patents were traded at least once in their economic life, and the cost of technology transfer had a selective effect, that is, better patents were more likely to be traded.

Serrano (2006) also built a model to explain this. Therefore, higher-value patents are more likely to be assigned. Due to the interrelatedness of technologies and filing strategies, a single technical solution is often divided into multiple patents. When assigning patents, it is typically necessary to bundle and assign multiple patents that have already been split, which not only increases the value of the patent assignment but also reduces the uncertainty that the assignee may face. Liu et al. (2012) examined issues relevant to patent portfolio assignment agreement from the perspective of patent portfolio, arguing that it would be easier to assign patent portfolio made up of similar patents. They also zoomed in on the applicability of law when some patents were invalid or a breach of the contract happened in the process of patent portfolio assignment. The motivation for patent assignment is a precondition for these actions to take place. Caviggioli and Ughetto (2013) investigated the motivations for the occurrence of patent assignment and assignee behavior and argued that changes in a firm's research field or the availability of non-core patents are likely to contribute to patent assignment behavior, while patents with extensive potential applications and a high valuation also significantly increase the willingness of potential assignees to purchase them. Jin et al. (2021) argued that technologies that meet the pressing needs of firms have a higher probability to be assigned.

Patent assignment relies on the intellectual property protection environment. Due to the intangible nature of patent assignment process, it is more prone to legal risks than typical transactional activities in the assigning process. After reviewing the status quo of international protection of intellectual property rights, Magic (2003) discussed the protection of intellectual property rights in technology transfer from the perspective of developed and developing countries, and introduced the role of patents in technology transfer and the influence of patent assignment on the current industrial trend and the future of global high-tech economy as a market behavior that can provide long-term fair value for both parties of the assignment. Due to the complexity and uniqueness of patent assignment, the primary risks associated with patent assignment occur during the contract negotiation process. Deng (2020) mainly analyzed the legal risks in the signing of the patent assignment agreement, and put forward four suggestions to reduce the legal risk: the qualification examination of the parties to the agreement, the search, analysis, and evaluation of patent information, selection of appropriate payment method and agreement on possible situations, and special agreement on individual terms.

Since the implementation of the *Outline of the National Intellectual Property Strategy* in 2008, the number of patents filings in China has increased rapidly, and patent assignment has become increasingly active accordingly. Some studies looked at the current situation of patent

assignment in China with the relevant data from recent years. Xie et al. (2019) used the social network analysis method to construct the network structure of patent assignment across 31 provinces/autonomous regions/municipalities in China, and concluded that the stability of inter-regional patent assignment and the absence of significantly abnormal cross-regional assignment data in these places indicated that patent assignment across regions in China are generally in a healthy state. Kang et al. (2020) constructed the patent assignment network between mainland universities and firms through the social network analysis and visualization approaches, finding that patent assignments between universities and firms occurred mainly within the province, and most were one-on-one assignments, indicating a large space for development for the patent assignment between universities and firms. Based on the objective information of patent assignment, S. Y. Zheng and Wang (2020) constructed a characteristic index system of technology transfer in the four dimensions of technology, law, market, and entity and held that based on the characteristic indexes, technology transfer could be predicted which can then drives innovation.

2.2.3 Patent licensing

Besides patent assignment, there is another equally important method of patent transactions, which is patent licensing. Compared to patent assignment, the scope of rights conveyed in patent licensing is generally smaller. In addition to the industrialized application of patented technology to produce products or services for returns, patentees can also gain profits through patent licensing. Patent licensing is the easiest, most direct, and primary way to obtain economic benefits with patents. It is also phased and revocable. In the patent licensing of most firms, the patentee aims to make profits, such as manufacturers of cell phones and other intelligent terminals who must pay royalty rates to Qualcomm when they use its chips (Z. W. Zhu, 2015). Arrow (1972) was the first to look at profits gained by patentees with patent licensing from the perspective of reducing production cost by invention. To be more specific, patent licensing is an act that the patent applicants or the patentee licenses another to exploit their patents in a certain area and within a certain period of time in an agreed way party within a specific region and for a certain period, to commercially implement the patent according to agreed-upon terms (Gao & Luo, 2014). The significant difference between patent licensing and patent assignment lies in the fact that specific licensing terms, including the duration of the license, are typically specified in a licensing agreement. Patent license is an important indicator to measure the transformation and application of patented technological achievements, which directly reflects the activity of the technology market and is also a major way of technological diffusion. Aoki and Tauman (2001) held that with the development of

technology spillover effect, the increase of licensees not only intensifies the competition among patentees of similar technologies, but also enhances the efficiency of licensees which is mainly manifested in the enhancement of performance. According to the scope of patent rights obtained by licensees after licensing, Bin (2009) classified patent licenses into ordinary licenses, sole licenses, exclusive licenses, and cross-licenses. In ordinary license, the patentee can also license the patent to any third party. There are generally multiple licensees, and both the patentee and the licensee can exploit the patent. In sole and exclusive license, the patentee is not allowed to license the patent to a third party. The difference lies in that the patentee cannot exploit it himself/herself in sole license, while the patentee in exclusive license can. In cross-license, the patentee and the licensee can exploit each other's patents to avoid infringement litigation and to reduce transaction costs, thus reaching a strategic partnership.

In practical patent licensing scenarios, the majority of licenses fall under the category of regular licenses due to their fewer restrictions and greater flexibility. Exclusive licenses, sole licenses, and cross-licenses are employed as supplementary options. Apart from the types of patent licenses, the cost and payment terms associated with patent licensing are also pivotal considerations in the licensing process.

Kamien (1992) proposed three common charging modes in patent licensing: (1) royalties charged according to the number of products or services of the patent exploited by the licensee, which is dependent on the number alone but cannot fully reflect the market value of the patented technology; (2) a fixed fee unrelated to the number of products or services, that is, the patentee collects the fees at one time; and (3) a mixture of fixed fees and royalties, i.e. after receiving a fixed fee from the licensee, the patentee also collects royalties according to the number of products or services of the exploited patent from the licensee. The three charging models each have their own characteristics. In actual licensing agreements, the licensors and licensees typically consider a combination of factors such as market conditions, the type of technology, its potential, and market size when determining the licensing fees. Clearly, the patentee can also design other licensing models in consideration of profit maximization, patent R&D cost, market potential, licensee's technical strength and other factors. According to an observation made by Rostoker (1983), among the patent license fee models, a combination of fixed fees and royalties accounted for 46%, royalties 39%, and fixed fees only 13%, and the other fee model 2%, indicating that a combination of fixed licensing fees and royalties is the most commonly accepted model by both licensors and licensees. Different licensing fee models have their own characteristics. Some studies have also examined the characteristics of different licensing models. X. H. Wang (2002) compared

fixed fees with royalties, and argued that patent licensing is a differentiated Cournot duopoly model, in which one party has the innovation ability to reduce costs. To the patentee, royalties may be a better choice than fixed fees, but the licensee favors the latter. The interaction between the patentee and the licensee is described as a three-stage non-cooperative game. The patentee acts as a Stackelberg leader who maximizes his/her profits from licensing based upon the demand function for the license (response or best response function).

Some scholars have studied the patent licensing strategy from the perspective of maximizing the patentee's license fees. Kamien and Tauman (1984) and Katz and Shapiro (1985) adopted the game theory framework to analyze the patentee's licensing strategy, arguing that selling patent licenses by auction could bring the patentee more profits than charging fixed fees. Jensen (1992) posited that the patentee should choose the fixed fee model for patent licensing when the success of innovation is uncertain and the patent life is shorter than the innovation life. Under these circumstances, the patentee can get the maximum profit by selling a patent license at a fixed fee. In patent licensing, information asymmetry might be another issue to consider as it also has an impact on the patent licensing strategy. Gallini and Wright (1990) noted that choosing licensing strategy is as complicated as the process of technology R&D, and that opportunism brought about by information asymmetry, specific investment, and imitation is ubiquitous in patent licensing. In the patent licensing market, in view of the possibility of opportunism on both sides of the licensing, the license agreement should be designed in a way to maximize the profits of the patentee, and the variable royalties might help deal with the adverse selection problem in the license. Beggs (1992) argued that royalties should be used instead of fixed fees in patent licensing in light of information asymmetry, so as to deeply aligning the interests of the patentee and the licensee and help them and licensee avoid risks.

Apart from fees and strategies, the transaction costs and incentives of patent licensing and their impact factors have been a focus of academic research (Sarmah et al., 2020). From the perspective of market entry, firms are able to establish cooperative relationships through patent licensing and at the same time expand the market share of new technologies, which is the reason why patentees tend to license non-core patents (Duplat et al., 2018). Caviggioli and Ughetto (2013) conducted an inductive analysis of the motives of patent licensing from the perspective of patentees, categorizing the motivation for patent licensing into six main factors: strategic motivation, financial motivation, management motivation, special patent motivation, transaction cost motivation, and external motivation. Y. D. Wang et al. (2016) found that licensees actively seek external licenses when they lack technological diversity and R&D

vitality and achieve innovation results by building stronger R&D capabilities with external technologies.

2.2.4 Commonality analysis of patent assignment and licensing

Patent assignment and licensing, as the two primary methods of patent transactions, share some common characteristics. For the choice between the two types of transactions, patent assignment and licensing, Jeong et al. (2013) showed that companies as patentees tend to license patents when uncertainty is low or transaction costs are high, and assign patents when it is the other way around. Because of the special characteristics of patents, patentees often face high search and transaction costs when engaging in patent licensing and sales activities (especially in immature technology markets), making it difficult for them to quickly find the right target (Srivastava & Wang, 2015). They experience difficulties in finding potential buyers and obtaining information about potential negotiators, and may be harmed by the opportunism of potential buyers during negotiation (Agrawal et al., 2015). Transaction cost theory suggests that when transaction costs are too high firms will choose to develop patents internally which is a process that will become more difficult for patents of high quality, and therefore, the likelihood of licensing or selling patents may increase as patent quality betters (Jeong et al., 2013).

Haans et al. (2016) suggested that there might be an inverted U-shaped curve relationship between patent transactions and patent quality, i.e., When patent quality is low, the number of patent transactions increases as patent quality increases, while when patent quality is high, the number of patent transactions decreases as patent quality decreases. Sharif (2018) conducted an empirical study of patent trading behaviors in China with data from the patent database and found that there is an inverted U-shaped relationship between the quality of invention patents and the probability of being licensed, while there is no link between the quality of utility models and the probability of assignment and licensing, and also that economically motivated patentees are less likely to assign their invention patents, while administratively motivated patentees are more likely to trade their patents. In China, different examination methods are applied to invention patents and utility models. Invention patents go through substantive examination to ensure their quality. Therefore, in this study, a comparative analysis was conducted between invention patents and utility models to investigate the impact of patent quality on firm performance.

In addition to the choices made regarding patent transaction behaviors and methods, patent assignment and license also share the following three common characteristics:

First, since patents have a specific term – 20 years for inventions, 10 years for utility

models, and 15 years for designs – all patents involved in transactions have a remaining term. The longer this remaining term, the longer the patent's monopoly rights term, the higher its economic value, and consequently, the higher the transaction price. It also makes potential patent recipients more willing to invest in the patented technology. Therefore, the length of the remaining term greatly influences the price and success rate of patent transactions.

Second, there are uncertainties in patent transaction price. Patents, as the subject of patent transactions, are intangible and non-standard. Valuing patents is a worldwide challenge. Despite various valuation methods such as cost-based, income-based, market-based, and option-based, there is no universally accepted authoritative valuation method. This is mainly due to the multitude of factors affecting patent prices, including the technical field, market prospects, supply and demand dynamics, research and development costs, anticipated returns, and market risks. Consequently, potential parties to the transaction find it difficult to rapidly agree on the price. Negotiations and discussions during the transaction process become a significant challenge.

Third, patent transaction prospects involve high risks. For potential recipients in patent transactions, the primary aim is to derive economic benefits by commercializing patented technology. However, the returns on patent technology are influenced by multiple factors, such as the stability and technical advancement of the patent itself, market maturity, and applicability, as well as the recipient's technological foundation, human resource allocation, product development capabilities, sustained research and development investments, and financial commitments. Therefore, the prospects of patent transactions are highly uncertain, which also constitutes a significant constraint in patent transactions.

2.3 Firm performance

Performance includes results and effects within a certain period of time. Firm performance generally refers to the results and effects achieved by a firm in a certain period of time. It reflects the marketability and profitability of a firm. Firms with better performance are more competitive in the market. Performance is the most important indicator of the operation and sustained growth of firms and also the purpose of the establishment of the firm. After a theoretical review of firm performance, an analysis in combination with the patent-related theories lay the theoretical basis for the hypothesis of this empirical study. Next, we will review the theories for firm performance and integrate it with patent-related theories for further analysis.

2.3.1 Overview of firm performance

In daily operational activities, firm performance indicators are introduced to quantitatively measure the development of firms, and the results from strategy planning to plan implementation are the basis for measuring firm performance. Therefore, firm performance generally refers to the final outcomes of management processes relevant to company objectives. Mithas et al. (2011) defined firm performance as a multidimensional structure with four elements: (1) customer centricity, including customer satisfaction and product or service performance; (2) financial and market results, including revenue, profit, market position, cash flow, and earnings per share; (3) human resources performance, including employee satisfaction; and (4) organizational effectiveness, including time of listing, level of innovation, and flexibility of production and supply chain. Among these elements, the evaluation of customer centricity, human resources, and organizational effectiveness is relatively subjective and hard to be aligned, whereas the performance of financial and market results is easier to be measured and more objective. Consequently, the research on firm performance is usually based on the performance of financial and market results. This is also the approach taken in this study.

Daft (1991) defined firm performance as the ability of an organization to achieve its goals by using resources efficiently and effectively, reflected through financial or market performance, allowing for the quantification of firm performance, which facilitates performance analysis or evaluation. The study of firm performance is mainly measured by financial performance evaluated through various financial indicators that reflect a firm’s profitability, operational efficiency, debt repayment capacity, and risk resilience, which alone, however, cannot fully reflect firm performance. Therefore, some scholars have expanded the measurement indicators of firm performance for a comprehensive evaluation. Fauzi et al. (2010) put forward the concept of Triple Bottom Line (TBL), expanding the dimensions the firm performance by incorporating society and environment as important components, and holding that firm performance should include three measurement dimensions: society, environment, and economy. Among them, society refers to the corporate social responsibility and socially responsible behaviors, such as the firm's impact on consumers, employees, shareholders, and communities. Environment refers to the firm's impact on the physical environment, such as the disposal of waste water, waste gas, waste residue, and hazardous waste and their impact on the environment. These two measuring elements are not as easily quantifiable for analysis as financial performance. In the business landscape, market mechanisms have also become performance measurement indicators for firms. Simons (1994)

defined firm performance using a market mechanism approach, where the performance is reflected through financial, factor, and customer product markets. In the financial market, firm performance satisfies shareholders and creditors in the form of financial indicators. In the factor market, the firm's ability to pay suppliers or other producers on time and in agreed amounts is used to measure firm performance. Finally, in the customer product market, firm performance is evaluated based on its ability to deliver value to customers. Simons (1994) notion of firm performance is similar to the input-output view of the firm, which holds that the firm exists only because of its contributions to shareholders/investors, suppliers, employees, and customers, and expects returns for all parties through market mechanisms.

2.3.2 Firm performance indicators

Indicators refer to the quantitative characteristics possessed by the target object, and firm performance indicators represent the quantitative characteristics of firm performance measured from different perspectives. Firm performance is generally measured with single or multiple indicators, and scholars have studied the quantified indicators and quantification methods from several perspectives. In accounting, the concept of firm performance is usually closely related to financial indicators such as profit, return on assets, and economic value added. Arguing that the return on assets is the most critical consideration in a firm’s operation, Hansen (1989) used the five-year average return on assets as a measure of firm performance, while, to adjust the impact of inflation and other factors on the return on assets, the risk-free interest rate determined by the interest rate of government bonds was subtracted from the average return on assets of each firm. Pulic (2000) argued that because of the increasing impacts of knowledge on firm performance, the accounting indicators for firm performance do not apply to performance measurement in the knowledge economy era and the measurement criteria also need to be adjusted accordingly. In the past few decades, many creative attempts have been made to measure firm performance based on unconventional methods, resulting in many indicators related to shareholder value analysis, such as the Economic Value Added (EVA) or other market-based indicators (e.g., Tobin’s Q) to reflect the direct and indirect impacts of knowledge. Tobin’s Q is a ratio between two different values of a firm, namely Tobin’s Q = MV / RC. MV is the market value of the firm in the financial market, while RC refers to the replacement cost, the basic value of the firm. In practice, as the replacement cost is difficult to get, it is generally replaced by the net assets of the firm. Tobin’s Q greater than one indicates that the firm has created value for society, otherwise, social resources are wasted, which is a simple and feasible firm performance measurement indicator (Tobin, 1969). Calantone et al. (2002) adopted key financial indicators

to measure firm performance and posited that there are four firm performance indicators, namely return on investment, return on assets, return on sales and overall profit. Orlitzky et al. (2003) proposed three alternative methods to measure the corporate financial performance (CFP), namely, market-based, accounting-based, and perception-based measurements, enabling comprehensive evaluation of firm performance. The market-based approach mainly measures financial performance, which reflects that shareholders are the main stakeholders of a company. The accounting-based approach usually involves indicators such as net income, return on assets, and return on equity. With the perception-based approach, the financial performance of the firm is judged subjectively by comparing with the financial indicators of other companies.

In strategic management theory, scholars have taken other perspectives and used different criteria to measure firm performance. For example, Venkatraman and Ramanujam (1986) divided firm performance into operational and financial performances. The former includes market share, product quality, and marketing effect, while the latter includes market-based performance (e.g., stock price, dividend, and earnings per share) and accounting-based performance (e.g., return on assets and return on equity). Kaplan (1992) first put forward the concept of balanced scorecard, opining that traditional financial indicators (such as ROI and EPS) alone cannot provide a clear and comprehensive performance target, nor can they focus on all key business areas that have a significant impact on the long-term survival, growth, and development of the company, but a balanced expression is needed. The balanced scorecard is also a strategic management system, which can clarify organizations' vision and strategy, and turn them into actions, and combine financial indicators such as ROI, RI, dividend yield, earnings per share and other key performance indicators such as customer's point of view, internal business process, and organizational growth, learning and innovation. Among the many types of firm performance indicators, return on assets (ROA) is the most commonly used measure in studies of firm behavior theory (Chen, 2008; Posen et al., 2018). Therefore, for the convenience and reliability of obtaining data from listed companies, this study selected two categories of dependent variables for regression analysis in the empirical research, including Tobin's Q value representing market performance, and the operating revenue representing financial performance. The study focuses on listed companies, where Tobin's Q well reflects market performance, while the operating revenue helps mitigate the interference of factors such as debt ratio in listed companies and provides a more accurate reflection of firms' financial performance.

2.3.3 Patents and firm performance

The relationship between patents and firm performance is the focal point of this study. Through a review of the literature, we aim to clarify the underlying logical connection between the two. Scholars generally agree that knowledge is a key factor for firms to gain and keep their competitive advantages and a key driver of firm performance and value creation (Grant, 1996; Makadok, 2001). It is a reliable tool to measure firm performance and is one of the fundamental factors of firm performance (Serenko & Bontis, 2013). The knowledge-based view argues that competitive advantage comes increasingly from knowledge resources and their utilization and development (Kogut & Zander, 1992; Spender, 1996). Thus, the overall performance of a firm depends on the creation of a valuable knowledge base by utilizing the complex knowledge and the use of that base for the management of defined strategic objectives (Zack, 1999).

The relationship between knowledge and firm performance has been studied as the former plays an important role in the latter. Bassi and Van Buren (1999) identified a direct relationship between knowledge capital and the performance of U.S. firms and the positive impact of knowledge capital in enhancing firm performance through a study of 500 U.S. firms. Similarly, Zeghal and Maaloul (2010) also found a positive correlation between knowledge capital and UK firm performance. Z. Wang and Wang (2012) investigated the quantitative relationship between knowledge sharing, innovation, and performance, and by developing a research model, concluded that knowledge sharing not only has a direct positive correlation with performance, but also affects innovation, thus contributing to firm performance. They found that explicit knowledge sharing has a greater impact on the speed of innovation and financial performance, while tacit knowledge sharing has a greater impact on the quality of innovation and operational performance.

Patents are an important output indicator of R&D activities and play an important role in firm performance as typical explicit knowledge closely relates to firms' innovation. Thus, the relationship between innovation, patents, and firm performance has also been studied. Hagedoorn and Cloodt (2003) argued that the number of patents or innovations (new processes, products or technologies) with patent rights gained is an important factor to measure organizational creativity and innovation performance. Innovation improves firm performance by ensuring a faster response to the environment through introducing new products in less time and at lower cost (Tidd & Bessant, 2018). Thus, it can be understood that the quantity of patents serves as an indicator of measuring a firm's innovation outcomes, and innovation, in turn, can enhance firm performance. Hence, the quantity of patents

indirectly promotes the firm performance. Geroski (1995) examined the effects of major innovations and patents on various types of firm performance indicators, such as accounting profits and stock market returns, and found that innovation and patents had no significant impact on firm performance, but that innovation-based firms were less susceptible to economic cyclicality and environmental pressures than non-innovation-based ones. As a result, innovation and patents enhance the ability of firms to adapt to their environment, which indirectly improves their performance. Guo (2021) used patents as a performance indicator of innovation output and efficiency, and conducted an empirical analysis with panel data at the provincial level of China.

