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Dynamic Strategies of Patent Licensing for Latecomer Firms under the Constraint of Technology Gap and Cost Advantage

Chen Bin

Doctor of Management

Supervisors:
PhD Sandro Mendonca, Assistant Professor,
ISCTE University Institute of Lisbon

PhD Xiao Yangao, Professor,
University of Electronic Science and Technology of China

December, 2019

BUSINESS
SCHOOL

Marketing, Operations and General Management Department

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Jury:

PhD Isabel Lourenço, Full Professor,
ISCTE University Institute of Lisbon
PhD Sandro Mendonca, Integrated researcher,
ISCTE University Institute of Lisbon
PhD Virginia Trigo, Professor Emeritus,
ISCTE University Institute of Lisbon
PhD Vítor Ferreira, Assistant Professor,
Escola Superior de Tecnologia e Gestão,
Instituto Politécnico de Leiria
PhD MA Yongkai, Full Professor
University of Electronic Science and Technology of China
PhD CHAI Junwu, Professor
University of Electronic Science and Technology of China

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Chen Bin

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Full name Chen Bin

Course Doctor of Management

Student number 201401

Email address 1260692117@qq.com

Personal email address 1260692117@qq.com

Telephone number 8613728829960

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CHEN BIN 陈斌

Abstract

Since China's reform and opening up, along with the continuous improvement of China's patent system, Huawei and other Chinese companies, as latecomer firms, have gone through a development process of technology introduction, technology imitation, imitation innovation, independent innovation, and open innovation. In this process, Chinese companies are charged high royalty fees. As their technological capabilities develop and cost advantages weaken, patent licensing renegotiations are initiated, all of which deserves careful review, especially the strategies adopted to reduce royalty fees.

The thesis adopts the mathematical model construction and derivation method based on game theory. A patent hold-up model based on the technology gap and cost advantages is then constructed to analyze the dynamic impact of gaps in technological capabilities and cost advantages on patent hold-up. The thesis further verifies the above theoretical research conclusions through empirical analysis and the case study. For example, the technology gap and cost advantages of the latecomer firms are analyzed at two points of time, namely, “ten years ago” and “the recent three years”. One of the important conclusions is that compared with ten years ago, in the recent three years, as the cost advantages of latecomer firms weaken and their technology gap with foreign leading companies narrows, the severity of hold-up encountered by latecomer firms has not mitigated, which demonstrates to some extent that in the case of reduced technology gap and weakened cost advantage, latecomer firms must adopt corresponding strategies to reinitiate negotiations with foreign leading companies in order to obtain lower royalty rates.

As a conclusion, the thesis proposes ways to achieve technological progress and patent-holdup to catching-up ICT. The Chinese ICT industry could take effective measures to control the labour cost and increase in investment in R&D, especially in basic research. Chinese companies should optimize the patent portfolio while working on technological advancement, realize the value of patents and establish and contribute to an improved IP system to facilitate IP operations. Foreign frontier firms can adapt and adjust their patent licensing strategies to fully utilize the infringement relief rule brought about by China’ s IP system reform, while actively seeking cooperation with Chinese companies like Huawei in emerging fields and look for the future technological pathways.

Key Words: Patent Licensing; Latecomer; Technology Gap; Cost Advantage.

JEL: M1; O32

Resumo

Desde a abertura económica da China, de dpois graças ao melhoramento contínuo do sistema de patentes da China, a Huawei e outras empresas retardatárias chinesas passaram por um processo de desenvolvimento de introdução tecnológica, imitação tecnológica, inovação em imitação, inovação independente e inovação aberta. Nesse processo, as empresas chinesas pagam altas taxas de licenciamento de patentes a entidades ocidentais. À medida que suas capacidades tecnológicas se desenvolvem e as vantagens de custo enfraquecem, renegociações de licença de patentes são iniciadas, todas as quais merecem uma revisão cuidadosa, especialmente as estratégias adotadas para reduzir as taxas de patentes.