Regarding the direct relations between patents and firm performance, scholars have conducted studies based on cases from different countries. Scherer (1965) analyzed the profit data of 448 firms in the U.S. from 1955-1959 and concluded that the growth of corporate profits was positively correlated to the output of inventions measured by patents, and that most firms' inventive activities drove profit increase through the growth of sales revenue rather than the expansion of profit margin, indicating the relatedness between patent quantity and the increase in firms' operating revenue. Bosworth and Rogers (2001) showed a positive correlation between R&D, patent activity, and market value using the Tobin's Q method based on R&D data from 1994-1996 and patent application data from 1996 from large Australian firms, indicating the relationship between patent quantity and Tobin's Q. Ernst (2001) conducted a panel data analysis of 50 German machine tool manufacturers from 1984-1992 to investigate the relations between German patent applications, European patent applications, and changes in firm performance. The study found that both types of patents contributed significantly to the increase in the sales of the firms, but the quality of European patent applications was higher than that of German patent applications and had a greater impact on sales growth. K. C. Chang et al. (2012) examined the relationship between firm performance and patent performance of Chinese pharmaceutical companies using a panel regression model and showed that the patent citation index H and the basic index EPI had a positive impact on the market value, sales and ROE of these companies and that patent citation index H and the basic index EPI were mainly determined by patent quantity. Christodoulou et al. (2018) used Chinese patent data to examine the role of Chinese patents in improving the financial performance of Chinese companies listed in Shanghai and Shenzhen stock exchanges from 2000-2010. The study showed that patents had an overall positive impact on financial performance, especially for efficiency-driven and customer-centered firms. Thus, there is a positive effect of patents on firm performance represented by the revenue and

Tobin's Q, and a similar positive effect on firm performance naturally occurs when the recipient of a patent transaction acquires an external patent which results in an increase in the number of patents that are directly owned or can be directly used by the recipient.

2.4 Chapter summary

This chapter reviewed the existing research literature from three aspects: overview of theories related to knowledge, patent and firm performance. Discussion the theory of knowledge covered three dimensions, namely, the foundation of the theory, classification of knowledge, and knowledge-based theory of the firm. The characteristics of knowledge, including non-exclusivity and transfer costs, form the theoretical basis for the existence of patents and patent transactions. Tacit and explicit knowledge classification is the key distinction between patents and experience. Patent transactions have an impact on firm performance through the mutual conversion of these two types of knowledge. The knowledge-based theory of the firm suggests that knowledge is crucial for a firm to gain and maintain a competitive advantage, making it a key influencing factor in firm performance. The foundation of the knowledge theory lies in the transfer and absorption of knowledge, which is a critical link in determining whether patent transactions affect firm performance, aligning with the theme of this study on patent transactions.

In terms of patent-based perspectives, the concept and role of patents were analyzed, with patents being essentially a trade-off between disclosure and monopoly rights, the latter being the source of their value. Two primary methods of patent transactions, patent assignment and license, were elaborated upon, and their common characteristics were derived based on an analysis of their respective features, identifying crucial factors that need to be considered in patent transactions.

Regarding firm performance, an overview of firm performance was presented to clarify its origin and concept. With this as a foundation, key firm performance indicators were summarized, highlighting important variables like the operating revenue, return on assets, and Tobin's Q from both financial and market performance perspectives. These serve as the theoretical basis for selecting dependent variables in the empirical study. Additionally, a deep analysis of the relationship between patents and firm performance was conducted, with literature indicating that patents have a positive impact on firm performance, primarily reflected through patent quantity. This literature review prepared a solid theoretical ground for constructing the conceptual model and formulating research hypotheses.

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Chapter 3: Conceptual Model and Research Hypotheses

Based on the literature review, this chapter will present the conceptual model of this study and explain the logic of the research, followed by the research hypotheses, so as to prepare the ground for the empirical study.

3.1 Object of study and core concepts

Defining the research subject and core concepts of the study is the basis on which the conceptual model and hypotheses are built. This section specifies the research subject of the thesis and defines the concepts related to internal and external assignment, internal and external licensing, and the number of assignments and licenses.

3.1.1 Object of study

The patent transaction behaviors studied in this thesis are limited to the two main patent transaction methods of patent assignment and licensing. Patent pledge, trust, securitization and other innovative patent transaction methods are much less common, which results in insufficient data to analyze their common characteristics. Meanwhile, as geographic proximity and linguistic and cultural similarities can reduce transaction costs and facilitate access to technology and knowledge, and domestic market size remains a key driver of firm-level innovation strategies and technological competitiveness (C. Huang & Sharif, 2015), only Chinese patent transactions are examined in this study.

This thesis selected A-shares companies (stocks in mainland China are categorized into A-shares and B-shares; A-shares are RMB ordinary shares, in which the investors are mainly institutions or individuals in mainland China, and are the mainstream securities market in China's capital market, while B-shares are RMB special shares, which are subscribed and traded in foreign currencies, and in which the investors are mainly from overseas or from Hong Kong, Macao, and Taiwan, China.) listed and still existing on the Shenzhen Stock Exchange and Shanghai Stock Exchange from 2008 to 2022 as the object of study, and obtained the annual financial data through their published annual statements and the data on annual patent application, assignment and licensing through the patent database Incopat (www.incopat.com) as the financial and patent data sources for the study.

Listed companies in China are strictly regulated by the *Company Law*, the *Accounting*

Law, the *Audit Law*, the *Measures for the Administration of Information Disclosure of Listed Companies* and other laws and regulations. They are required to publish complete and accurate R&D and performance data that meet international standards and other significant matters affecting the company's operations. The data therefore are highly reliable, which supports the justification of the research result. Listed companies were chosen as the object of study because of three reasons. Firstly, listed companies can represent the most dynamic and competitive domestic firms in China's economic activities, especially a large number of knowledge-intensive high-tech firms. They represent the trend of the knowledge economy era and are more innovative with greater potential, so the study of their patent assignment and licensing behaviors is highly representative. Secondly, the financial data of listed companies such as the operating revenue, net profit, and return on equity are regularly disclosed and audited, which can reflect the changes of firm performance more accurately. Thirdly, listed companies are generally larger in scale and have stronger awareness of intellectual property rights. They tend to acquire new technologies to facilitate the development through such market transaction behaviors as patent assignment and licensing. Therefore, the data on patent assignment and licensing of listed companies are larger in quantity and more representative. In addition, the patent transaction data of listed companies are easier to verify, and the interference of abnormal data can be excluded as far as possible. On the one hand, in November 2018, China's Ministry of Finance and China National Intellectual Property Administration issued the *Regulations on Disclosure of Accounting Information Related to Intellectual Property Rights*, which makes the disclosure of some intellectual property information mandatory. On the other hand, listed companies tend to actively disclose intellectual property information represented by patents for the sake of corporate interests. Liu and Bao (2020) concluded that IP information disclosure has a significant impact on company value and is positively correlated with it. Yang and Lu (2018) held that IP asset information disclosure can increase share prices.

In June 2008, the State Council issued the *Outline of the National Intellectual Property Strategy*, emphasizing that "independent innovation is encouraged to acquire IPRs and be commercialized and industrialized, and enterprises are guided to realize the market value of their IPRs through rights transferring, licensing, pledging or other means", offering policy support to patent assignment and licensing. In December of the same year, the third amendment to the Patent Law was passed, further refining the law. With "improving innovation capacity" as the legislative purpose, this revision raised the standard of patent right verification and enhanced the protection of patents, indicating that China's patent system had

ushered in a new stage of development. In addition, China saw an explosive growth in the number of patent applications since 2008, with the total number of applications increasing from 828,000 to 5,365,000 in 2022, a growth of 548%, which provided a quantitative basis for patent assignment and licensing. The thesis chose 2008 as the starting year to study the impact of patent assignment and licensing behaviors on the firm performance of companies listed on A-shares from 2008-2022 based on the perspective of patent assignees. The study covered the data of 15 years to ensure that firms had sufficient time to transform externally acquired patented technologies into firm performance, and to avoid possible interference from short-term performance fluctuations on the research results.

For the convenience of actual operation, listed companies generally have a large number of subsidiaries across different sectors or locations. The operating performance of these subsidiaries also obviously affects that of the listed companies. Meanwhile, these subsidiaries are also the ones conducting patent transaction behaviors as some of the patent assignment and licensing behaviors of listed companies are actually carried out through the subsidiaries. A look at the patent assignment and licensing data of subsidiaries can reflect the patent transactions of the listed companies more comprehensively. Shi et al. (2022) studied 779 Chinese cross-border acquisitions between 2006 and 2015 for the relationship between subsidiaries of Chinese firms and their outbound acquisition behaviors, finding that these subsidiaries are more likely to make overseas acquisitions in search of strategic assets including patents, which also suggests that Chinese firms tend to make patent transactions through their subsidiaries if necessary. For this reason, the annual reports of the listed companies for 2008, 2013, and 2022 in this study are more representative. A list of the subsidiaries of the listed companies was sorted out and the patent assignment and licensing data of the subsidiaries were integrated into the patent data of the listed companies, which effectively ensures the comprehensiveness and accuracy of the data.

3.1.2 Internal and external assignment

Internal assignment refers to patent assignment by a “related party” to the listed company. According to the specification of the term “related party” in the *Implementation Guidelines for Related Party Transactions of Listed Companies of Shanghai Stock Exchange*, the thesis selected the most representative types of related parties, including parent companies which are the controlling shareholder of the listed companies, sister companies controlled by the controlling shareholder of the listed companies, natural persons who directly or indirectly hold more than 5% of the shares of the listed companies, and directors, supervisors, and senior managers of the listed companies, parent companies, and sister companies. Based on

the definition of the related party, the Guideline also defines Related Party Transactions (RPT). Matters that may lead to the transfer of resources or obligations between listed companies or their controlling subsidiaries and related parties of the listed companies are deemed as related party transactions. Assigning the intangible asset, patent, is the transfer of resources. The patent assignment between listed companies and related parties is an act of purchasing assets, which constitutes a related party transaction. Therefore, the thesis defined patent assignment between listed companies and related parties as internal assignment. In patent transactions, transaction costs are extremely high due to widespread information asymmetry, while the close communication and trust established between related parties can effectively reduce transaction costs and thus reduce uncertainty due to information asymmetry, and related transactions are harmless and even beneficial to firm performance (Fisman & Wang, 2010; Ryngaert & Thomas, 2012), especially in emerging markets that lack robust mechanisms (Fang et al., 2018). Therefore, internal assignment of patents in China is somewhat common, and comparing it with external assignment can help to analyze in depth the impact of patent transactions on firm performance and whether such related transactions have a potential positive impact on firm performance.

In external assignment, patents are assigned to listed companies by non-related parties, that is, patents are assigned by external entities other than related parties, and listed companies acquire the ownership of external patents through marketization. The external patent knowledge generally needs to be absorbed before it can be transformed into a firm’s sustained competitiveness. External assignment is also a more common behavior in patent assignment and more of a marketized transaction.

3.1.3 Internal and external licensing

Similar to the definition of internal assignment in the previous section, internal licensing refers to patent licensing by related parties to listed companies. The related parties also include the parent company and sister company of listed companies, natural persons who directly or indirectly hold more than 5% shares of listed companies, and directors, supervisors and senior managers of listed companies, parent companies, and sister companies. Similarly, in external licensing, the patents are licensed to listed companies by external entities that will not have related party transactions.

3.1.4 Invention and non-invention patents

In China's patent system, there are three types of patents, namely, invention, utility models, and designs. Among them, the invention patent can only be granted after preliminary examination, publication, and substantive examination. The patent needs to be outstanding,

advanced, stable, technical, and conducive to protecting the technical solutions corresponding to both the product and method. Utility models and designs on the other hand can be granted through preliminary examination, and are less stable. Utility models, also known as gadgets, can only protect the corresponding technical solutions of products to some extent. The technical solution only needs to have substantial features and advances, and the protection is relatively weak. The application for design patents is not subject to substantive examination. Such patents mainly protect the shape, pattern, and color of the product. The application for utility models only requires substantive features and advancement, but the protection is less effective. Although the examination criteria and quality of utility models and designs have improved in recent years, there is still a big gap compared with invention patents. Therefore, the thesis took the invention patents with high technical content and rights stability which are subject to substantive examination as one category, and non-invention patents (utility models and designs) with low technical content and weak rights stability that do not need substantive examination as the other. Annex Table 1 shows the characteristics of the three types of patents.

3.1.5 Number of patent assignments and licenses

The number of assignments refers to the cumulative number of patent assignments to the listed companies during 2006-2020, including internal and external assignments, that is, the cumulative number of patents added to the listed companies through patent assignment. Patent assignment includes the assignment of patent application rights and patent rights. Given the great uncertainty in the process of application, the patent may be rejected. With application rights assigned, listed companies may probably not be able to own the patent in the end. Furthermore, the number of patent application right assignments in reality is much smaller than that of patent right assignments. In light of this reason, the thesis only counted the granted patents assigned to the listed companies in the number of assignments, excluding the assignment of patent application rights. Meanwhile, according to the Patent Law, the transfer of patent rights is effective from the date of registration. Therefore, the number of assignments in the thesis in particular refers to the cumulative number of granted patents assigned to the listed companies from 2006 to 2020.

The number of licenses refers to the cumulative number of patent licenses the listed companies received during 2006-2020, including the number of internal and external licenses, that is, the number of patents that could be legitimately exploited by the listed companies after obtaining them through patent licensing. Since the differences between different types of patent licenses are not significant and do not affect the implementation of patented technology by listed companies, the thesis did not distinguish between specific types of patent licenses,

that is, ordinary licenses, sole licenses, exclusive licenses, and cross-licenses were all included in the license quantity count. According to the *Rules for the Implementation of the Patent Law of China*, the patent license agreement concluded by the patentee and the licensee shall be registered at the patent administration department under the State Council. The filing date of the patent license, therefore, could be used as the time when patent license occurs. Meanwhile, for the same reason as patent assignment, the number of licenses in this thesis only counts patent licenses of which the license contract filing date is after the patent grant date. In conclusion, the number of licenses refers to the cumulative number of patent licenses received by the listed companies from 2006 to 2020.

3.2 Conceptual model

This thesis examines the impact of patent assignment and patent licensing on the performance of publicly traded companies from the perspective of recipient firms. Building upon theoretical research, the study operationalizes and conceptualizes the theories, proposing a conceptual model to simplify and clarify the research, thus establishing the empirical research path for this study.

3.2.1 Conceptual model

In patent transactions, there are primarily two methods: patent assignment and patent licensing. These two differ significantly in terms of their operational procedures, rights usage duration, and scope. Therefore, in the conceptual model, both methods are studied separately to explore their impact on firm performance. Additionally, the theory of knowledge suggests that transferring external knowledge incurs costs that are positively correlated with the complexity of knowledge and its relevance to existing knowledge reserves. When transferring knowledge within affiliated companies or subsidiaries, these costs can be reduced. Hence, this thesis also investigates patent transactions as internal and external transactions. Furthermore, the patent theory indicates that patent quality affects firm performance. Considering the actual situation of patent examination in China, invention patents undergo substantive examination, while utility models and designs undergo only formal examination. These two differ in quality. Therefore, we categorize patents into invention patents and non-invention patents for research purposes. The thesis structured patent transaction behaviors from the three dimensions of transaction mode, transaction scope, and patent type, as shown in Figure 3.1. The types of transaction include patent assignment and licensing. The scopes of transaction include internal and external transactions. The types of patents are invention and non-invention patents. The

transaction modes chosen in this study are patent assignment and licensing, which are the most common practice and whose data can be easily collected for analysis, so as to better examine the impact of different transaction modes on firm performance. Based on the reality of China, related transaction behaviors of listed companies are more common. After combing the patent assignment and licensing data, it was found that a large number of patents of the listed companies also came from related parties. The thesis therefore distinguished between related transactions and non-related transactions in patent assignment and licensing, defined the former as internal transactions and the latter as external transactions, so as to analyze the impact of different transaction scopes on firm performance. Specifically, in terms of the scope of transaction, patent assignment behaviors were subdivided into internal and external assignment, and so were patent licensing behaviors. With regard to patent types, patents were divided into invention and non-invention patents based on their characteristics, so as to examine the impact of different patent types on firm performance.

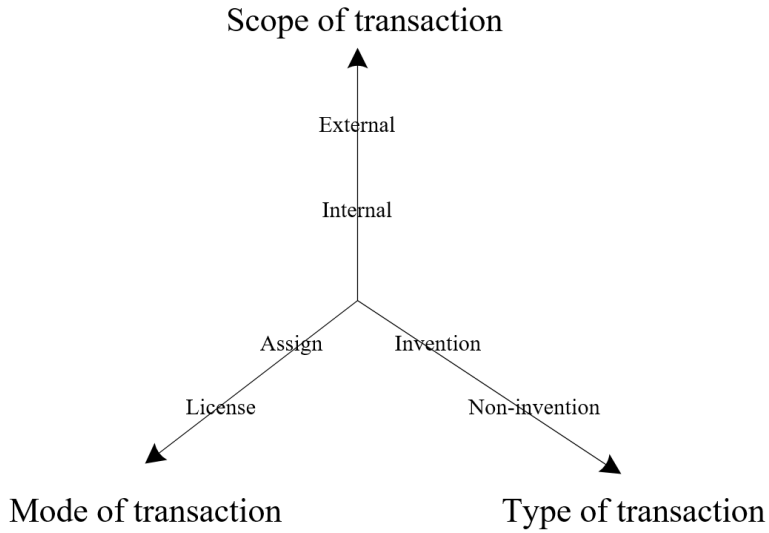

Figure 3.1 Three dimensions of patent transactions

In the process of patent assignment and licensing, the number of patents is the basic factor and the basic data used in the majority of empirical research on patents. The patent portfolio can be more easily built and the technological capability of the recipient firm could only be effectively improved when the firm has acquired a certain number of patents. Consequently, the firm performance will be significantly enhanced. Moreover, after the assigning or licensing of each patent, the recipient company generates cumulative effects through knowledge absorption, which continue to impact firm performance in subsequent years. Therefore, the analysis of the three dimensions was based upon the cumulative number of patent assignments and licenses of the listed companies over the period.

After being acquired by the firm through assignment or licensing, the external patented technology is then transformed into the firm's know-how through knowledge absorption, which is further utilized to develop or upgrade new products and processes, thus improving the firm performance. Better firm performance is mainly manifested in the increase of the return on equity, operating revenue, and corporate asset. These are also common metrics in firm performance theory, where the operating revenue is the most crucial indicator and forms the basis for other performance metrics. In particular, the listed company may appear more promising to the public. As a consequence, its market capitalization grows, and the Tobin's Q increases accordingly. Our study focuses on listed companies whose market capitalization constantly fluctuates with market changes. Therefore, Tobin's Q is a better indicator of the extent to which a company is recognized by the market and can more effectively reflect changes in firm performance. So as shown in Figure 3.2, the thesis selected the Tobin's Q and operating revenue as firm performance indicators and as the dependent variables of the regression analysis in the study.

Based on the aforementioned analysis, patent transaction behaviors are deconstructed from three dimensions. There are two scenarios under each of the three dimensions of transaction mode, transaction scope, and patent type. As shown in Figure 3.2, patent transaction behaviors can be subdivided into eight scenarios. Patent assignment transactions are subdivided into internal and external invention patent assignment, and internal and external non-invention patent assignment. Patent licensing behaviors include internal and external invention patent licensing, and internal and external non-invention patent licensing. The basis of these eight scenarios is the cumulative number of patent transactions received by the listed companies. Thus, the dependent variables for the regression analysis were drawn.

The independent and dependent variables studied act as a bridge through knowledge absorption. After acquiring patents, firms internalize them into their own technical capabilities through knowledge assimilation before transforming them into firm performance. As a result, the conceptual model of this study was derived as shown in Figure 3.2, which is the basis of the research hypotheses.

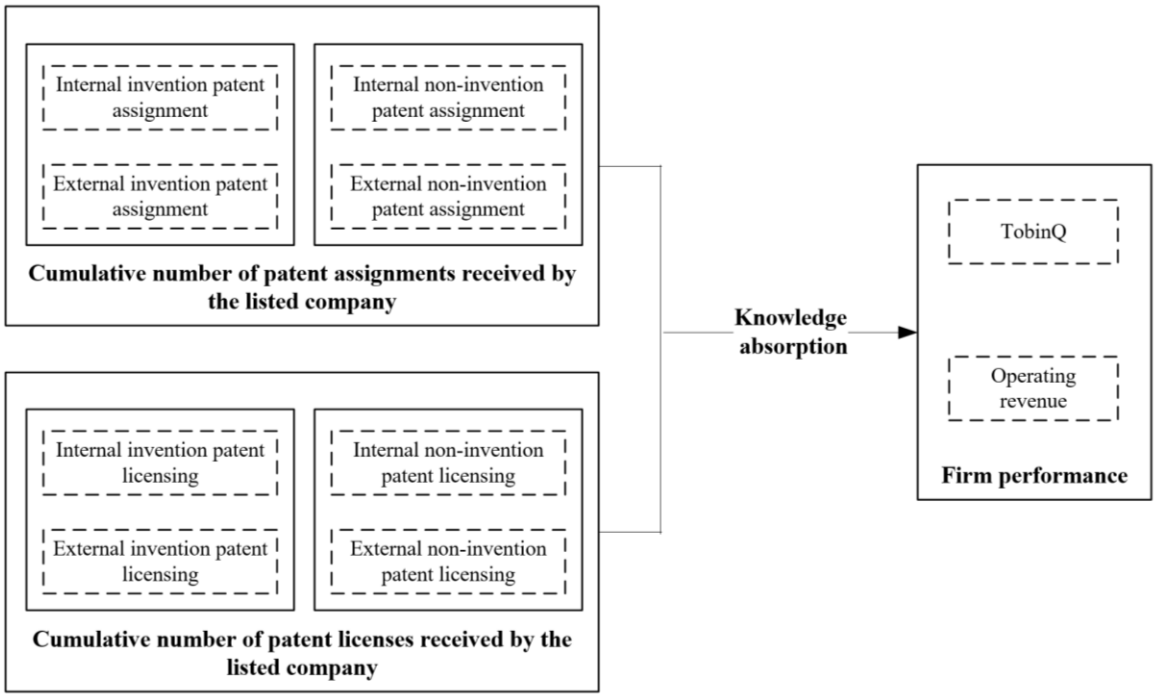

Figure 3.2 Conceptual model of the impact of patent assignment and licensing on firm performance

3.2.2 In-depth analysis of the conceptual model

Pricing is important to the operation of the technology market as the its core and focus, and a large body of literature has examined how various factors determine the price of technology transactions (Shen et al., 2023). However, price data on patent transactions are generally not publicly available because of the non-standardness of technology market objects, which makes it difficult to conduct regression analysis with the price as the variable. So this thesis analyzed patent transactions from other perspectives. Based on the literature review in Chapter 2 and the conceptual model discussion in the previous section, this thesis analyzed the impact of patent assignment and licensing on firm performance from three perspectives.

3.2.2.1 Relationship between the cumulative number of patent assignments and licenses and firm performance

Firms can gain various benefits by acquiring external technologies, such as shortening R&D time, avoiding R&D risks, and complementing with internal knowledge. Firms can learn, assimilate, and then transform the external knowledge into internal knowledge, which ultimately improves their innovation capability and competitive advantage (Chatterji, 1996; Cohen & Levinthal, 1989; Henderson & Cockburn, 1996). Granstrand et al. (1992) found that the acquisition of external technologies was positively correlated to the growth of sales revenue. Such sales revenue is similar to the operating revenue in this study. Palacios-Marqués et al. (2013) empirically examined 222 Spanish firms in the biotechnology and

telecommunications industries through the structural equation modeling and concluded that there was a significant positive correlation between knowledge transfer and firm performance. Hence, conducting knowledge transfer through patent transactions will contribute to enhancing firm performance.

Sherer (1965) argued that successful inventions and innovations can increase sales margins and open up new opportunities for profitable sales growth which also drives the increase in the operating revenue of the firm. For the recipient firm, the direct impact of the patented technology is an increase in sales or profits. Sales revenue is a direct indicator of market changes and the direct result of the innovation results brought about by absorbing knowledge through patent transactions. Considering that profitability may be subject to artificial adjustments within the company, and that sales revenue is not easily manipulated, a comprehensive analysis of the operating revenue, profit and return on assets might provide a more comprehensive picture of the impact of patent assignment on firm performance. Based on this, firms that acquire external patented technologies through patent assignment experience an increase in sales revenue, profit, and return on assets and the growth in the operating revenue is more direct and reliable. In an empirical study of data on the number of patents of Chinese listed companies, X. Xu and Tang (2010) verified the hypothesis that the larger number of patents a firm had, the greater contribution they made to corporate value and performance, which also showed the strong link between the number of patents and firm performance and the positive correlation between the two. Lin and Jin (2009) analyzed the patent and performance data of 1,000 manufacturing companies in Taiwan from 2004 - 2007, and showed that the number of patents had a significant positive correlation with the operating revenue and net profit, and that this performance impact also had a deferred effect, that is, the impacts on performance may not necessarily be immediately reflected in the same year but rather gradually manifests itself in subsequent years. Therefore, the more patents a firm acquires through patent assignment, the more significant the improvement of firm performance is (operating revenue, profit, and return on assets). Hence the performance will gradually manifest itself.

Similar to patent assignment, patent licensing is an important way for firms to acquire external technology and can have a positive impact. Chesbrough (2003) argued that with the external knowledge licensed, the licensee can fill the technological gap by using the technology, which in turn improves the firm's technological capability. Consequently, the firm will have better performance. Some scholars have also studied patent licensing from the perspective of innovation performance. Wang et al. (2013) opined that patent licensing can

enhance the learning and innovation capabilities of the licensee in three ways. First, the licensee gains access to the licensor's knowledge; second, the patent license agreement includes the transfer of tacit knowledge in addition to explicit knowledge, which is also the key to whether the patent license can meet expectations; finally, when new knowledge comes in, patent licensing stimulates the licensee's R&D efforts through deliberate learning. Meanwhile, the data of 71 Chinese licensee companies indicated that the more licenses a company receives, the better its innovation performance will be afterwards. W. P. Wang et al. (2013) posited that the number of patent licenses (e.g., the number of patent licenses received per 100,000 people) is a key factor affecting innovation performance. The innovation performance of a firm is an indicator of the effectiveness of a firm's innovation (Q. Li, 2020). Hollanders and Esser (2007) argued that the sales revenue of a firm's new products can be a major indicator of innovation performance. Thus, innovation performance can be considered as an important component of firm performance. Firms receiving patent licenses achieve growth in innovation performance indicators (e.g., sales revenue, profit), and thus firm performance is improved.

In summary, the cumulative number of patent assignments and licenses both have a positive impact on firm performance. This positive effect may take some time to become evident.

3.2.2.2 Relationship between the cumulative number of internal and external patent assignments and licenses and firm performance

Internal patent assignment is a related transaction behavior in which with common shareholders making decisions collectively, one party in the transaction can have a substantial impact on the other, typically leaning towards a positive influence. This can include providing guidance on patent technology to accelerate absorption and sharing all the technical secrets and details within the patent technology. Related transactions can replace contracts or market exchanges, reduce transaction costs, and overcome production difficulties in technology transfer, which is consistent with the view of transaction cost theory (Coase, 1937; Williamson, 1985). A patent is traded in patent assignment. Due to the uniqueness of the patentee and that patents are the typical non-standard goods, patent trading is largely different from ordinary commodity transactions. It takes more time and efforts to find the contact information of the patentee and to negotiate and supervise the execution of the transaction, thus increasing the transaction costs of external patent assignment. These increased transaction costs will naturally have a certain degree of negative impact on the firm

performance. According to W. A. Li and Luan (2000), related transactions can save the cost of market price searching, information, negotiation, and monitoring of contract realization, and reduce the transaction cost. Since related transactions can cut transaction costs, internal patent assignment might have a positive impact on firm performance which is more evident than external assignment. S. J. Chang and Hong (2000) studied the resource sharing and internal transactions among the members of Korean conglomerates and concluded that by sharing technology and advertising resources which is the process of sharing knowledge within the group, the performance of each member firm could be effectively improved, which was the main source of competitive advantage for Korean firms. Such sharing among related firms maximizes the technological value of patents, which effectively improves firm performance. Pizzo (2011) argued that in developing countries that lack efficient capital, labor, and product markets, there are information asymmetries, agency problems, and market imperfections that add to the risk of firm-related activities, while intra-group transactions result in better allocation of financial resources and economies of scale, which leads to more opportunities for growth and influence and improves firm performance. Although the Patent Law has been constantly improved with four amendments since it came into force in 1985 in China, there is still a large gap in the implementation compared with the patent laws in century-old developed economies, especially in patent assignment, where information asymmetry and market imperfections are particularly prominent, making the high costs of external patent transactions more pronounced. Moreover, related parties generally share common goals and can allocate resources more rationally to reduce disputes and conflicts in patent assignment and licensing, making patent knowledge transfer more effective and improving the performance of the recipient firm.

Therefore, internal patent assignment and licensing can effectively reduce risks in patent transactions and bring new technology to the firm, indicating a positive correlation with firm performance. This correlation is greater than the correlation between external patent assignment and licensing and firm performance.

3.2.2.3 Relationship between invention and non-invention patents and firm performance

Among inventions, utility models and designs, as inventions are substantively examined, they have better stability of rights, higher criteria of examination, and a higher level of technical innovation. This innovation generally implies that the corresponding technology has better market prospects, making it easier to increase revenue and thus improve the company’s performance. Therefore, a distinction can be made between inventions and non-inventions

(utility models and designs that have not undergone substantive examination) to study the different effects on firm performance. Ernst (2001) found that different types of patents improved firm performance to different extents. Lin and Jin (2009) argued that firms performed better when they filed more invention patents, which demonstrates a more prominent role of invention patents in enhancing firm performance. Xu and Tang (2010) examined the impact of R&D activities on firm value and performance with the data on the number and types of patents of Chinese listed companies, and concluded that patents of different quality contributed differently to firm performance, and that invention patents with a higher degree of innovation contributed the most to firm performance.

Therefore, under the same circumstance, the assignment and licensing of invention patents have a more significant positive impact on firm performance compared with non-invention patents.

3.3 Research hypotheses

Through the analysis of patent assignment and licensing, internal and external patent assignment and licensing, and invention and non-invention patents, this thesis put forward the following research hypotheses. In the theory of knowledge absorption, the source of knowledge is the main factor affecting the effectiveness of knowledge absorption. In patent transaction activities, the most important factor that determines the source of knowledge is between external and internal patent assignment and licensing. External patent assignment and licensing are external knowledge, while internal patent assignment and licensing are internal knowledge. Therefore, the research hypotheses of this thesis were specifically developed from two dimensions: external and internal.

The thesis proposed H1a, H1b, H1c and H1d for external patent transactions with the Tobin's Q as the dependent variable:

H1a: The Tobin's Q of the firm is positively correlated with the external invention patent assignment;

H1b: The Tobin's Q of the firm is positively correlated with the external non-invention patent assignment;

H1c: The Tobin's Q of the firm is positively correlated with the external invention licensing; and

H1d: The Tobin's Q of the firm is positively correlated with the external non-invention patent licensing.

Meanwhile, the thesis proposed H2a, H2b, H2c and H2d with the operating revenue as the dependent variable:

H2a: The operating revenue of the firm is positively correlated with external invention patent assignment;

H2b: The operating revenue of the firm is positively correlated with external non-invention patent assignment;

H2c: The operating revenue of the firm is positively correlated with external invention patent licensing; and

H2d: The operating revenue of the firm is positively correlated with external non-invention patent licensing.

With respect to the internal patent transactions, this thesis proposed H3a, H3b, H3c and H3d with the Tobin's Q as the dependent variable:

H3a: The Tobin's Q of the firm is positively correlated with the internal invention patent assignment;

H3b: The Tobin's Q of the firm is positively correlated with the internal non-invention patent assignment;

H3c: The Tobin's Q of the firm is positively correlated with the internal invention patent licensing; and

H3d: The Tobin's Q of the firm is positively correlated with the internal non-invention patent licensing.

Meanwhile, the thesis proposed H4a, H4b, H4c and H4d with the operating revenue as the dependent variable:

H4a: The operating revenue of the firm is positively correlated with the internal invention patent assignment;

H4b: The operating revenue of the firm is positively correlated with the internal non-invention patent assignment;

H4c: The operating revenue of the firm is positively correlated with the internal invention patent licensing; and

H4d: The operating revenue of the firm is positively correlated with the internal non-invention patent licensing.

Given that the technical content of the invention patent is higher than that of the non-invention patent, when other factors remain the same, the invention patent might have a more significant positive impact on firm performance.

3.4 Chapter summary

Based on the literature review in Chapter 2, this chapter first defined the object of study and core concepts, on the basis of which the conceptual model was proposed from the three dimensions of transaction mode, transaction scope, and patent type, followed by proposing the research hypotheses, which prepared the ground for the empirical study.

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Chapter 4: Data Collection and Descriptive Statistics

Based on the conceptual model and research hypotheses presented in Chapter 3, this chapter will provide a detailed description of the research data sources for this thesis from the perspective of data collection and descriptive statistics related to the variables.

4.1 Sample selection

For the empirical study of the hypotheses proposed in the previous chapter, we sorted out the data by selecting 1,538 companies listed in Shanghai and Shenzhen stock exchanges before January 1, 2008, including 807 from Shanghai Stock Exchange Main Board, seven from Shanghai Stock Exchange B-shares, 450 from Shenzhen Stock Exchange Main Board, 267 from Shenzhen Stock Exchange SME Board, and seven from Shenzhen Stock Exchange B-shares. In total, 814 companies were listed in Shanghai Stock Exchange and 724 in Shenzhen Stock Exchange. Sample sizes from the two exchanges were similar, which ensured the representativeness of the samples.

Considering the practical scenario of financial consolidation between listed companies and their controlling subsidiaries, this study included the consolidated subsidiaries of the listed companies within the sample, which amounted to a total of 48,319 consolidated subsidiaries. The determination of these consolidated subsidiaries was primarily based on data disclosed in the annual reports of the listed companies. Additionally, we have cross-verified this information using the “Tianyancha” commercial database.

4.2 Data collection

This thesis obtained the patent assignment and licensing data of 1,538 listed companies from the Incopat database, a global patent database developed by Beijing Incopat Co., Ltd. Incopat collects more than 100 million pieces of patent information from 120 countries/organizations/regions around the world, with the patents’ full-text available for download. It is updated weekly and contains all Chinese inventions, utility models and designs filed from the establishment of China’s modern patent system in September 1985 to the present day. In the database, patent data of 22 countries have been particularly collected

and processed with the Incopat database, and legal information like patent litigation, assignment, licensing, pledge, re-examination invalidation and customs record are linked to patent literature. The information that can be searched and downloaded includes patent name, abstract, filing date, grant date, legal status, citations, patent family information, and assignment and licensing history. Therefore, Incopat provides quick access to patent assignment and licensing data of listed companies and their holding subsidiaries, and ensures the accuracy and reliability of the data. The China and Global Patent Examination Information Inquiry website is the official website of China's patent examination, on which the data on the change of applicants and patentees (i.e., patent assignment) in the change of patent records are publicly available. Data from this website were used to verify the patent assignment data of Incopat. Meanwhile, the patent licensing data of Incopat were verified with the data from the *Registration of Patent Right Pledge and Patent Exploitation License Agreement* published by the China National Intellectual Property Administration. Based on the information of the listed companies and their holding subsidiaries, patent assignment and licensing data from 2006 to 2020 were exported from Incopat, and a total of 17,468 pieces of patent licensing data and 37,402 pieces of patent assignment data were obtained.

In this study, the financial data of 1,538 listed companies were acquired from CSMAR, RESSET and WIND databases. The financial data mainly included indicators like solvency, operational capacity, profitability, development capacity, and composite indicator of listed companies, and there were several sub-indicators under each indicator. The three databases are the mainstream financial databases in China, which collect all the financial data disclosed in the annual reports of listed companies. This Thesis mainly used the financial data from CSMAR, and had the data cross-checked with RESSET and WIND to ensure the accuracy. Apart from this, the thesis also verified the abnormal financial data of part of the listed companies with their annual reports.

The thesis collected data on the patent assignment and licensing and financial data.

The collection of patent assignment and licensing data included the following steps: (1) We imported the directories of 1,538 listed companies and 48,319 consolidated subsidiaries into the "applicant or assignee" column of Incopat's patent database in batches, obtained the corresponding search results, and ticked " patent title, applicant, application number, patent type, application date, granting date, country of disclosure, number of assignments, assignment date, assignor, assignee, number of licenses, license agreement filing date, licensor, licensee, license type", and exported the table of bibliographic data to obtain the original patent information of the listed companies and consolidated subsidiaries; (2) We

filtered the information of the items in the bibliographic data table, selected "invention patent" as the type of patent, "China" as the country of disclosure, "≥ 1" as the number of assignments, "January 1, 2006 - December 31, 2020" as the date of assignment, "≥ 1" as the number of licenses, and "January 1, 2006 - December 31, 2020" as the date of filing of license agreement, and got the table of assignment and licensing bibliographic data; and (3) We took the name, stock code and year of listing of the listed company as dimensions (i.e. one column each for the name, stock code, and year of listing), processed the assignment and licensing data in the table of bibliographic data, and attributed the data of each consolidated subsidiary to the listed company. As a result, the assignment and licensing data of each listed company formed a matrix of 15 rows and 4 columns, where the 15 rows represented the 15 years from 2006 to 2020, and the 4 columns represented the number of internal licenses, external licenses, internal assignments, and external assignments, respectively. The numbers of patent assignments and licenses for each year were filled into the corresponding boxes in the matrix by type as elements of the matrix, i.e., patent licenses and assignments occurring between the listed companies and their consolidated subsidiaries and between consolidated subsidiaries were internal assignments and licenses, while other cases were considered as external assignments and licenses. If there was no assignment or license data for the year, the numbers of internal and external licenses, internal and external assignments were all zero. The final data table of assignments and licenses from 2006 to 2020 was then obtained. Meanwhile, for potential abnormal data, such as multiple assignments of one patent or a patent involving a large number of licensees, the public search platform of the China National Intellectual Property Administration was used to further verify the relevant patent information. It is an official database and the search is not as convenient as Incopat, but it can cross-verify with the firm's patent license filing and patent right change information database of the Administration, thus ensuring the accuracy of patent assignment and licensing data.

The financial data were collected in the following steps: (1) We entered the 1,538 listed companies into GSMAR, chose the annual data from 2006-2022, and exported the raw financial data, including balance sheet, income statement, cash flow statement, profitability statement, solvency statement, development capacity statement, and relative value indicator statement; (2) In each table of the raw financial data, Tobin's Q, operating revenue, total assets, current ratio, quick ratio, gross operating margin, and debt-to-asset ratio were selected to obtain the financial data table for 2008-2022 relevant to this study; and (3) The stock codes of listed companies were used as characteristic elements to match the assignment and licensing table from 2006-2020 with the financial data table from 2008-2022 to obtain the

aggregated data. Since the Tobin's Q, operating revenue, and total assets data were collected two years after the assignment and licensing, the assignment and licensing data in 2006 corresponded to the Tobin's Q, operating revenue, and total assets in 2008, and analogously, the assignment and licensing data in 2020 corresponded to the Tobin's Q, operating revenue, and total assets in 2022. The control variables of total assets, operating gross margin, selling expense ratio and debt-to-asset ratio in the financial data were synchronized, thus the assignment and licensing data of 2021 and 2022 in the table were expressed by N/A. The summary table of patent assignment and licensing data and financial data of the listed companies was then obtained.

4.3 Definition of variables

The dependent variables studied in this thesis are operating revenue and Tobin's Q to measure the financial and market performance of the firm. The operating revenue constitutes the firm performance indicator, while Tobin's Q is the market performance indicator. Tobin's Q is the ratio of the firm's market capitalization to total assets. Firms are profit-oriented social organizations, and all their activities are ultimately reflected in their operating revenue. For listed companies as the representatives of outstanding Chinese firms, their operating revenue can well represent the financial performance and reflect the impact of patent trading activities on firm performance. Besides, the operating revenue is an indicator of the size of a firm and the source of its net profit. Analyzing the operating revenue may directly reflect the growth of firms. Tobin's Q can reflect the public's recognition of the value of the listed company. Companies better recognized by the public have a higher Tobin's Q. Consequently, it can be used as an indicator of firms' market performance and reflect the influence of patent trading activities on firm performance.

The independent variables in this study are the number of patent assignments and the number of patent licenses. The patents include invention and non-invention patents, and the non-invention patents includes utility model patents and design patents. Since utility models and designs are not subject to substantive examination in China, they have low stability and are easily invalidated through patent invalidation procedures. The assignment and licensing of these patents may bring greater uncertainty to the recipient, thus creating greater interference with the operating revenue and Tobin's Q. Therefore, this thesis selected the assignment and licensing of patents as the independent variables to reflect more accurately the impact of patent transactions on firm performance. Meanwhile, a large portion of patent transactions in

China are conducted between subsidiaries of the listed company. In order to distinguish between the impact of internal patent transactions and that of external patent transactions on firm performance, the independent variables studied here were subdivided into the number of internal patent assignments, the number of external patent assignments, the number of internal patent licenses, and the number of external patent licenses.