A tese adopta o método de construção e derivação de modelos matemáticos com base na teoria dos jogos. Um modelo de patente *holdup* baseado no fosso tecnológico e vantagens de custo é então construído para analisar o impacto dinâmico do *holdup* dos espaços nas capacidades tecnológicas e vantagens de custo. A tese verifica ainda as conclusões teóricas da pesquisa acima por meio da análise empírica e do estudo de caso. O fosso tecnológico e as vantagens de custo das empresas retardatárias são analisadas em dois momentos, a saber, "dez anos atrás" e "os últimos três anos". Uma das conclusões importantes é que, em comparação com dez anos atrás, nos últimos três anos, à medida que as vantagens de custo das empresas retardatárias enfraquecem e seu fosso tecnológico com as empresas dominantes estrangeiras diminuiu, a gravidade de patente *holdup* encontrado pelas empresas retardatárias não se mitigou, o que demonstra até certo ponto que, no caso de fosso tecnológico reduzido e vantagem de custo enfraquecida, as empresas retardatárias devem adotar estratégias correspondentes para reiniciar as negociações com empresas estrangeiras dominantes a fim de obter acesso mais económico a tecnologias proprietárias.

A tese propõe maneiras de alcançar o progresso tecnológico e o gerir o *holdup* nas novas tecnologias de informação e comunicação (TIC). As empresas chinesas de NTIC devem tomar medidas eficazes para controlar os custos de trabalho e aumentar o investimento em I&D (Investigação e desenvolvimento), especialmente em pesquisa básica. As empresas chinesas de NTIC devem optimizar o portfólio de patentes enquanto trabalham no avanço tecnológico, criar confiança em sua tecnologia própria, perceber o valor das patentes e estabelecer e melhorar um sistema de PI (propriedade intelectual) para facilitar as estratégias de operação. As empresas avançadas estrangeiras devem adaptar-se e ajustar oportunamente suas estratégias de licenciamento de patentes, utilizar totalmente a regra de alívio de infração trazida pela reforma do sistema de PI da China, buscar activamente a cooperação com empresas chinesas como a Huawei em campos emergentes e olhar para futuras avenidas tecnológicas.

Palavras-chave: Licença de Patentes; Empresas Retardatárias; Fosso Tecnológico; Vantagem de custo

JEL: M1; O32

摘 要

改革开放以来，随着中国专利制度的不断完善，如华为等中国后发企业，经历了技术引进，技术模仿，模仿创新，自主创新和开放创新的发展历程。在此过程中，中国公司往往被外国领先企业收取高额专利费。随着其技术能力的发展和成本优势的减弱，后发企业开始进行专利许可重新谈判，采取降低专利许可费等策略。

本文采用基于博弈论的数学模型构建与推导方法，基于技术差距和成本优势构建专利劫持模型，以分析技术能力和成本优势的差距对专利劫持的动态影响。本文通过实证分析和案例研究，进一步验证了以上理论研究结论。例如，后发企业的技术差距和成本优势是在两个时间点进行分析的，即“十年前”和“近三年”。一个重要的结论是，与十年前相比，近三年来，随着后发企业的成本优势减弱以及与外国领先企业的技术差距缩小，后发企业所遇到的专利劫持的程度并未得到缓解。这在某种程度上表明，在技术差距缩小和成本优势减弱的情况下，后发企业必须采取相应的策略来重新启动与外国领先公司的谈判，以降低特许权使用费。

最后，论文对中国的信息通信技术企业和外国领先企业如何取得技术进步以及反专利劫持提出了建议。即，对中国 ICT 企业来说，应采取措施有效控制人力成本，加大对技术研发投入，特别是基础性研发的投入，在重视技术能力进步的同时积累并夯实专利组合，培育技术自信，实现专利价值，确立和健全有利于经营战略的知识产权体系，为换道超车夯实基础。对西方领先企业来说，应适应形势发展及时调整现有专利许可策略，遵循并充分利用中国知识产权制度变化带来的侵权救济规则，主动在新兴领域与华为等中国企业合作，谋求未来的“相对竞争优势”。

关键词: 专利许可; 后发企业; 技术差距; 成本优势

JEL: M1; O32

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Contents

List of Tables

List of Figures

Chapter 1: Introduction

In this new era of innovation and development, patents have increasingly become one of the strategic key resources for enterprises and even countries to participate in global competition. From the perspective of enterprise development, patent licensing is not only an important way for the patent owner to profit from the patent, but also an effective way for the demander to gain access to technology; From the point of international trade, the indicator of balance of payments for the use of intellectual property (IP) is an important leverage for the developed countries to balance international trade, and hangs like the Sword of Damocles over the developing countries. Over the past 40 years of reform and opening up, latecomer firms in China have gone through a development process from technology introduction and imitation to imitation innovation, independent innovation and open innovation. Meanwhile, China's patent system has also gone from passive legislation to active revision and continuous improvement. In this process, Chinese companies bore high patent royalty fees at the beginning, and later began to renegotiate patent license agreements as their own technical capabilities improved and cost advantages weakened, all of which is worthy of careful summarization and research, especially with regard to the strategies taken by the companies to reduce patent royalty fees.