The control variables selected in this study include the total assets, current ratio, quick ratio, gross margin, and debt-to-asset ratio, which play important roles in the business development of firms. The 1,538 listed companies varied largely in total assets, current ratio, quick ratio, gross margin, and debt-to-asset ratio. For instance, the total assets, gross margin, selling expense ratio, and debt-to-asset ratio of Shenzhen Overseas Chinese Town Co., Ltd. (000069.SZ) in 2012 were 72.998 billion, 23.92%, 2.19%, and 69.95% respectively, while those of Shenzhen Neptunus Biology (000078.SZ) in the same period were 5.863 billion, 1.57%, 1.92%, and 81.97% respectively. These indicators might have a large impact on the operating revenue and Tobin's Q of the firm. It was necessary to control for these variables so that other indicators did not interfere with the regression analysis result or affect the accuracy of the analysis. Among these variables, the total assets refer to all assets owned or controlled by the listed company that can generate economic benefits; current ration = current assets / current liabilities ; quick ratio = quick assets / current liabilities; gross margin = (operating revenue - operating cost) / operating revenue, where operating revenue refers to the sum of revenues earned by the listed company through its business, and operating cost refers to the sum of all costs incurred by the listed company in its operation; debt-to-asset ratio = total liabilities / total assets, where total liabilities refer to the combined debts the firm owes.

4.4 Descriptive statistics

The descriptive statistics in this section reviewed and sorted out the data, and presented the overall data of the listed companies and the independent, dependent, and control variables, and related data of the empirical study with texts and graphs, which enables a more direct view of the variables of the study.

4.4.1 Data overview

Of all the data of the listed companies, the changes in total assets and return on equity are extremely important as these two are key financial indicators in the operations of firms. Next, descriptive explanations of these two sets of data will be provided, offering an overview of the basic characteristics of the listed companies from a macro perspective.

The total assets of listed companies represent the sum of all monetary-measured economic resources controlled by these companies and serve as the fundamental resource for generating economic returns for these listed companies. During 2008-2022, the assets of the listed companies grew rapidly year by year, as shown in Table 4.1, which also kept pace with the growth rate of China's economy. Nevertheless, there was a significant gap between the mean and the median values of the listed companies' assets, which also indicated that there were some large heavy asset companies in the portfolio of the listed companies, which affected the representativeness of the mean asset indicator. These companies are also the cornerstone of China's sustained economic growth. The total assets of the 1,538 listed companies increased from 47.09 trillion yuan in 2008 to nearly 230 trillion yuan, an increase of 4.89 times. Against the background of the rapid growth of the overall assets of the listed companies, it seemed even more valuable to study the role of the patented technologies acquired by the listed companies. During this period, the median value of the assets also grew significantly, from 1.911 billion yuan to 9.427 billion yuan, up 4.93 times, similar to the growth of total assets.

Table 4.1 Total assets of the listed companies, 2008-2022 (unit: 100 million yuan)

Year	Total assets	Mean	SD	Median
2008	470922.18	306.19	3768.59	19.11
2009	588649.45	382.74	4678.30	21.93
2010	694961.57	451.86	5402.74	26.03
2011	822823.66	535.00	6213.33	31.78
2012	942294.52	612.68	6998.33	34.96
2013	1049477.50	682.37	7660.31	39.30
2014	1173223.01	762.82	8401.40	44.47
2015	1326258.54	862.33	9235.13	52.94
2016	1512206.61	983.23	10267.50	64.89
2017	1635298.11	1063.26	10971.30	72.26
2018	1755950.78	1142.45	11685.78	75.79
2019	1880237.38	1224.11	12388.36	81.01
2020	2011440.78	1310.38	13108.40	85.45
2021	2153811.02	1400.12	13883.41	90.05
2022	2299796.82	1490.39	14648.70	94.27

Source: CSMAR, RESSET, WIND

The return on equity of the listed companies is a value obtained by dividing the total profit of all listed companies by the total net assets. In terms of the ROE, the operating revenue of the listed companies during the period of 2008-2022 showed large fluctuations, Overall, the mean and median values fell into the range of 5%-10%. As shown in Table 4.2, the mean and median values peaked in 2010 and then showed a slight decline. The two values hit the bottom in 2022, basically consistent with China's economic trend during this period.

Table 4.2 ROE of the listed companies, 2008-2022 (%)

Year	Mean	SD	Median
2008	5.62	16.65	6.66
2009	7.66	14.15	7.86
2010	9.72	11.94	9.19
2011	8.55	13.99	8.12
2012	6.91	11.89	6.63
2013	6.17	13.73	6.56
2014	6.04	13.80	6.13
2015	4.71	15.36	5.64
2016	5.91	12.47	6.02
2017	7.09	15.05	6.80
2018	5.26	16.88	6.20
2019	5.61	15.23	5.91
2020	4.89	14.51	5.75
2021	4.75	13.89	5.66
2022	4.62	13.46	5.37

Source: CSMAR, RESSET, WIND

4.4.2 Descriptive statistics of independent variables

The numbers of patent assignments and licenses were selected as the independent variables in the thesis. Since it took some time for patent assignment and licensing to have an impact on the dependent variables, we set the lag time to two years and the analysis was made on the patent assignments and licenses of the listed companies during 2006-2020 which corresponded to the changes in the Tobin's Q and operational revenue during 2008-2022.

4.4.2.1 Overview of patent assignment and licensing

After being obtained by the listed company, the patented technology continues to affect firm performance and exerts a lasting impact on firm performance in the life cycle or the patent term of the patented technology. Therefore, when describing the numbers of patent assignments and licenses in the thesis, the cumulative number was chosen as it could better mirror this continuous effect. The number of patent assignments and licenses in 2006 is only based on the that year's data; from 2007, the cumulative number of patent assignments and licenses includes both the quantity for that year and the cumulative sum of patent assignments and licenses from previous years. However, the data for patent assignments and licenses in 2006 only includes the quantity for that year.

As illustrated in Figure 4.1, during 2006 and 2020, the cumulative number of patents assigned to the listed companies increased from 125 to 37,402, an increase of close to 300 times, and that of patents licensed jumped from 196 to 17,468, up over 89 times. The former obviously grew more than the latter. The total number of assignments and licenses increased from 321 to 54,870, an increase of more than 171 times. Both showed a high-speed growth momentum, echoing the surge of patent applications in China during this period. At the same

time, the differences in the absolute value of the cumulative number between patent assignments and licenses gradually widened, which indicates that although these two modes are the mainstream modes of patent transactions, the bigger increase in patent assignments may suggest a preference by the listed companies.

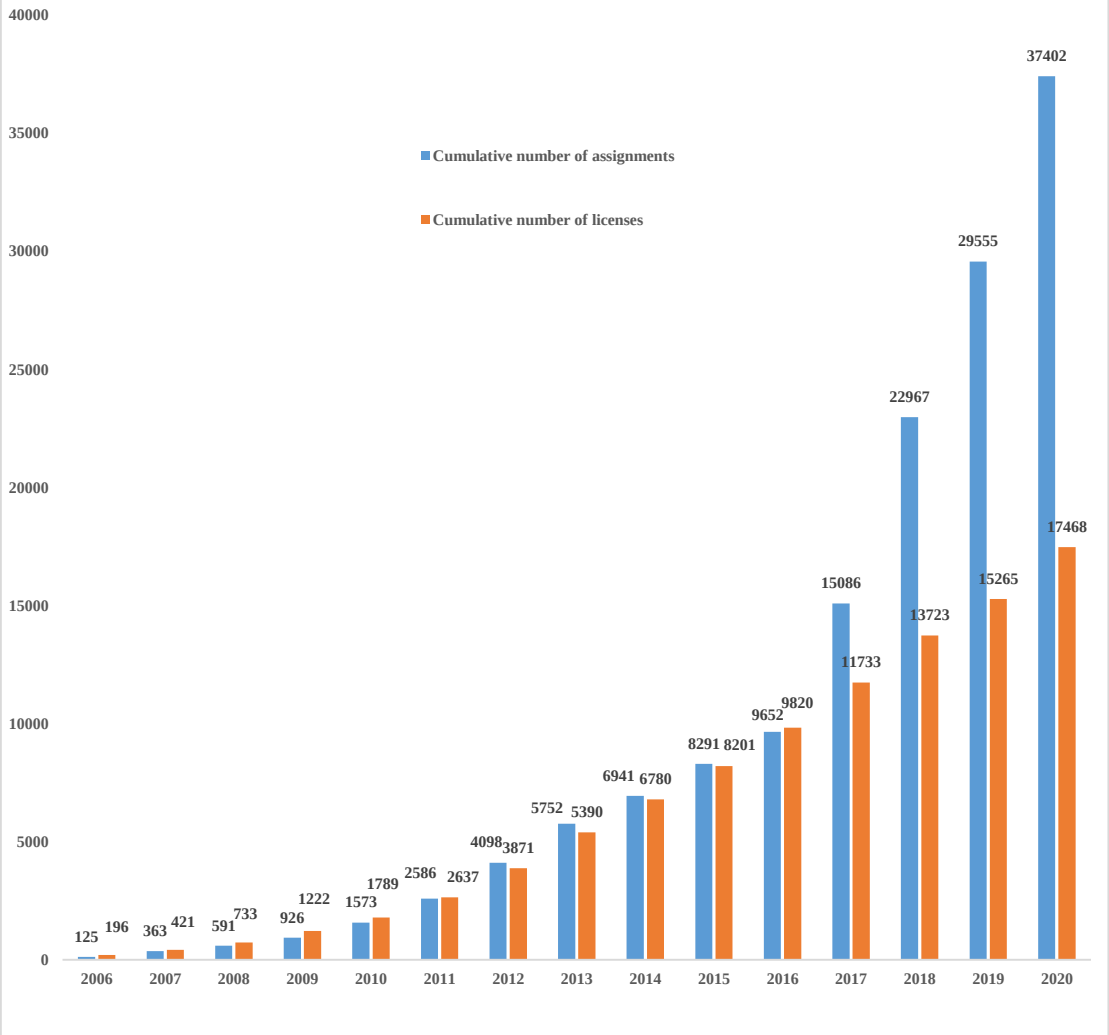

Figure 4.1 Cumulative numbers of patent assignments and licenses, 2006-2020

Source: Incopat (www.incopat.com)

In the same period, as shown in Figure 4.2, the cumulative number of internal assignments and licenses and that of external assignments and licenses also grew rapidly, but the former remained greater than the latter. This shows that internal assignments and licenses are the most important means for the listed companies to acquire patented technologies. Therefore, in Chapter 5, empirical studies will be conducted separately for external and internal patent transactions to reveal whether these two types of patent transactions have different impacts on firm performance. During this period, the number of internal assignments and licenses grew from 186 to 38,106, an increase of almost 205 times. The number of external assignments and licenses increased from 135 to 16,764, an increase of more than 124

times. The increase of internal assignments and licenses was more significant.

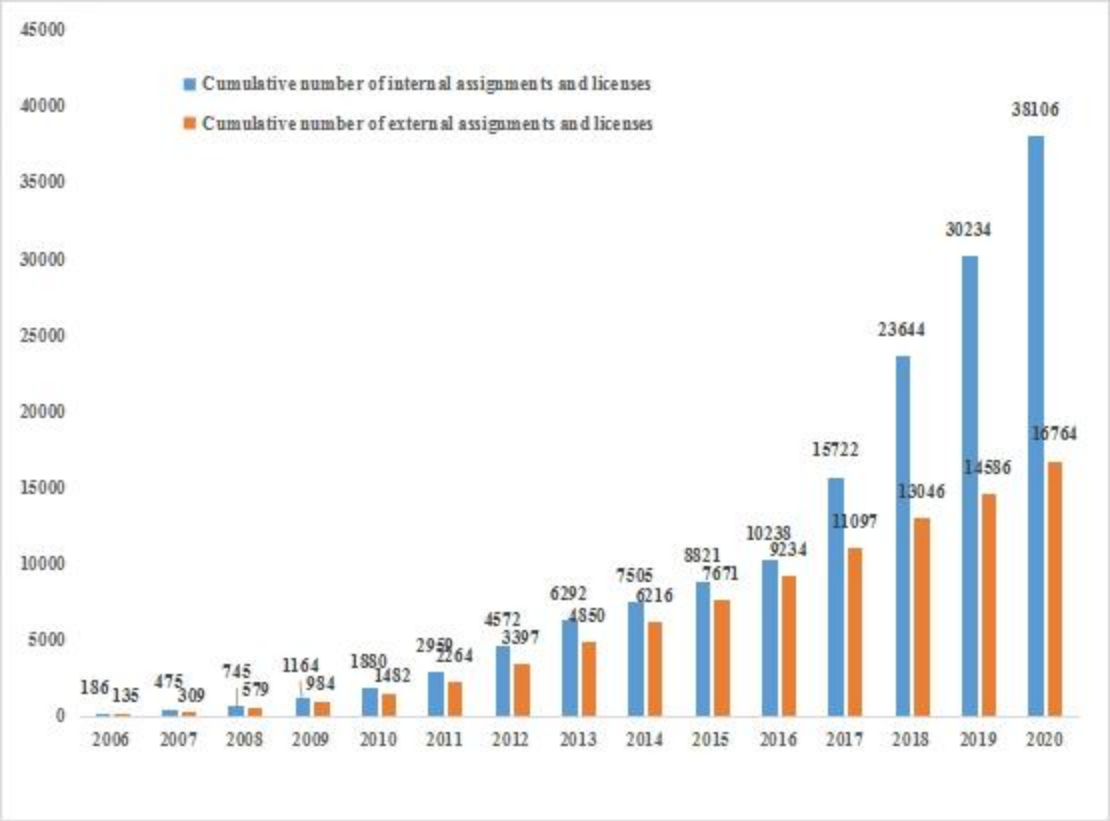

Figure 4.2 Cumulative numbers of internal and external assignments and licenses, 2006-2016

Source: Incopat (www.incopat.com)

In terms of patent types, as illustrated in Figure 4.3, the cumulative numbers of assigned and licensed inventions and non-inventions both grew rapidly. However, the number of invention patents has gradually surpassed the number of non-invention patents, indicating a greater emphasis on invention patents in patent transactions. As shown in Figure 4.3, among them, the number of inventions increased from 111 to 30,395, up by more than 274 times, and that of non-inventions from 210 to 24,475, up by more than 117 times. The number of invention patents increased significantly faster, and the gap with that of non-invention patents gradually narrowed. The ratio of the number of non-invention patents to that of invention patents dropped from 1.89 to 0.81. Invention patents' stronger representativeness of valuable technical solutions over non-invention patents also indicates that the main purpose of patent transactions of the listed companies had gradually shifted to technology acquisition. During 2006-2020, the cumulative number of invention patent licenses and assignments of the listed companies was 30,395, with 111 in 2006 increased to 7,518 in 2020, showing a year-on-year increase except for a brief decline in 2014. The total number of invention patent licenses and assignments increased more than 67 times, indicating the huge demand and market potential of the patent trading market, and therefore justifying the value of studying the impact of such

behavior on the performance of the listed companies.

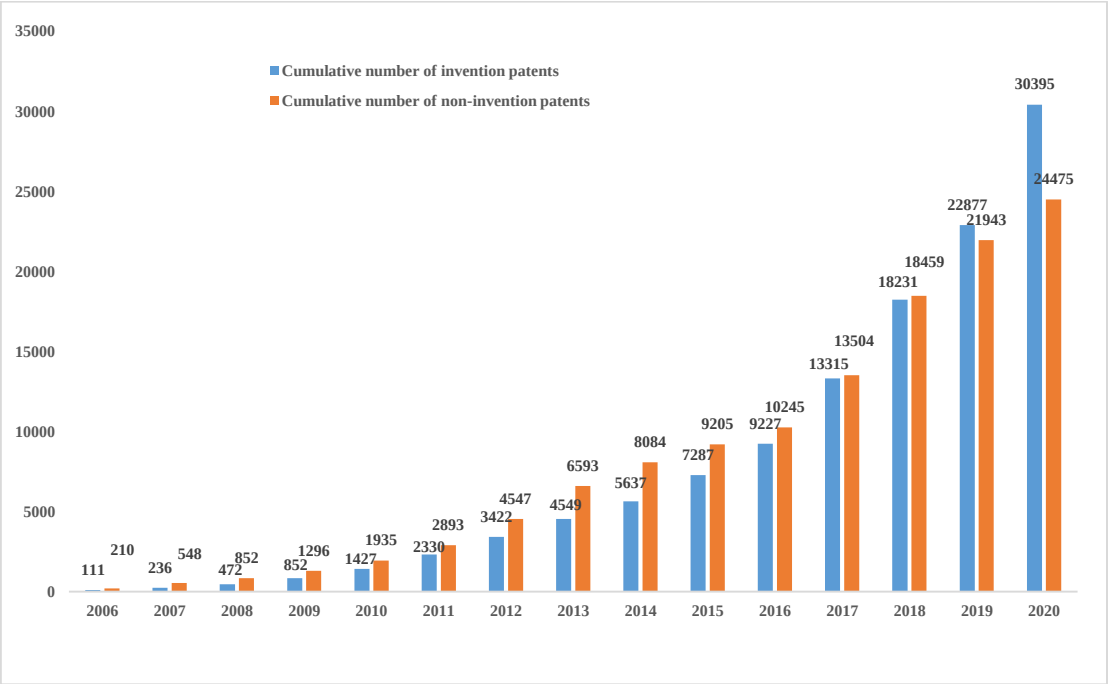

Figure 4.3 Cumulative numbers of assigned and licensed invention patents and non-invention patents, 2006-2020

Source: Incopat (www.incopat.com)

With regard to invention patents with a greater significance, as the two main ways to acquire patented technology, the numbers of invention patent assignments and licenses among the listed companies from 2006 to 2020 were similar, whereas the number of patent assignments was slightly lower than that of patent licenses in most years, indicating that the listed companies were not limited to a specific way when acquiring technology. The number of invention patent licenses increased from 81 in 2006 to 1,941 in 2020 by nearly 24 times, indicating that the listed companies received patent licenses more frequently, which has become an important way to acquire technology. However, there was a significant disparity between internal and external invention patent licenses. The number of internal invention licenses was much smaller than that of external invention licenses over the same period between 2006 and 2020. Moreover, this gap seemed to be widening, with the number of internal invention licenses accounting for 18.52% of the total number of invention licenses in 2006, falling to 2.78% in 2020. It can be seen that when the listed companies acquire technology from outside, they generally do so through licensing, while when they acquire technology from inside, they use licensing less and less due to more flexible and convenient transaction negotiation and consideration payment. The number of invention patent assignments of the listed companies increased from 30 in 2006 to 5577 in 2020, which is a

growth of more than 185 times, a growth far exceeding that of patent licenses. This suggests that patent assignment of the listed companies has become an important way to acquire technology together with patent licensing and gained increasing popularity. However, there was a significant difference between the number of internal and external invention patent assignments, where the number of external invention assignments was much smaller than that of internal invention assignments in the same period from 2006 to 2020. Thus, it can be seen that the listed companies are less likely to resort to assignment when acquiring technology from external sources, while they prefer assignment when acquiring technology from internal sources.

4.4.2.2 Analysis of the firms receiving invention patent assignment and/or licensing

An analysis of the number of assignments and licenses of patents, especially invention patents, received by the listed companies can help identify the characteristics of technology acquisition by these companies. Among the 1538 listed companies, 908 did not receive any invention patent license or assignment, accounting for 59.03%, which shows that even among listed companies, there are still not many receiving invention patent assignment and/or licensing, and that the patent transaction market is still in the early stage in China, with a lot of room for development. Among the 630 listed companies that received invention patent assignment and/or licensing, 145 received 1-5 licenses and assignments; 99 received 6-10; 291 received 11-100; and only 95 received more than 100. Among these companies, 313 (49.68%) received licenses only, 209 (33.17%) received assignments only, and 108 (17.14%) received both. This also indirectly indicates that the licensing of invention patents is a more common way of patent transaction for listed companies.

After analyzing the licensing and assignment data, the top ten companies in terms of the number of patent licenses and assignments were identified. As illustrated in Table 4.3, the total number of invention patent licenses and assignments of these ten companies stood at 24,049, accounting for 43.85% of the total number of 54,870, indicative of an extremely high concentration of patent licenses and assignments. Moreover, the patent licenses and assignments were mainly found in the manufacturing industry, especially in the electronic information, which also indicates that the technology in such industries iterated faster and that the listed companies in this sector were more inclined to acquire technology through patents. The business of BOE which had the largest number of invention patent licenses and assignments covered electronic products, communication equipment, mechanical and electrical equipment, hardware, and construction materials. In 2020, its shipment of LCD panels ranked first over LG Electronics of South Korea, taking up 22.9% of the global market share (Incopat (www.incopat.com).

Table 4.3 Top ten listed companies in the number of invention patent licenses and assignments

Name	Stock code	Total number of invention patent licenses and assignments	Industry
Tunghsu Azure	000040	1240	Photovoltaic power generation equipment
CPT Technology	000536	1257	Display panel
NARI-TECH	600406	1369	Grid automation equipment
CREC	601390	1438	Municipal Engineering Construction
Founder Technology	600601	1445	Electronic component
Hisense	000921	2019	White goods
QJMOTOR	000913	2336	Motorcycles
Taishan Pectroleum	000554	3970	Oil and petrochemicals trading
Haier Smart Home	600690	3980	White goods
BOE	000725	4995	Display panel

Source: Incopat (www.incopat.com)

4.4.3 Descriptive statistics of control variables

During 2008 and 2022, the gross margin of the listed companies was relatively stable as a whole. As shown in Table 4.4, the average gross margin of the listed companies fluctuated in the range of 2%-12%. In order to avoid excessively high gross margin of some firms or negative gross margin of loss-making firms from affecting the mean value of the listed companies, the median gross margin of sample firms was also extracted. The median was more stable than the mean, fluctuating within 4%-8%. It can be seen that the gross margin of the listed companies did not change significantly during the period of 2008-2022, which is suited for analyzing the performance of patent transactions.

Table 4.4 Gross margin of the listed companies, 2008-2022

Year	Mean	SD	Median
2008	7.49%	29.97%	6.26%
2009	7.49%	26.57%	5.60%
2010	6.28%	26.94%	4.53%
2011	7.42%	32.52%	4.67%
2012	6.74%	43.58%	4.48%
2013	6.48%	43.84%	4.60%
2014	7.52%	41.09%	5.74%
2015	11.96%	41.74%	7.44%
2016	4.65%	48.67%	6.41%
2017	9.13%	26.47%	7.38%
2018	5.70%	35.46%	6.38%
2019	6.20%	42.84%	6.73%
2020	5.47%	38.81%	5.41%
2021	6.26%	31.52%	4.83%
2022	5.17%	28.56%	4.77%

Source: CSMAR, RESSET, WIND

During 2008-2022, the annual debt-to-asset ratio of the listed companies was basically

flat. As shown in Table 4.5, the mean value was around 53% and the median value was around 52%. 2012 was a turning point in the trend. The debt-to-asset ratio increased from 2006 to 2012, and decreased from 2012 to 2022.

Table 4.5 Debt-to-asset ratio of the listed companies, 2008-2022

Year	Mean	SD	Median
2008	53.25%	35.13%	51.21%
2009	53.22%	28.69%	52.09%
2010	53.81%	30.78%	52.79%
2011	53.80%	29.43%	53.32%
2012	53.12%	24.77%	53.67%
2013	52.52%	21.41%	53.41%
2014	52.13%	22.50%	52.07%
2015	50.84%	22.78%	50.58%
2016	49.82%	21.86%	49.80%
2017	50.11%	22.73%	50.31%
2018	51.90%	32.16%	50.74%
2019	50.70%	31.58%	49.37%
2020	52.30%	30.34%	52.71%
2021	51.60%	23.48%	52.18%
2022	50.10%	28.61%	51.84%

Source: CSMAR, RESSET, WIND

During 2008-2022, the current ratio of the listed companies showed a slight increase, with the median value up from 1.18 in 2008 to 1.31 in 2022. As shown in Table 4.6, the mean value was between 1.6-1.9, and the median value between 1.1-1.5. Among them, the median value in 2016 reached the peak 1.42.

Table 4.6 Current ratio of the listed companies, 2008-2022

Year	Mean	SD	Median
2008	1.67	2.23	1.18
2009	1.71	2.43	1.25
2010	1.81	3.15	1.29
2011	1.94	5.79	1.30
2012	1.71	1.89	1.30
2013	1.72	1.70	1.29
2014	1.81	2.57	1.30
2015	1.85	2.23	1.36
2016	1.95	2.43	1.42
2017	1.94	2.35	1.41
2018	1.89	2.68	1.37
2019	1.91	2.37	1.29
2020	1.86	2.82	1.33
2021	1.89	2.61	1.24
2022	1.83	2.73	1.31

Source: CSMAR, RESSET, WIND

During 2008-2022, the quick ratio of the listed companies increased slightly, with the median value increasing from 0.74 in 2008 to 0.92 in 2022. As shown in Table 4.7, the mean value was between 1.1 and 1.5, and the median value between 0.7 and 1. The median value reached the peak 0.98 in 2017.

Table 4.7 Quick ratio of the listed companies, 2008-2022

Year	Mean	SD	Median
2008	1.19	2.06	0.74
2009	1.24	2.32	0.81
2010	1.31	2.87	0.82
2011	1.40	4.67	0.83
2012	1.22	1.76	0.80
2013	1.23	1.46	0.83
2014	1.29	1.83	0.84
2015	1.38	1.95	0.91
2016	1.49	2.22	0.97
2017	1.48	2.03	0.98
2018	1.45	2.37	0.96
2019	1.45	2.37	0.96
2020	1.23	1.86	0.85
2021	1.34	1.92	0.93
2022	1.41	2.28	0.92

Source: CSMAR, RESSET, WIND

4.4.4 Descriptive statistics of dependent variables

The Tobin's Q and operating revenue are chosen as firm performance indicators studied in this thesis. Descriptive statistics of the Tobin's Q and operating revenue of the listed companies from 2008-2020 will be presented in the following sections.

4.4.4.1 Descriptive statistics of Tobin's Q

Tobin's Q value is a market performance indicator. Listed companies with a higher Tobin's Q usually have better performance in the stock price, and appear more promising to the market, which also indicates better market performance. During 2008-2022, the Tobin's Q value of the listed companies fluctuated widely, which was related to the immaturity of China's capital market and violent market fluctuations. During 2008 and 2013, China's capital market demonstrated an obvious upward trend. As a result, the Tobin's Q value in this period was significantly higher than that of other years. As shown in Table 4.8, from 2008 to 2022, the average Tobin's Q of the listed companies fluctuated between 1.6 and 3.1, up to 3.05 in 2013 and down to 1.68 in 2020. In terms of the median value, the overall trend of Tobin's Q was basically consistent with the mean, but with a smaller value. The median value of Tobin's Q fluctuated between 1.1 and 2.3, up to 2.3 in 2008 and down to 1.17 in 2020.

Table 4.8 Tobin's Q of the listed companies, 2008-2022

Year	Mean	SD	Median
2008	2.82	3.02	2.30
2009	2.11	2.72	1.56
2010	1.90	1.90	1.49
2011	2.04	1.77	1.53
2012	2.37	2.36	1.77
2013	3.05	4.40	2.21
2014	2.60	3.42	1.90
2015	2.14	2.29	1.57
2016	1.75	1.82	1.20
2017	2.26	2.75	1.62
2018	1.75	1.99	1.21
2019	1.72	2.56	1.19
2020	1.68	3.14	1.17
2021	1.77	2.86	1.20
2022	1.73	2.72	1.22

Source: CSMAR, RESSET, WIND

4.4.4.2 Descriptive statistics of the operating revenue

The listed companies registered a continuous rapid growth in the operating revenue during 2008-2022. As shown in Table 4.9, the mean value increased from 7 billion to 31.822 billion yuan from 2008 to 2022, more than a threefold increase. In terms of the median value, although it was smaller than the mean value in the same year, the growth trend remained consistent. It increased from 1.173 billion in 2008 to 5.142 billion yuan in 2022, which was also more than a threefold increase.

Table 4.9 Operating revenue of the listed companies, 2008-2022

Year	Mean	SD	Median
2008	70.00	499.71	11.73
2009	71.92	479.90	12.40
2010	98.26	676.41	15.35
2011	121.22	879.08	18.31
2012	131.76	970.52	19.70
2013	143.29	1015.04	21.74
2014	149.13	1020.69	23.41
2015	145.82	816.65	24.82
2016	157.63	804.86	29.94
2017	188.17	964.93	35.33
2018	212.56	1030.87	36.06
2019	240.11	975.35	40.41
2020	266.43	866.76	44.07
2021	292.97	743.52	47.63
2022	318.22	956.18	51.42

Source: CSMAR, RESSET, WIND

4.4.5 Characteristics of assigned and licensed patents

This section will shed further light on patent assignment and licensing for listed companies by analyzing the characteristics of the patents assigned and licensed, concluding which types of

patents are more likely to be assigned and licensed, and the characteristics of these patents.

4.4.5.1 Proportion of each type of patents

The total number of patents involved in the assignment and licensing activities from 2008 to 2022 was 39,226, slightly lower than the total number of assignments and licenses since some patents were assigned or licensed for a couple of times. As illustrated in Figure 4.4, utility models took up the largest share of 54%, totaling 20,984; followed by invention patents, with 15,037 accounting for 38%; and designs, with 3,205 cases and accounting for only 8%. This was also generally consistent with the proportions of different patent types in China's patent applications.

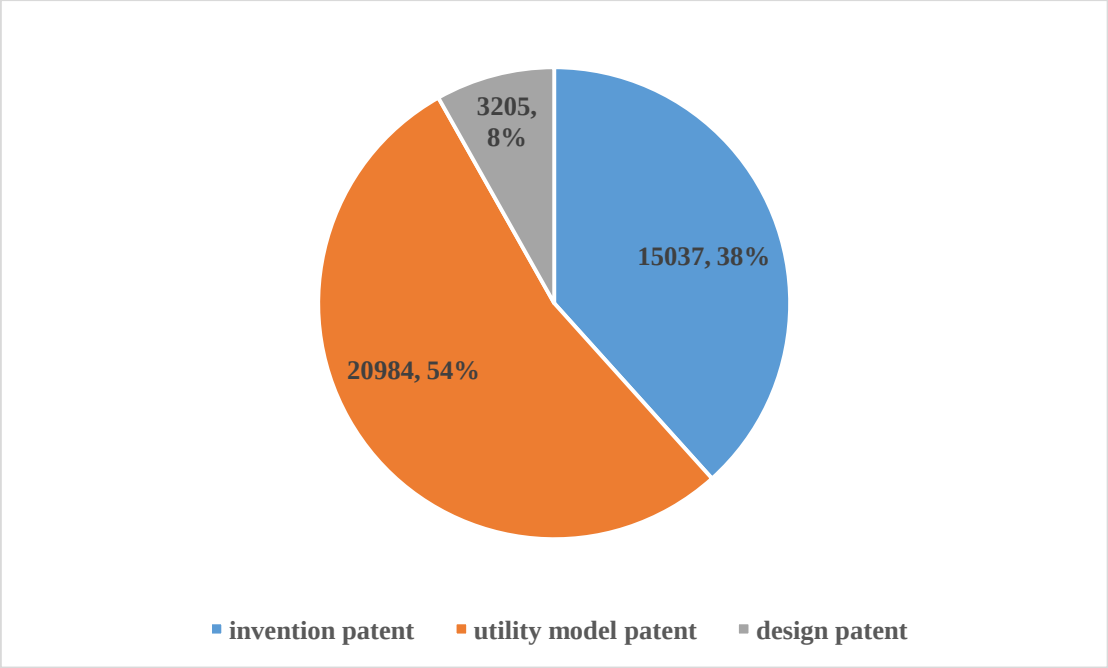

Figure 4.4 Distribution of the types of assigned and licensed patents

Source: Incopat (www.incopat.com)

4.4.5.2 Patent filing time

Among the 39,226 assigned and licensed patents involved, the applications were filed in 1994-2018 and concentrated in 2010-2014, as shown in Figure 4.5. The largest number of patents was filed in 2013, reaching 6,632. Patent applications grew in line with patent assignments and licenses. The patents filed in recent years involved relatively less assignments and licenses due to their recentness in application time and that some have not been granted.

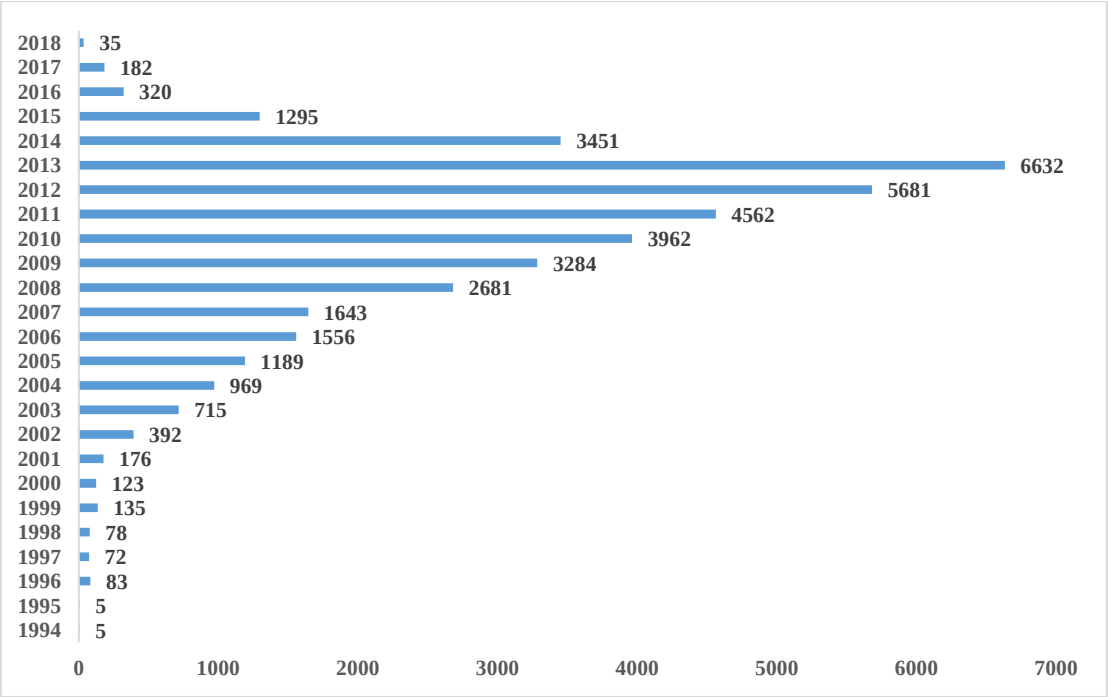

Figure 4.5 Application time distribution of assigned and licensed patents

Source: Incopat (www.incopat.com)

4.4.5.3 Analysis of the IPC of inventions and utility models

Both inventions and utility models are technology patents and have IPCs as a result of the information such as technical subjects, functions, and application extracted from the content of patent application documents. The IPC is primarily used for the technical classification of patents, facilitating patent search and examination. It can also be used to analyze the technical fields to which the patents belong and sort out the hot technical domains for patent assignment and licensing. A patent document may involve multiple technical subjects, hence there may be multiple classification codes, but there is only one primary classification code. We employ the primary classification code for analysis in this study. As shown in Figure 4.6, the three largest categories among inventions and utility models are: G - Physics; B - Performing operations, transportation; and H - Electricity, accounting for 22%, 19%, and 18% respectively.

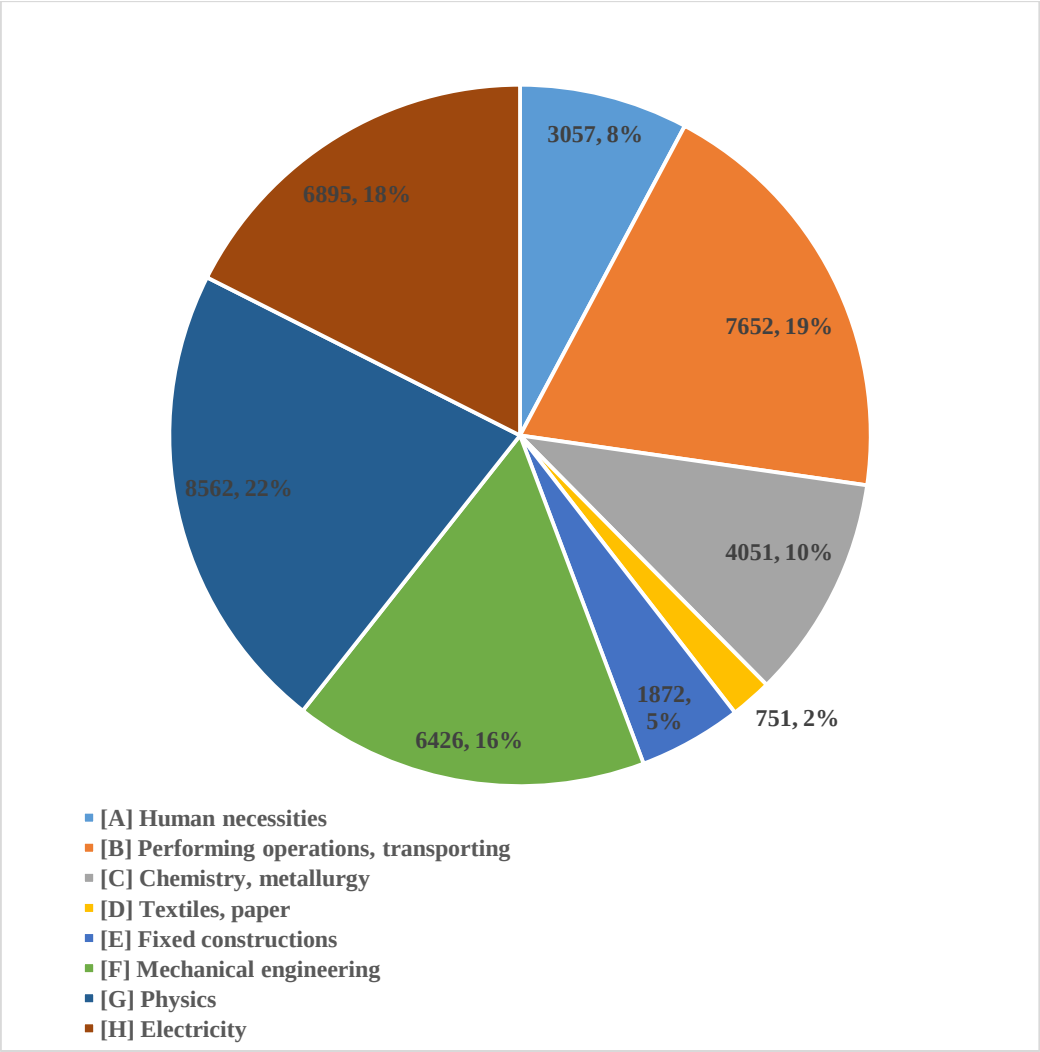

Figure 4.6 IPC of inventions and utility models, 2006-2020

Source: Incopat (www.incopat.com)

Here are examples of patent transactions with IPC codes:

Invention: Direct downward backlight module backlight light source and light mixing method (Application number: 201310500853.7; Application date: October 22, 2013; Grant date: December 30, 2015)

Patent holder BVCH Optronics (Sichuan) Corp assigned it to Sichuan Changhong Electric Co., Ltd. (Stock code: 600839.SH)

It is an external invention patent assignment.

IPC codes: H01L33/50 and H01L33/48, with the former being the main classification code representing the semiconductor device technology field.

Invention: Crane drum structure and configuration method for crane comprising said structure (Application number: 201210204441.4; Application date: June 20, 2012; Grant date: September 16, 2015)

Patent holder Shanghai SANY Science and Technology Co., Ltd. assigned it to Zhejiang

SANY Equipment Co., Ltd., a wholly-owned subsidiary of SANY Heavy Industry Co., Ltd. (Stock code: 600031.SH)

Shanghai SANY Science and Technology Co., Ltd. is an affiliated company.

It is an internal invention assignment.

IPC code: B66D1/14, "winches; capstans; hoists, pulley block; cranes" technology field.

Utility model: Shore-based simulation testing system for multi-node connection of underwater observation network (Application number: 201220621952.1; Application date: November 22, 2012; Grant date: April 24, 2013)

Patent holder Zhejiang University licensed it to Zhongtian Technology Marine Systems Co., Ltd., a subsidiary of Jiangsu Zhongtian Technology Co., Ltd. (Stock Code: 600522.SH)

It is an external utility model license.

IPC code: G01R31/00, "measurement of electrical variables; measurement of magnetic variables" technology field. This is also consistent with the current technology hotspots such as intelligent manufacturing, artificial intelligence, new energy vehicles, and new energy.

This suggests that in technology hotspots, the patent market has promising prospects, substantial growth opportunities, a wide range of potential trading partners, and a greater inclination for transactions to take place.

4.5 Chapter summary

This chapter detailed the data source of the empirical study, specifically, the sample selection, data acquisition, and variables definition. Descriptive statistics of the data was then elaborated, followed by presenting the overall situation of patent transactions with figures and tables. This formed a bigger picture of the characteristics of patent transactions, which also corroborated with the empirical study in Chapter 5.

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Chapter 5: Empirical Analysis

Following the descriptive statistics of the data, this chapter will conduct an empirical study based on the collected data. First, the correlation of the variables, independent variables and control variables in the research hypotheses will be discussed. The regression analysis for patent assignment and licensing will then be conducted with Tobin's Q and operating revenue as the dependent variables to test the hypotheses proposed in Chapter 4, followed by the regression results to check the robustness with weighted Tobin's Q and the logarithm of total assets as the dependent variables.

5.1 Correlation analysis of regression variables

Before the regression analysis, the collinearity between variables that may affect the regression results can be avoided by verifying the correlation between the variables. Table 5.1 presents the correlation matrix of the regression variables. The correlation between variables was all smaller than 0.7, which could preliminarily rule out possible collinearity.

Table 5.1 Correlation matrix

	Mean	SD	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)
Tobin's Q	1.880	1.045	1													
Operating revenue	22.89	23.54	-0.262***	1												
External invention patent licenses	2.490	25.152	-0.036***	0.128***	1											
External non-invention patent licenses	2.575	10.228	-0.073***	0.152***	0.145***	1										
Internal invention patent licenses	0.308	1.855	-0.007	0.073***	0.183***	0.107***	1									
Internal non-invention patent licenses	1.171	8.198	-0.036***	0.106***	0.110***	0.369***	0.557***	1								
External invention patent assignments	2.485	15.632	-0.035***	0.103***	0.252***	0.146***	0.150***	0.072***	1							
External non-invention patent assignments	10.330	90.574	-0.027***	0.077***	0.072***	0.118***	0.054***	0.026***	0.505***	1						
Internal invention patent assignments	2.435	18.973	-0.042***	0.150***	0.075***	0.093***	0.105***	0.046***	0.356***	0.331***	1					
Internal non-invention patent assignments	5.982	59.862	-0.040***	0.113***	0.032***	0.074***	0.083***	0.131***	0.181***	0.181***	0.786***	1				
Debt-to-asset ratio	0.503	0.193	-0.271***	0.247***	0.026***	0.055***	0.013	0.037***	0.022**	0.014	0.007	0.028***	1			
Current ratio	1.607	1.034	0.276***	-0.183***	-0.016*	-0.004	0.000	-0.015	-0.015	-0.001	-0.009	-0.017*	-0.719***	1		
Quick ratio	1.180	0.883	0.261***	-0.164***	-0.006	0.010	0.008	0.002	-0.004	0.015	0.006	-0.006	-0.707***	0.949***	1	
Gross margin	0.234	0.143	0.244***	-0.171***	-0.005	-0.022**	0.032***	0.003	0.012	-0.002	-0.000	-0.012	-0.382***	0.345***	0.359***	1

*** p<0.01, ** p<0.05, * p<0.1

5.2 Regression analysis with the Tobin's Q as the dependent variable

This section uses Tobin's Q as the dependent variable to conduct regression analysis to verify whether internal and external patent assignment and licensing have a positive impact on the Tobin's Q of the listed companies, and the significance of this effect.

5.2.1 Regression analysis of invention patent transactions

A regression analysis was carried out with the Tobin's Q as the dependent variable, and the cumulative numbers of external invention patent licenses, internal invention patent licenses, external invention patent assignments, and internal invention patent assignments as the independent variables. Regression Model 1 took the Tobin's Q as the dependent variable, and the debt-to-asset ratio, the current ratio, quick ratio, gross margin, and covid as control variables. Regression Model 2 took the Tobin's Q as the dependent variable, the debt-to-asset ratio, the current ratio, quick ratio, gross margin, and covid as control variables, and various types of invention patent transactions as independent variables. The regression results of Model 1 and 2 were presented in Table 5.2.

Table 5.2 Regression results of the Tobin's Q and invention patent transactions

Item	Regression Model 1	Regression Model 2
Intercept term	0.43***	0.38***
	(14.75)	(12.72)
Debt-to-asset ratio	-0.06	-0.08**
	(-1.55)	(-2.20)
Current ratio	0.02	0.02
	(0.73)	(1.18)
Quick ratio	0.00	-0.01
	(0.13)	(-0.87)
Gross margin	0.10***	0.09***
	(6.33)	(5.82)
Covid	0.43***	-0.14***
	(14.75)	(-23.66)
External invention patent licenses		0.13***
		(8.81)
Internal invention patent licenses		-0.08
		(-0.43)
External invention patent assignments		0.05*
		(1.88)
Internal invention patent assignments		0.09**
		(2.18)
R^2	0.13	0.13
R^2 (within)	0.08	0.11
Sample size	10292	10292
Test	F (5,9639)=87.46,p=0.00	F (9,9635)=80.88,p=0.00

* p<0.1 ** p<0.05 *** p<0.01, the value inside the parentheses represents the "t value"

In the regression analysis, Model 1 was the control variable group, and Model 2 added four invention patent transaction methods as independent variables on the basis of Model 1.

The R^2 was 0.13. For control variables, there was no significant correlation between the current ratio or quick ratio and the Tobin's Q of firms. However, a significant correlation was observed between the gross margin, debt-to-asset ratio, and covid. The gross margin had a positive impact on the Tobin's Q at a significance level of 1% (the standardized regression coefficient was 0.09, and t value was 5.82). The debt-to-asset ratio had a negative impact on the Tobin's Q at a significance level of 5% (the standardized regression coefficient was 0.08, and t value was -2.20). Covid had a negative impact on the Tobin's Q at a significance level of 1% (the standardized regression coefficient was 0-0.14, and t value was -23.66). For the independent variables, external invention licenses had a positive effect on the Tobin's Q at a significance level of 1% (the standardized regression coefficient was 0.13, and t value was 8.81). External invention assignments had a positive effect on the Tobin's Q at a significance level of 10% (the standardized regression coefficient was 0.05, and t value was 1.88). Internal invention assignments had a positive effect on the Tobin's Q at a significance level of 5% (the standardized regression coefficient was 0.09, and t value was 2.18). Internal invention licenses had no significant positive impact on the Tobin's Q.

Therefore, according to the regression results, among the hypotheses related to Tobin's Q and invention patent transactions, H1a (The Tobin's Q of the firm is positively correlated with the external invention patent assignment), H1c (The Tobin's Q of the firm is positively correlated with the external invention patent licensing), and H3b (The Tobin's Q of the firm is positively correlated with the internal invention patent assignment) were supported. However, H3c (The Tobin's Q of the firm is positively correlated with the internal invention patent licensing) was not supported.

5.2.2 Regression analysis of non-invention patent transactions

In the second regression analysis, the Tobin's Q was the dependent variable, and the external non-invention patent licenses, internal non-invention patent licenses, external non-invention patent assignments, and internal non-invention patent assignments were the independent variables. Regression Model 3 took the Tobin's Q as the dependent variable, and the debt-to-asset ratio, current ratio, quick ratio, gross margin, and covid as the control variables. Regression Model 4 took the Tobin's Q as the dependent variable, the debt-to-asset ratio, current ratio, quick ratio, gross margin, and covid as the control variables, and various types of non-invention patent transaction behaviors as the independent variables. The regression results were presented in Table 5.3.

Table 5.3 Regression results of the Tobin's Q and non-invention patent transaction behaviors

Item	Regression Model 3	Regression Model 4
Intercept term	0.43***	0.38***
	(14.75)	(12.72)
Debt-to-asset ratio	-0.06	-0.08**
	(-1.55)	(-2.20)
Current ratio	0.02	0.02
	(0.73)	(1.18)
Quick ration	0.00	-0.01
	(0.13)	(-0.87)
Gross margin	0.10***	0.09***
	(6.33)	(5.82)
Covid	0.43***	-0.14***
	(14.75)	(-23.66)
External non-invention patent licenses		0.13***
		(5.50)
Internal non-invention patent licenses		0.03
		(0.38)
External non-invention patent assignments		0.07***
		(4.84)
Internal non-invention patent assignments		0.03
		(0.92)
R^2	0.13	0.13
R^2 (within)	0.08	0.10
Sample size	10292	10292
Test	F (5,9639)=87.46, p=0.00	F (9,9635)=72.16, p=0.00

In this regression, Model 3 was the control variables group, and the correlation between control variables and the Tobin's Q was measured. The R^2 was 0.13. Since the impact of patent transactions was not considered, this was similar to the regression results in Model 1. For the control variables in Model 4, there was no significant correlation between the current ratio or quick ratio and the Tobin's Q. The gross margin had a positive impact on the Tobin's Q at a significance level of 1% (the standardized regression coefficient was 0.09, and t value was 5.82). The debt-to-asset ratio had a negative impact on the Tobin's Q at a significance level of 5% (the standardized regression coefficient was 0.08, and t value was -2.2). Covid had a negative impact on the Tobin's Q at a significance level of 1% (t value was -23.66). The regression results showed that the gross margin had a significant positive impact on the Tobin's Q of firms, while the debt-to-asset ratio and covid had negative impacts on the Tobin's Q.

On the basis of Regression Model 3, Regression Model 4 added four types of non-invention patent transactions as independent variables, namely, the external non-invention patent licenses, internal non-invention patent licenses, external non-invention patent assignments, and internal non-invention patent assignments. The R^2 was 0.13. For the independent variables, the cumulative number of external non-invention patent licenses had a

positive impact on the Tobin's Q at a significance level of 1% (the standardized regression coefficient was 0.13, and t value was 5.5). The cumulative number of external non-invention patent assignments had a positive impact on the Tobin's Q at a significance level of 1% (the standardized regression coefficient was 0.07, and t value was 4.84). The regression results of Regression Model 4 showed that external non-invention patent transactions including both assignment and licensing could improve the Tobin's Q of firms, while no significance was observed for internal transactions.

Therefore, according to the regression results, among the hypotheses concerning the Tobin's Q and non-invention patent transactions, H1b (The Tobin's Q of the firm is positively correlated with the external non-invention assignment, and H1d (The Tobin's Q of the firm is positively correlated with the external non-invention patent licensing) were supported.

As shown in Table 5.2 and Table 5.3, the regression results of external invention transactions and the Tobin's Q are more significant, indicating that both assigned and licensed external invention patent knowledge could improve the Tobin's Q, which further enhanced the firm performance.

5.3 Regression analysis with operating revenue as the dependent variable

This section conducts regression analysis with the operating revenue as the dependent variable to test whether there is a positive effect of internal and external patent assignment and licensing on the operating revenue of the listed companies, and the significance of such effects.

5.3.1 Regression analysis of invention patent transactions

In the regression analysis with the operating revenue as the dependent variable, the regression model was also established from the two dimensions of patent assignment and licensing to draw the regression results. Firstly, regression analysis was conducted from the perspective of invention patent transactions. The results were obtained based on Regression Model 5 and 6 by introducing the group of control variables as shown in Table 5.4.

Table 5.4 Regression results of the operating revenue and invention patent transactions

Item	Regression Model 5	Regression Model 6
Intercept term	10.74***	10.61***
	(307.98)	(327.63)
Debt-to-asset ratio	0.32***	0.27***
	(7.21)	(6.88)
Current ratio	0.02	0.04
	(0.60)	(1.63)
Quick ration	0.07***	0.03
	(3.32)	(1.47)
Gross margin	-0.00	-0.02
	(-0.19)	(-1.18)
Covid	0.17***	0.10***
	(26.15)	(18.49)
External invention patent licenses		0.21***
		(14.12)
Internal invention patent licenses		0.92***
		(4.60)
External invention patent assignments		0.22***
		(7.72)
Internal invention patent assignments		0.16***
		(4.27)
R^2	0.11	0.17
R^2 (within)	0.21	0.39
Sample size	10505	10505
Test	F (5,9852)=156.44,p=0.00	F (9,9848)=105.38,p=0.00

Model 5 was the control variables group, and Model 6 added four invention patent transaction behaviors as independent variables on the basis of Model 5. The model fit (R^2) was 0.17. In the control variables, the current ratio, quick ratio, and gross margin did not show significant correlations with the operating revenue, while debt-to-asset ratio and covid showed a significant correlation. The debt-to-asset ratio had a positive effect on the operating revenue at a significance level of 1%, where the standardized regression coefficient was 0.27 and the t-value was 6.88. Meanwhile, covid had a positive effect on the operating revenue at a significance level of 1%, where the standardized regression coefficient was 0.1 and the t-value was 18.49.

The four behaviors all had positive impacts on the operating revenue. Among them, external invention licenses had a positive effect on the operating revenue at a significance level of 1%, with a standardized regression coefficient of 0.21 and a t-value of 14.12. Internal invention licenses had a positive effect on the operating revenue at a significance level of 1%, with a standardized regression coefficient of 0.92 and a t-value of 4.6. External invention assignments had a positive effect on the operating revenue at a significance level of 1%, with a standardized regression coefficient of 0.22 and a t-value of 7.72. Internal invention assignments had a positive effect on the operating revenue at a significance level of 1%, with

a standardized regression coefficient of 0.16 and a t-value of 4.27. Regression results of Model 6 showed that absorption of invention patients, from both external and internal through both licensing and assignment of the listed companies could increase the operating revenue.

Therefore, according to the regression results, for the hypotheses related to the operating revenue and invention patent transaction, H2a (The operating revenue of the firm is positively correlated with external invention patent assignment), H2c (The operating revenue of the firm is positively correlated with external invention patent licensing), H4a (The operating revenue of the firm is positively correlated with the internal invention patent assignment), and H4c (The operating revenue of the firm is positively correlated with the internal invention patent licensing) were all supported.

5.3.2 Regression analysis of non-invention patent transactions

This regression analysis was conducted from the perspective of non-invention patent transactions, and the regression analysis results were obtained based on Regression Model 7 and 8 by introducing the group of control variables as shown in Table 5.5.

Table 5.5 Regression results of the operating revenue and non-invention patent transactions

Item	Regression Model 7	Regression Model 8
Intercept term	10.74***	0.25***
	(307.98)	(6.27)
Debt-to-asset ratio	0.32***	0.04*
	(7.21)	(1.77)
Current ratio	0.02	0.03
	(0.60)	(1.42)
Quick ration	0.07***	-0.02
	(3.32)	(-0.90)
Gross margin	-0.00	0.11***
	(-0.19)	(18.71)
Covid	0.17***	0.25***
	(26.15)	(6.27)
External non-invention patent licenses		0.17***
		(7.52)
Internal non-invention patent licenses		0.57***
		(6.50)
External non-invention patent assignments		0.15***
		(10.79)
Internal non-invention patent assignments		0.12***
		(4.40)
R^2	0.11	0.15
R^2 (within)	0.21	0.37
Sample size	10505	10505
Test	F (5,9852)=156.44,p=0.00	F (9,9848)=102.54,p=0.00

As the control variables group, Model 7 measured the correlation between the control variables and the operating revenue of the firm. The R^2 was 0.11. For control variables, there was no significant correlation between the current ratio or gross margin and the operating

revenue. The debt-to-asset ratio had a positive impact on the operating revenue of firms at a significance level of 1% (the standardized regression coefficient was 0.32, and t value was 7.21). The quick ratio had a positive impact on the operating revenue at a significance level of 1% (the standardized regression coefficient was 0.07, and t value was 3.32). Covid had a positive impact on the operating revenue at a significance level of 1% (the standardized regression coefficient was 0.17, and t value was 26.15).

Model 8 added the cumulative numbers of external non-invention patent licenses, internal non-invention patent licenses, external non-invention patent assignments, and internal non-invention patent assignments as independent variables on the basis of Model 7, and the R^2 was 0.15. Among the independent variables, external non-invention patent licenses had a positive impact on the operating revenue at a significance level of 1% (the standardized regression coefficient was 0.17, and t-value was 7.52). Internal non-invention patent licenses had a positive impact on the operating revenue at a significance level of 1% (the standardized regression coefficient was 0.057, and t-value was 6.5). External non-invention patent assignments had a positive impact on the operating revenue at a significance level of 1% (the standardized regression coefficient was 0.15, and t-value was 10.79). Internal non-invention patent assignments had a positive effect on the operating revenue at a significance level of 1% (the standardized regression coefficient was 0.12, and t-value was 4.4). Results of Model 8 showed that whether external or internal, licensing or assignment, knowledge absorption of non-invention patents could increase the operating revenue of the listed companies.

Therefore, according to the regression results, among the hypotheses related to the operating revenue and non-invention patent transactions, H2b (The operating revenue of the firm is positively correlated with external non-invention patent assignment), H2d (The operating revenue of the firm is positively correlated with external non-invention patent licensing), H4b (The operating revenue of the firm is positively correlated with the internal non-invention patent assignment), and H4d (The operating revenue of the firm is positively correlated with the internal non-invention patent licensing) were all supported.

5.4 Review of regression results

In total, 16 regression results shown in Tables 5.6 were obtained from the regression analysis of the Tobin's Q and the operating revenue. First, in terms of the source of patents, the impact of knowledge absorption through external patent transactions by the listed companies on firm performance was more significant than that through internal patent transactions. Specifically,

among the eight regression results for external and internal patent transactions, all external transactions showed a significant positive effect on firm performance, while five of the internal transactions showed a significant positive relationship. Second, in terms of patent transaction methods, among the eight regression results of patent assignment and the eight results of licensing, seven of the patent assignment showed a significant positive effect, while six of the patent licensing showed a significant positive relationship. Third, with respect to the types of patents being traded, among the eight regression results for invention patents and the eight results for non-invention patents, seven of invention patents showed a significant positive effect, while six of non-invention patents showed a positive effect.

Table 5.6 Review of regression results

Firm performance			Operating revenue	Tobin's Q
Invention	External	Assignment	Significantly positive	Significantly positive
		Licensing	Significantly positive	Significantly positive
	Internal	Assignment	Significantly positive	Significantly positive
		Licensing	Significantly positive	
Non-invention	External	Assignment	Significantly positive	Significantly positive
		Licensing	Significantly positive	Significantly positive
	Internal	Assignment	Significantly positive	
		Licensing	Significantly positive	

Therefore, as a whole, most types of patent transactions had a positive impact on the operating revenue and Tobin's Q of the listed companies.

Further, as the operating revenue is the actual revenue of the listed company, excluding the interference from market factors in Tobin's Q regression, a deeper exploration into the analysis results with the operating revenue as the dependent variable, such as comparing the positivity or negativity and the magnitude of the regression coefficients, can more profoundly reveal the impact of patent transactions on firm performance, thus more clearly addressing the research questions posed in Chapter 1.

First, the regression coefficient for external invention licensing was 0.21, slightly less than the 0.22 for external invention assignment. The coefficient for internal invention licensing was 0.92, larger than the 0.16 for internal invention assignment. The coefficient for external non-invention licensing was 0.17, while that for the corresponding assignment was 0.15. The internal non-invention licensing had a coefficient of 0.57 while that for the assignment was 0.12. Except for the slightly weaker positive impact of external invention licensing on operating revenue compared to external invention assignment, in other scenarios, licensing had a stronger positive impact on operating revenue than assignment. Compared to patent assignment, patent licensing had a more positive effect on firm performance.explain

Second, the regression coefficient for external invention licensing (0.21) was greater than

that for external non-invention licensing (0.17). The coefficient for external invention assignment (0.22) surpassed that for external non-invention assignment (0.15). The coefficient for internal invention licensing (0.92) was larger than that for internal non-invention licensing (0.57), and the coefficient for internal invention assignment (0.16) exceeded that for internal non-invention assignment (0.12). All the coefficients for invention were greater than those for non-invention, indicating that invention patent transactions have a more positive impact on firm performance compared to non-invention patent transactions.

Third, the coefficient for external invention licensing (0.21) was smaller than that for internal invention licensing (0.92), but the coefficient for external invention assignment (0.22) was more than that for internal invention assignment (0.16). The coefficient for external non-invention licensing (0.17) was smaller than that for internal non-invention licensing (0.57), yet the coefficient for external non-invention assignment (0.15) exceeded that for internal non-invention assignment (0.12). There was no clear pattern in the relations of regression coefficients between external and internal transactions, suggesting that from an operating revenue perspective, it is inconclusive as to which type of patent transaction, internal or external, has a more positive effect on firm performance. In summary, for the recepient company, patent licensing is more beneficial to performance than assignment, and invention patent transactions have a more positive effect than non-invention patent transactions.

5.5 Robustness testing of regression analysis

To ensure the robustness of the results for the Tobin's Q and operating revenue, the following tests were also conducted in this thesis and all the results are presented in Table 5.7 and 5.8.

There are multiple calculation methods regarding Tobin's Q which will result in different values (Lewellen & Badrinath, 1997). Different formulas may affect the significance of the regression results. The Tobin's Q (market capitalization / total assets) was used in the above discussions. Therefore, in order to test the robustness of the regression results, Tobin's Q-B (market capitalization A / (total assets - net intangible assets)) was chosen as a proxy for the operating efficiency in this section.

Table 5.7 presented the regression results after using Tobin's Q-B as a proxy for Tobin's Q. The regression results showed that the significance was consistent with that presented in Tables 5.2 and 5.3, i.e., for invention patents, external invention licensing, external invention assignment, and internal invention assignment all improved firm performance. For non-invention patents, only external patent transactions for knowledge absorption had a significant

effect on the improvement of the Tobin's Q.

Table 5.7 Robustness testing results of the Tobin's Q

Model 9		Model 10	
Intercept term	0.426*** (13.521)	Intercept term	0.434*** (13.870)
Debt-to-asset ratio	-0.118*** (-3.127)	Debt-to-asset ratio	-0.123*** (-3.249)
Current ratio	-0.011 (-0.516)	Current ratio	-0.010 (-0.437)
Quick ration	-0.002 (-0.089)	Quick ration	-0.001 (-0.073)
Gross margin	0.101*** (6.604)	Gross margin	0.107*** (7.040)
Covid	-0.128*** (-21.568)	Covid	-0.124*** (-20.780)
External invention patent licenses	0.144*** (9.688)	External non-invention patent licenses	0.132*** (5.702)
Internal invention patent licenses	-0.060 (-0.326)	Internal non-invention patent licenses	0.059 (0.743)
External invention patent assignments	0.100*** (3.366)	External non-invention patent assignments	0.100*** (6.600)
Internal invention patent assignments	0.105** (2.447)	Internal non-invention patent assignments	0.032 (1.039)
R^2	0.127	R^2	0.126
R^2 (within)	0.103	R^2 (within)	0.096
Sample size	10292	Sample size	10292
Test	F (9,9635)=72.548,p=0.000	Test	F (9,9635)=64.014,p=0.000

Table 5.8 presents the LnAsset of the firm as a proxy for the operating revenue in order to perform robustness testing. The regression results showed that the significance was consistent with those presented in Table 5.4 and 5.5, i.e., when patent transaction was done through licensing or assignment, there was a significant positive effect on the LnAsset, whether external or internal, invention or non-invention.

Table 5.8 Robustness testing results for the operating revenue

Model 7		Model 8	
Intercept term	7.090*** (691.916)	Intercept term	7.092*** (849.054)
Debt-to-asset ratio	0.110*** (8.368)	Debt-to-asset ratio	0.091*** (8.482)
Current ratio	-0.014* (-1.846)	Current ratio	-0.004 (-0.477)
Quick ration	0.015*** (2.605)	Quick ration	0.021*** (3.858)
Gross margin	0.006 (1.093)	Gross margin	0.019*** (4.075)
Covid	0.047*** (31.229)	Covid	0.046*** (32.376)
External invention patent licenses	0.000** (1.973)	External non-invention patent licenses	0.001*** (5.592)
Internal invention patent licenses	0.002** (2.446)	Internal non-invention patent licenses	0.000** (1.998)
External invention patent assignments	0.000 (0.283)	External non-invention patent assignments	0.000* (1.892)
Internal invention patent assignments	0.000*** (3.605)	Internal non-invention patent assignments	0.000* (1.657)
R^2	0.204	R^2	0.162
R^2 (within)	0.238	R^2 (within)	0.306
Sample size	10505	Sample size	10505
Test	F (9,10495)=164.933,p=0.000	Test	F (9,9848)=154.017,p=0.000

In this section, the regression results were tested for robustness by means of proxies. As illustrated in Table 5.9, the regression results in both Table 5.7 and 5.8 were consistent in the significance. The significant levels were basically the same. Therefore, the results of the empirical analysis of this thesis are robust.

Table 5.9 Comparison of the robustness analysis results

Firm performance			Operating revenue	Tobin's Q
Invention	External	Assignment	Significantly positive	Significantly positive
		Licensing	Significantly positive	Significantly positive
	Internal	Assignment	Significantly positive	Significantly positive
		Licensing	Significantly positive	
Non-invention	External	Assignment	Significantly positive	Significantly positive
		Licensing	Significantly positive	Significantly positive
	Internal	Assignment	Significantly positive	
		Licensing	Significantly positive	

5.6 Suggestions for patent transactions based on the empirical study

The empirical analysis results indicate that most patent transactions have a significant positive impact on firm performance, and that no patent transaction has a negative impact on firm

performance. Based on the research results in terms of transaction quality, scope, and mode, we put forward the following suggestions for firms and the government. Firms can increase R&D efforts, improve the quality of patent applications and transactions, and cultivate high-value patents, with a focus on the application and transaction of invention patents; they are encouraged to seek external patent transaction opportunities and join the patent pool; they are also suggested to actively participate in patent cross-licensing and improve their performance through professional alliances such as patent pool. The government can actively encourage cross-enterprise invention patent transactions with a focus on the quality, mode, and scope of patent transactions, thus promoting economic growth.

5.6.1 Implications and suggestions for firms based on the regression results

Patent transactions means that through the patent transaction market, firms adopt appropriate transaction modes considering factors such as the status of the technological sector, their knowledge base, and human resources in order to better benefit from the patent transaction behavior, thus effectively improving their performance. From the perspective of the recipient, firms can formulate patent transaction strategies in various ways. To be more specific, developing patent transaction strategies from the following aspects may help firms improve performance through patent transactions.

Since external patent transactions can positively impact firm performance, firms shall actively engage in external patent transactions to obtain differentiated core technologies. In the era of the knowledge economy and globalization, knowledge has become an important strategic resource for firms' development. Patents are a kind of explicit knowledge. This thesis verified the positive impact of patent transactions on firm performance through an empirical study. Various forms of patent transactions, including assignment and licensing of invention and non-invention patents, can exert a favorable influence on a firm's overall performance. Moreover, compared to internal patent transactions, external patent transactions can have a more significant positive impact on firm performance. Firms can engage in patent transactions through a multitude of channels, such as technology markets, patent trade exhibitions, and patent open licence, as mechanisms to access patented technologies. To facilitate such patent transactions, reduce associated transactional costs, and enhance the probability of successful outcomes, firms must establish internal systems and mechanisms that are conducive to patent trading. This may entail the appointment of a dedicated patent transaction manager, responsible for regularly aggregating industry-specific technical data, patent information, patent transaction records, and patent open licence data. This comprehensive approach serves to mitigate information-related costs while enabling firms to

formulate transactional agreements, devise pricing strategies, and engage in negotiations with patentees, ultimately increasing the success rate of these transactions.

Furthermore, firms can actively enhance their performance by participating in patent transactions through the establishment of patent strategic alliances. This strategic approach enables firms to forge closer collaborative ties with patentees, facilitating the exchange and acquisition of patented technologies. Such an alliance is based on the development needs of firms and the common interests of all members. Firms, universities, research institutions or other bodies form a cooperative organization based on certain rules through contracts. Members can cross-license patented technologies, draw from each other's strengths, and improve their competitiveness in the industry. Hence, within patent strategic alliances, patent licensing serves as the primary mode of transactions for patents. The patent strategic alliance is a new type of intellectual property strategic organization under the market economy. It can bring together many technical fields, integrate the technical advantages of all parties, break down the technical barriers of the industry, and reduce the phenomenon of the "tragedy of the anticommons" caused by patent thickets (X. Zhu, 2019). Taking the computer industry as an example, the computer industry includes technical fields such as scientific computing, data processing, auxiliary technology, artificial intelligence, and network applications. Patent alliances can gather technological advantages in these fields. Through patent strategic alliances and patent pools, firms can obtain patented technology at a lower cost and be more competitive. Against economic globalization, firms can no longer adapt to the development of the times by just standing alone. Only by joint development, resource sharing and advantages complementing can they win a place in the market.

Compared to non-invention patents, the transaction of invention patents has a more significant positive impact on firm performance. Therefore, firms should attach great importance to technological innovation and actively incubate high-value invention patents. In the era of knowledge-based economic growth driven by innovation, having core technology and intellectual property rights plays a pivotal role for firms in navigating complex market landscapes and bolstering their industrial competitiveness. Research and development of technology serve as the wellspring of progress for businesses and the cornerstone of their technological prowess. It not only fosters innovation and knowledge creation but also elevates a firm's technological capabilities, thereby securing a competitive edge. While many firms excel in innovating their business models, their strength in original technological innovation often falls short. As economic globalization continues to evolve, there are formidable barriers and monopolies when it comes to technology acquisition and imitation. Firms that have long

relied on technology imports not only diminish their capacity for autonomous innovation but also risk getting caught in the unfavorable cycle of perpetual "reimportation", which hinders sustainable development. This is particularly true in technology-intensive industries, where firms must accumulate technological advantages to enhance their economic competitiveness. At present, global economic growth is sluggish and marked by significant uncertainty. To better navigate the ever more intricate market environment, firms can intensify their efforts in technology research and development, amass more knowledge and know-how, and build up a robust patent portfolio.

During their business operations, firms are involved in ongoing R&D activities. The continuous R&D endeavors result in the accumulation of substantial technical knowledge. However, this accumulated knowledge becomes advantageous in patent transactions only when it is converted into patents. The results of our empirical study indicate that compared to non-invention patents, invention patent transactions have a more significant positive impact on firm performance. Therefore, while engaging in R&D activities, firms should file patent applications promptly for their research outcomes, cultivate high-value patents, and pay special attention to the application and transaction of intention patents, thereby creating a substantial patent portfolio. The process of production and operation is often accompanied by R&D activities. Continuous R&D activities can generate considerable patents. The accumulation of patents, especially invention patents, can effectively increase the voice of firms in patent transactions and help firms win more opportunities of cross-licensing of patents, thereby reducing the patent transaction costs and improving firm performance.

First of all, firms should prioritize R&D activities, view technological innovation as the key to its sustainable competitiveness, provide reliable manpower, financial and resource support for R&D activities, and establish effective and reliable mechanisms to ensure that R&D activities can be timely and effectively translated into research results which help formulate technical documents. Firms should also establish a complete patent filing system to transform the R&D results into patents with a dedicated individual or department responsible for tasks such as patent technology exploration, patent application strategy, and patent application outsourcing. Finally, firms also need to establish a reliable patent management system, pay annual fees for acquired patents in a timely manner, avoid patent expiration, and abandon patents that no longer have market value to reduce the maintenance costs.

Compared to patent assignment, patent licensing has a more significant positive impact on firm performance. Therefore, firms should actively join industry and technology to engage in patent cross-licensing and lower licensing barriers. As the innovation-driven development

strategy is being further implemented, the transformation of technological achievements, with patents as a representative, is becoming increasingly common between firms, as well as between research institutes and firms. This has led to the emergence of a patent transaction market. During the development of this market, the unique nature of patents and the diversity of transaction methods have made the transactions complex. Factors such as patent characteristics, transaction teams, policy terms, and legal risks have contributed to the challenges in conducting patent transactions, resulting in frequent disputes and substantial economic losses for both parties involved. The results of our empirical study indicate that compared to patent assignment, patent licensing has a more significant positive effect on the performance of listed companies. Therefore, firms can build dedicated teams for patent transactions, actively engage in patent cross-licensing, and participate in technology alliances such as patent pools to improve their performance.

Evaluating the value of patents, which are the subject of these transactions, is a complex task. Currently, common methods for valuing patents include the cost method, market method, and income method. However, accurately determining the price of such intangible assets is often challenging, and it usually requires multiple rounds of negotiations between the parties engaged in patent transactions to arrive at a final price. Due to the intricate nature of patent transactions, many firms and research institutes opt to utilize patent brokers to facilitate these transactions. Patent brokers serve as intermediaries, enabling transactions between buyers and sellers. They do not engage in technical research and development or handle patent application matters. Patent brokers play a vital role in patent transactions by connecting supply and demand, making transactions possible between previously unconnected parties, and reducing search and transaction costs for both sellers and buyers. The importance of patent brokers in the technology market is multifaceted. They not only establish connections among previously unrelated parties but also enhance the value of patent transactions by offering a wide range of services. In addition to patent brokers, firms can also manage patent searches and negotiations, and complete transactions through internal specialized departments.

The object of patent transaction is an intangible asset. Since there is no physical object in patent transaction, it is difficult for both parties to reach agreement on the price and method. This is where a professional team steps in to fight for an advantageous position for the firm in patent transaction. However, patent transaction talents need to have interdisciplinary knowledge about patent, law, and economy. Firms often desperately lack such talents. At present, the vast majority of intellectual property talents are trained by universities and research institutions, while firms have not been given sufficient attention to the talent training

system due to their limited education and training capabilities.

Talent training by firms is different from that by university, with the former emphasizing more on practical capabilities. Costs are also considered in the training process. In order to build a professional team that better suits the firm's situation, the following approaches can be considered. Firstly, firms can carry out targeted training in light of the professional background of the personnel. For example, staff with a professional background of economics can be trained with a focus on patent valuation ability. Secondly, a joint training mechanism between universities and firms can be established. The strategic cooperation between universities and firms can be deepened. A new mechanism for training talents can be developed by combining the strengths of the industry, university and research community, which can provide employees with cutting-edge knowledge and opportunities to improve practical ability, and cultivate the practical talents urgently needed by firms. Lastly, firms can strengthen on-the-job training, select in-service employees with a specialist background and willingness to grow for training on patent transaction abilities, innovate the teaching methods according to different categories and levels of talents, adopt experimental and innovative teaching, and set up corresponding practical curriculum, so as to strengthen skills training of talents and improve their practical ability.

5.6.2 Implications and suggestions for patent transaction policies based on the regression results

It is a well-established measure for the government to facilitate the development of the industry through corresponding policies for macro-control. By formulating corresponding policies to encourage patent transaction and improve the market environment, the government can facilitate the positive role of patent transaction in improving performance of the recipient firms, thus promoting economic growth.

Since patent transactions have a significant impact on the performance of listed companies, the government should further enhance patent protection to provide legal guarantee for the ultimate value realization of patent transactions. Patent rights are a form of exclusive rights granted to inventors for their creations within a certain period. During the patent protection term, others are not allowed to use the invention or patent for commercial purposes without the consent of the patentee. The primary reason for the government to grant patent protection is to stimulate innovation. Patents provide inventors with temporary monopolies, allowing them to gain greater returns from their innovations than their investments. This further motivates individuals or businesses to invest in research and development. Different countries vary in their patent protection systems. The establishment of

such a system requires considering factors such as legal applicability and judicial practices. It aims to create protection policies that align with current economic development and foster a better business environment for patent transactions.

Patent protection is a prerequisite for patent transactions. Although China's Patent Law has undergone four revisions and patent protection has become more comprehensive, there still exists a significant gap when compared to the patent protection systems in developed countries. This is primarily reflected in the lower cost of patent infringement, the lower compensation for patent rights infringement, difficulties in providing evidence, and long litigation periods. All of these factors can reduce the motivation of firms to participate in patent transactions. Patent protection can be carried out through a combination of administrative and judicial protection, bringing into play the characteristics of different protection methods so as to ensure the interests of research and development entities to the greatest extent possible, thereby improving the market environment for patent transactions and removing obstacles for firms to participate in patent transactions.

Administrative protection of patents has the characteristics of timely response, flexible punishment and proper protection, especially being able to deal with infringement acts quickly, thus safeguarding the interests of patentees and avoiding the problems of difficulty in providing evidence and long litigation periods. Judicial protection has the characteristics of strong authority and high credibility, which is especially suitable for handling important cases in patent infringement, thus mitigating the issue of low losts of patent infringement.

Further optimizing the allocation of software and hardware resources required for patent transactions and reducing transaction costs and barriers to significantly increase the volume of invention patent transactions. Since invention patent transactions have a more significant positive impact on firms than those of non-invention patents, the government can create a patent transaction platform to actively guide enterprises in conducting invention patent transactions. Patent is an intangible asset with great uncertainty in its technical, market and legal value, and patent buyers and sellers usually negotiate under great uncertainty. The asymmetry of information, the inability to assess the value of patents, and the lack of circulation in the patent market bring higher transaction costs and more difficulties to patent transactions. The inefficient and illiquid patent transaction market results in long cycles and unstable prices of patent transactions. The patent market often lacks liquidity and efficiency for several reasons. Firstly, the valuation of patents is more challenging compared to most other commodities. This difficulty does not solely stem from patents being intangible assets, as other intangible assets like brands can usually be valued. What makes patents unique is that

each one is inherently distinct in its definition, making them lack "comparability". In many markets, comparability plays a crucial role in assessing the value of specific assets. Secondly, both parties involved in the patent market face significant search costs. For patentees, the cost of identifying all current and potential users can be prohibitively high. Similarly, potential patent buyers or users find it challenging to identify all patented technology providers, especially when their products are complex and reliant on rapidly evolving technology. This becomes even more daunting when they need to identify all potential technology providers within a short timeframe.

Patented technology only becomes a driving force for economic growth when it is translated into actual productivity. In order to further promote patent transformation, increase technological output, and enhance the core competitiveness of both the nation and enterprises, the State Council proposed in the *14th Five-Year Plan for the Protection and Application of Intellectual Property Rights* to foster the development of a comprehensive intellectual property operation service platform, promote the transformation of intellectual property, and build a professional patent transaction platform to reduce patent search costs and speed up patent transactions. Driven by national policies and development initiatives, patent trading platforms have emerged. The role of the platforms is to facilitate the transformation of innovative outcomes, maximize the utilization of these innovations, and leverage internet technologies to provide users with comprehensive patent trading services.

Patent transaction platform is a third-party platform that provides transaction guarantee and systematic services for both buyers and sellers. Such a platform needs to be down-to-earth and market demand-oriented, integrate the high-value patent resources of universities, research institutions, and businesses, build a new patent transaction model integrating "patent transaction + public platform + science and technology finance", and provide buyers and sellers with convenient, efficient and fair transaction methods. In addition to providing basic policy, transaction, finance, search, analysis, and training functions, the platform also provides guarantee for smooth transactions between buyers and sellers by introducing technology brokers, innovating patent portfolio methods, enriching patent sources, and formulating assessment methods. Patent seekers can adopt online or offline transaction methods to trade patents with organizations such as universities, enterprises, research institutions or individual patentees through the patent public information obtained from the platform. The patent transaction platform can help buyers and sellers shorten the transaction cycle, reduce information asymmetry and lower transaction costs on the basis of open information. At the same time, the patent transaction platform can also establish a credible

patent transaction center, further enhancing the vitality of the patent transaction market.

Implementing preferential policies with greater incentives and encouraging firms to form industry and technology alliances so as to cultivate patent licenses with high technological value. Patented technology is a kind of knowledge information and its object is an intangible asset. Patent transactions usually have large uncertainties and high transaction costs. The implementation of tax preferential policies can reduce the cost and uncertainty of transactions, increase the purchase intention, and promote patent transactions. Tax preference is a preferential policy to exempt or reduce the value-added tax and income tax on the income obtained from eligible patent transactions. At present, there are problems such as narrow scope of preferential policies, few local policies, and limited eligible entities. For example, tax preferential policies for patent transactions are mainly found at the national level, and there are few local tax preferential policies. Tax preferential policies for patent transactions mainly focus on VAT and income tax reduction, and the scope of is narrow. Eligible entities mainly include technology developers, and there are fewer preferential policies for technology transferees.

As a major power in economy and technology, China now has a continuously expanding patent market and increasingly active patent transactions. It is necessary to formulate better tax preferential policies to provide institutional guarantee for patent transactions, promote the transfer and transformation of patented technology results, and further promote the development of the patented technology market.

In respect of policy introduction, local governments can combine the characteristics of local industries and introduce preferential tax policies for targeted patent transactions to promote transactions of patented technology in the region. In terms of eligible entities, government can include more companies for tax preferences. The patent recipient is the key to technology transformation, and the inclusion of the patent recipient can reduce the risk and cost of its technology transaction and improve its patent purchase intention. In terms of the scope, governments can expand the scope of tax benefits. In addition to income tax preferences for technology transfer, technology development, consulting, services and other technology transactions can also be included in the scope of tax benefits and income tax deduction and exemption. In addition, individual income tax deductions and exemptions can be given to technology brokers on their government subsidies.

Taking effective regulating measures to reduce false patent transactions. This thesis took 1,538 companies listed on the Shanghai and Shenzhen Stock Exchanges as the object of study, and verified the positive impact of patent transactions on firm performance through empirical

research. However, the companies selected have certain R&D capabilities, economic strength, and reputation, whose behaviors are under the eyes of the public. Consequently, their patent transaction behaviors are more based on the real technical needs. The motive of patent transactions of some SMEs in the market, however, is not to improve performance, but to trade the certificate or to obtain government subsidies, which leads to many false patent transactions in the market.

False patent transactions will not only disrupt the patent transaction market and affect patent transactions that really need to be transformed, but also create false patent transaction data, which is not conducive to the planning and formulation of patent transaction policies by relevant government departments. In order to regulate the patent transaction market and create a world-class business environment, it is necessary to formulate precise regulatory policies for patent transactions, strengthen supervision and review, curb patent transactions that are not for the purpose of patent exploitation, and strictly review the transaction parties and patentable subject. At the same time, governments shall strengthen the monitoring and filing of patent transaction registration data such as patent assignment and licensing. Relevant local departments should handle abnormal patent transactions in a timely manner, reduce false transactions, and promote transactions of patents that really need to be transformed.

5.7 Chapter summary

In the regression analysis, we divided patent transactions by the two dimensions of patent assignment and licensing, and performed regression analysis with the Tobin's Q and operating revenue as the dependent variables respectively. The regression results helped test the eight research hypotheses. The regression results were compared and analyzed, and the conclusions of the empirical research were drawn. The results show that most types of patent transactions have a positive impact on the operating revenue and Tobin's Q of listed companies. Patent assignment and licensing have a positive effect on firm performance. Additionally, based on the regression results of operating revenue, patent licensing has a more significant positive impact on firm performance than patent assignment, and invention patent transactions have a more pronounced positive effect on firm performance compared to non-invention patent transactions. Additionally, robustness tests were conducted using Tobin's Q and the natural logarithm of total assets to validate the regression results of Tobin's Q and operating revenue. Based on these findings, this chapter also proposed corporate patent trading strategies and policy recommendations to stimulate the vitality and functionality of the patent market.

Chapter 6: Conclusions and Future Studies

Based on the discussion in the previous five chapters, this chapter will present the conclusions and research limitations and look into future studies.

6.1 Conclusions

In the first chapter, this thesis described the research background from four aspects: the knowledge economy era, patent trends in China, the status quo of patent assignment and licensing in China, and the industrialization and exploitation of patents in China. It also identified the object of study and research questions: Do patent assignment and licensing both have a positive impact on firm performance? Do invention and non-invention patents, internal and external patent transactions have different impacts on firm performance, and are there differences in the degree of this impact? This was then followed by elaborations on the research method and framework. In the second chapter, a review of the theories related to knowledge, patent and firm performance was presented to lay the theoretical foundation of the study. The review of knowledge-based perspectives covered the fundamentals of knowledge, knowledge classification, the knowledge-based theory of the firm, and theories on knowledge transfer and absorption. In the context of patent research, the review encompasses the concept and role of patents, patent assignment, patent license, and a comparative analysis of patent assignments and licenses. In terms of firm performance, the review is conducted from three perspectives: firm performance, firm performance indicators, and the relationship between patents and firm performance. On the basis of the literature review, in the third chapter, the object of study was first defined, with a focus on patent assignments and licenses conducted by companies listed on the Shenzhen Stock Exchange and the Shanghai Stock Exchange. Furthermore, it clarified four core concepts: internal and external assignments, internal and external licenses, invention patents and non-invention patents, and the quantity of assignments and licenses. The conceptual model of this study was then constructed, followed by the proposal of 16 research hypotheses from three dimensions: transaction mode, transaction scope, and patent type. Chapter 4 explained the data used in the study through data collection and descriptive statistics. Based on the detailed descriptions of sample selection, data acquisition, and variables determination, it presented the descriptive statistics of

independent variables, dependent variables, control variables, and the characteristics of patents of this study. After introducing the data, Chapter 5 discussed the empirical study with the correlation analysis, regression analysis with Tobin's Q and operating revenue as the dependent variables, a review of the regression results, the findings, and the robustness testing. On the basis of the empirical study, it proposed patent trading strategies from the perspective of firms, and policy recommendations on patent trading from the perspective of the government.

The regression analysis indicates that most types of patent transactions have a positive impact on firm performance. Detailed analysis from the perspectives of transaction scope, transaction methods, and patent types is as follows:

In terms of the scope of transaction, all the eight research hypotheses related to external patent transactions were supported, indicating that all external patents had a significant positive impact on the performance of the listed companies. Out of the eight research hypotheses for internal patent transactions, five have been supported, indicating that internal patents had a significant positive impact on the performance of these companies in only five scenarios. This suggests that, compared to internal patents, external patents have a more significant positive effect on the performance of the listed companies.

With regard to the transaction method, out of the eight research hypotheses related to patent assignment, seven have been supported. For the eight hypotheses related to patent licensing, six have been supported. The two are roughly equivalent. Combined with the analysis of regression coefficients for operating revenue, this indicates that under the same conditions, compared to patent assignment, patent licensing may have a more significant positive impact on the performance of listed companies.

From the perspective of patent type, seven out of the eight research hypotheses related to invention patents have been supported, while for the eight hypotheses concerning non-invention patents, six have been supported. Combined with the analysis of regression coefficients for operating revenue, this indicates that under the same conditions, compared to non-invention patent transactions, invention patent transactions will bring a more significant positive impact on the performance of listed companies.

6.2 Limitations and future research

The thesis examined the listed companies as a whole, and made an empirical study on the impact of patent assignment and licensing on the performance of the listed companies. In the

study of listed companies, the characteristics of different listed companies, such as the industry, scale and ownership structure of the company, were not considered, and the influence of patent assignment and licensing on different companies might be quite different. An in-depth analysis of such differences will reveal the relationship between patent transaction and firm performance in a deeper manner, so as to formulate more favorable trading strategies for different companies. On this basis, the patent transaction policies for different companies will be more targeted, which will further improve the positive impact of patent transaction on the economy. Therefore, in future studies, listed companies can be subdivided according to the industry, asset scale, and ownership structure, so as to study the influence of patent transactions on the performance of different types of listed companies and to further reveal the underlying patterns of patent transaction activities.

Moreover, this study only used the Tobin's Q and operating revenue as the dependent variables for regression analysis, without comparing to other dependent variables. Considering more dependent variables for regression analysis might help gain a deeper understanding of the impact of patent transactions on the performance of listed companies. In future research, other dependent variables can be selected for comparative analysis to further reveal the comprehensive impact of patent transactions on the performance of listed companies.

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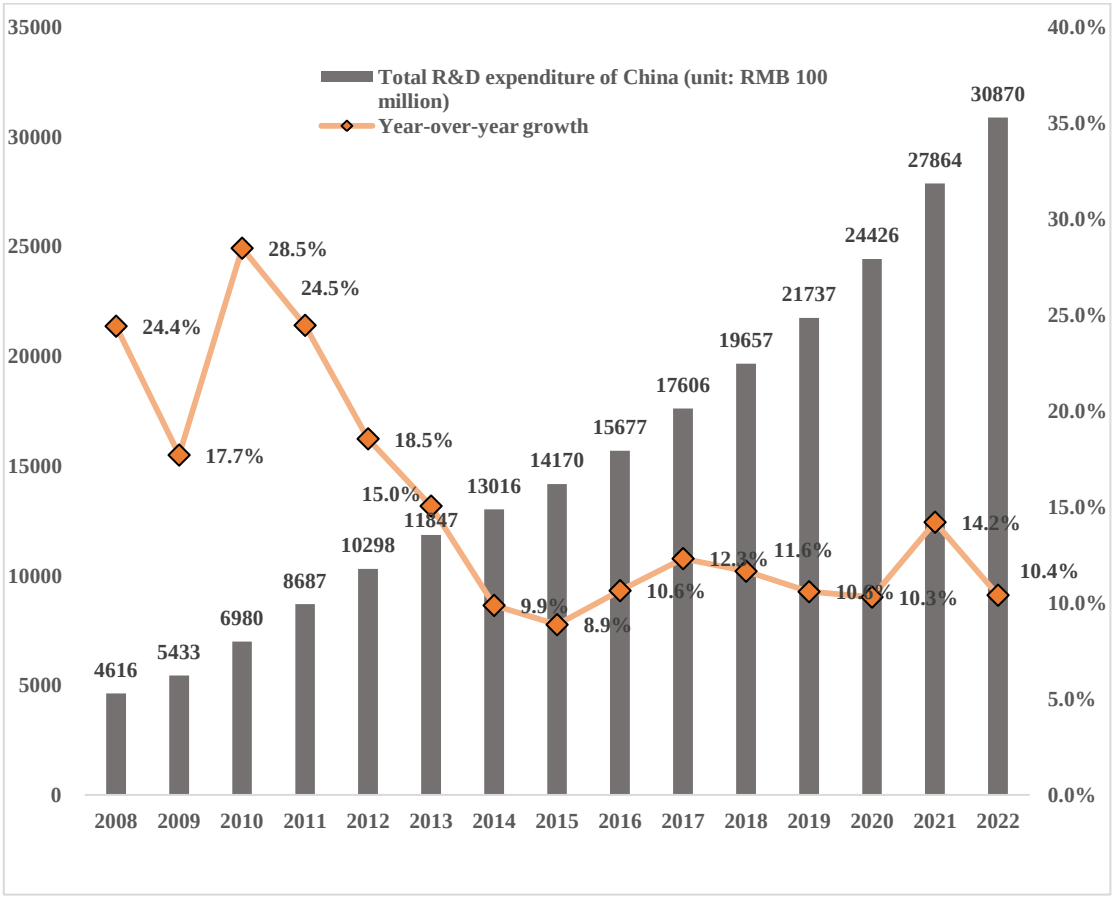
Annex

Annex Tables

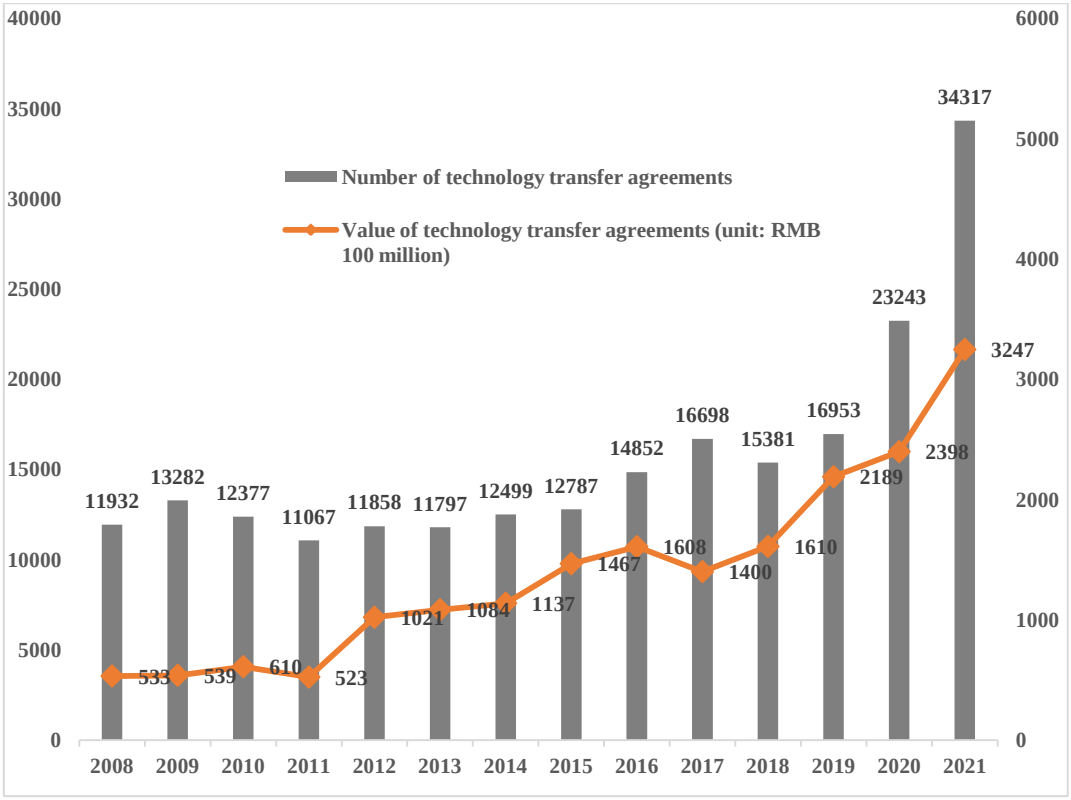
Annex Table 1 Characteristics of the three types of patents in China

Characteristics	Invention	Utility model	Design
Application	Long examination; generally two to three years; two phases: application publication and substantive examination; and difficult to be granted	Short examination; generally six to nine months; preliminary examination only; easier to be granted	Short examination; generally three to six months; preliminary examination only; easier to be granted
Object of protection	Products, methods or improved new technical solutions	New practical technical solutions from the shape and/or structure of products	New designs for industrial application created from the shape and/or pattern of products, or the combination of color, shape, and pattern
Protection term	20 years	10 years	15 years
Stability of patent rights	High	Low	Low
Technical content	High	Average	Low
Fees	High application fees, high maintenance fees	Low application fees, low maintenance fees	Low application fees, low maintenance fees

Annex Figures



Annex Figure 1 Total R&D expenditure of China, 2008-2022 (unit: 100 million)



Annex Figure 2 Technology transfer agreements in China, 2008-2021

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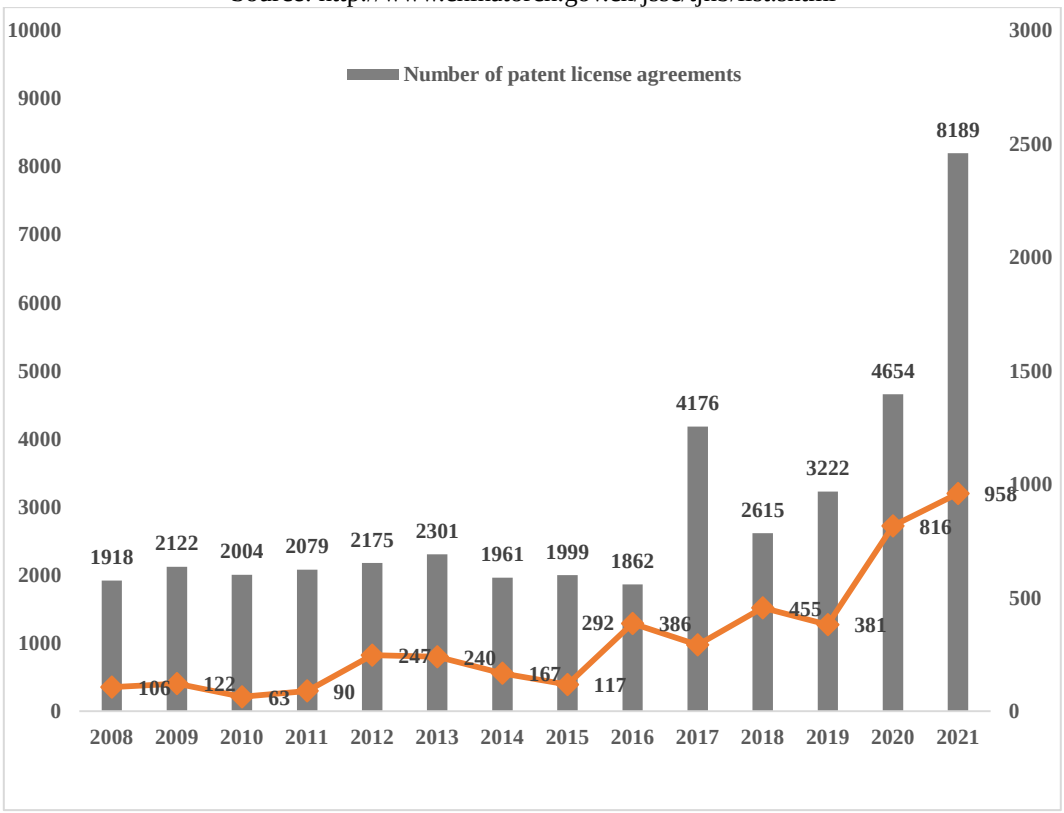

Annex Figure 3 Patent license agreements in China, 2008-2021

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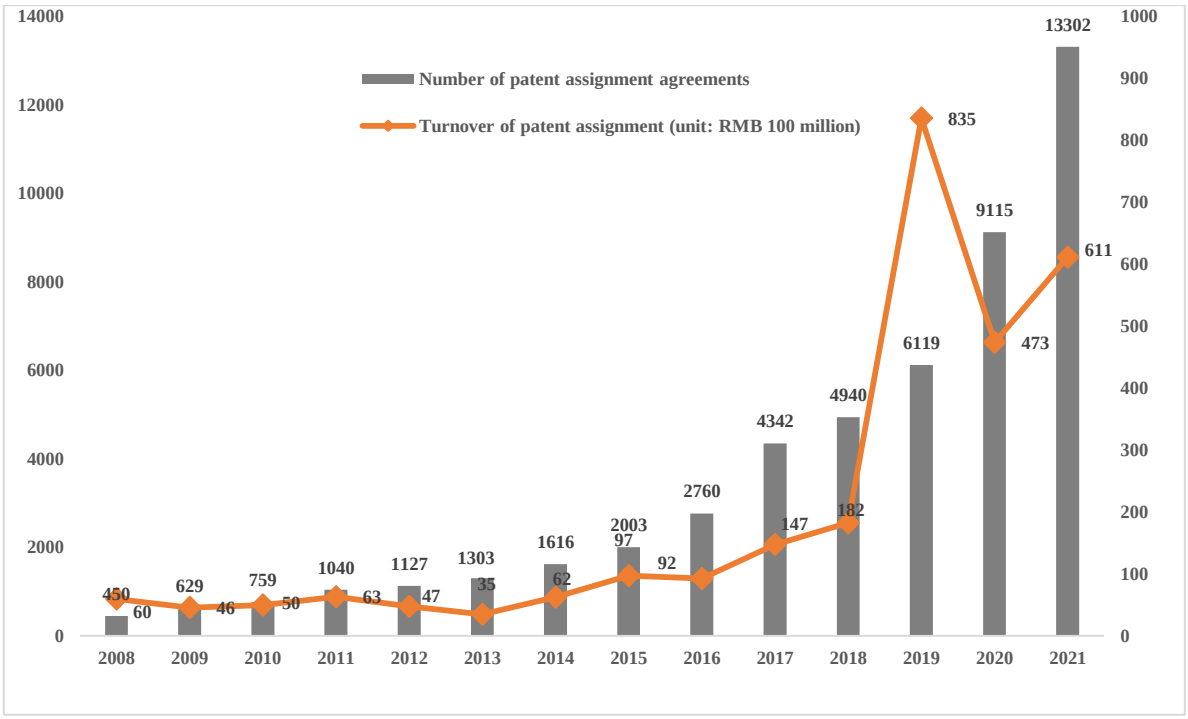
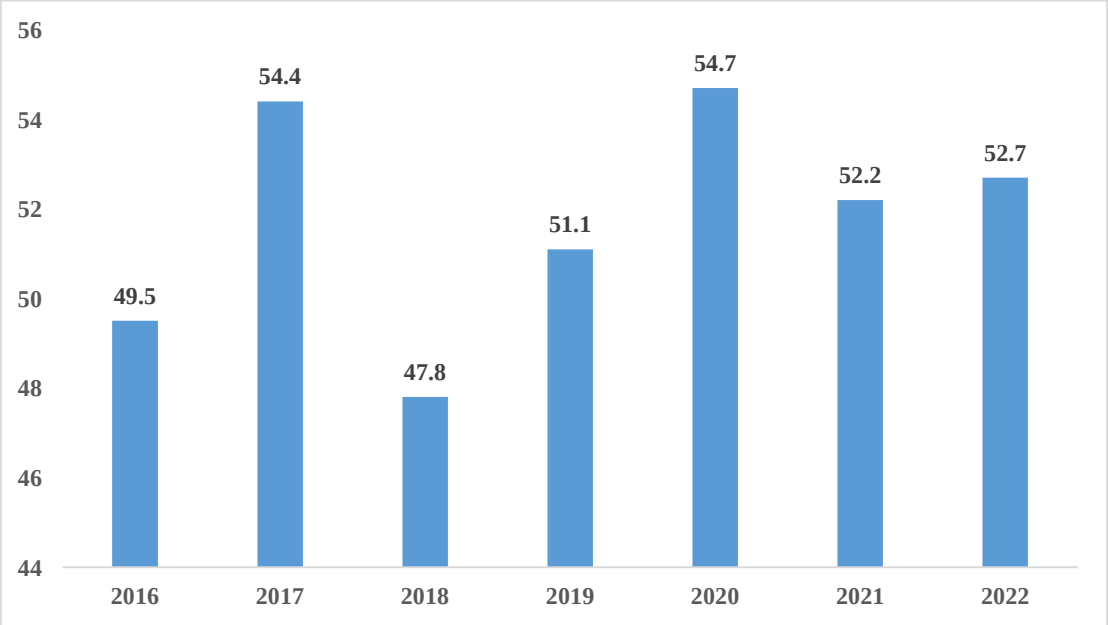
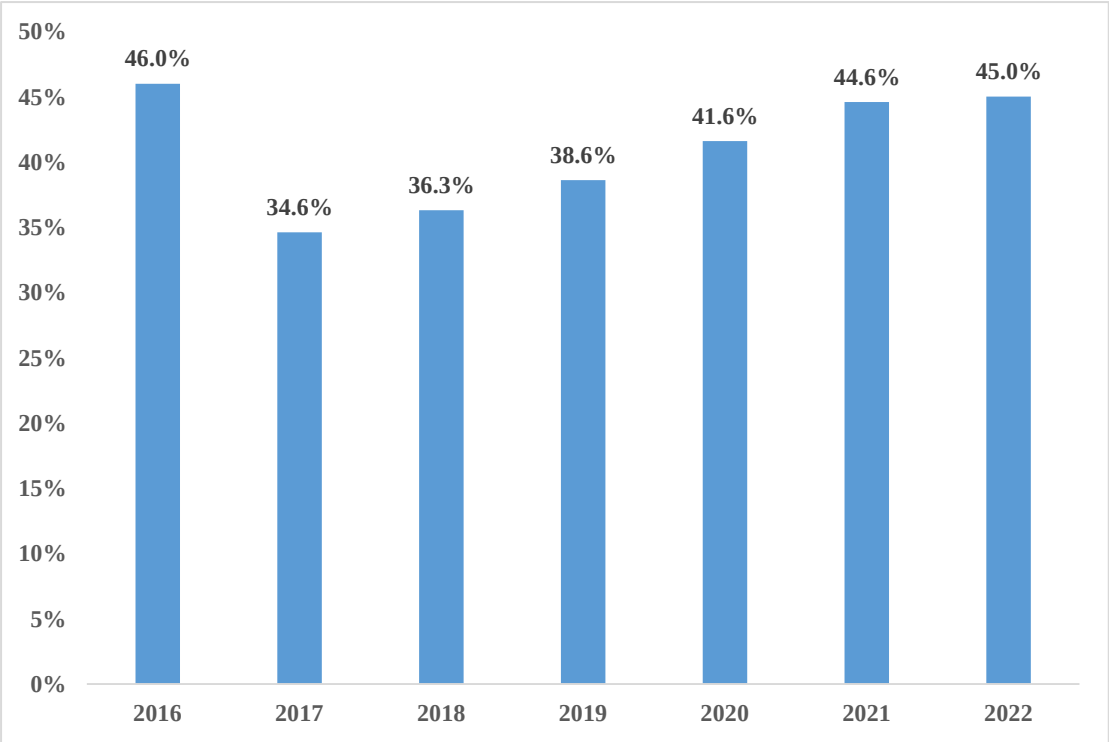


Annex Figure 4 Patent assignment agreements in China, 2008-2021



Annex Figure 5 Patent transfer and transformation index in China, 2016-2022



Annex Figure 6 Patent industrialization rate, 2016-2022