1.1 Research background, questions and methods

1.1.1 Research background

(1) Major countries continue to increase investment in research and development (R&D), and the number of patent applications worldwide has surged

Granstrand (1999, 2006), Rogers (2004), Greenhalgh and Rogers (2010) find that with the development of knowledge economy and a growing awareness of the critical role of innovation in business success and economic growth, research and development (R&D) expenditure as a percentage of GDP, also known as R&D intensity, has been increasing, and the number of intellectual property rights (IPR) applications and authorizations, especially patent applications and authorizations has been rising year by year, which demonstrates the value of patents in commercial competition. Patent quality, value realization and protection have become the primary tasks faced by enterprises, especially innovative ones. All these indicators may yield a systematic and evidence-based appreciation of the countries' capacity to take part in a globalizing knowledge economy (Wang et al., 2019).

According to the World Bank data, R&D intensity of the G20 economies was on the increase between 1996 and 2015 (G20 Finance Ministers and Central Bank Governors Meeting was founded in December 16, 1999 with its members including Japan, France, Britain, Italy, Canada, Germany, China, South Africa, India, Brazil, Russia, Saudi Arabia, Mexico, Australia, Turkey, Argentina, the Republic of Korea, Indonesia and the European Union. Encompassing 2/3 of the world's population, G20 members account for 85% of the world economy and their trade volume makes up over 80% of global trade). Due to incomplete statistics, Australia, Indonesia, Saudi Arabia and South Africa were excluded from the calculation. As demonstrated in Figure 1-1, (1) R&D intensity of the above countries except Britain and France rose to varying degrees from 1996 to 2015; (2) R&D intensity of the developed countries and regions such as the United States, Japan, Germany, France, Britain, Canada and South Korea has stayed at above 1.5%. In the United States, Japan, Germany and Korea, it has remained above 2.5% in recent years; in the Republic of Korea and Japan, it grew from 2.43% and 2.77% in 1996 to 4.22% and 3.25% in 2015 respectively, an increase of 73.66% and 17.33%; (3) R&D intensity of the emerging countries such as China, Russia, India, Brazil, Argentina, Mexico and Turkey stood at below 1% in 1996, a large gap with the above-mentioned developed countries. However, R&D intensity has grown in the past 15 years in the emerging countries. In China, it increased from 0.57% in 1996 to 2.06% in 2012, surpassing Italy, Britain and Canada and even getting close to the European Union.

With the increase of R&D spending, the number of patents, an important means of protecting innovation by legal means, has also been increasing. As shown in Appendix 2.1, since the mid-1980s, the number of patent applications only for inventions in the world (statistical specification is inventions, the same below) has risen from 822,823 in 1980 to 3,168,900 in 2017, an increase by 3.85 times and an average annual growth of 3.80%.

The number of international patent applications under the Patent Cooperation Treaty (PCT) has grown annually. As shown in Appendix 2.2, PCT applications rose from 19,806 in 1990 to 243,500 in 2017, increasing by 12.29 times and 9.94% year-on-year.

As Appendix 2.3 demonstrates, the number of patent applications in the United States has maintained steady growth from 104,329 in 1980 to 606,956 in 2013, an overall increase of 5.81 times and a 5.43% growth year-on-year. The amount of invention patent applications in China jumped from 8,558 in 1985 to 1,381,594 in 2017. Since China joined the World Trade Organisation (WTO) in 2001, its growth rate has risen by 21.77 times, making China surpass the Republic of Korea in 2004, Europe in 2005, Japan in 2010 and the United States in 2011. The Republic of Korea has also increased their patent applications very rapidly, surpassing Europe in 1995 and maintaining a close momentum as Europe. Japan was once the world's largest patent applicant, taking the leading position for many years. However, its number of applications started to decline after reaching the peak of 427,078 in 2005, and was surpassed by the United States and China in 2006 and 2010 respectively.

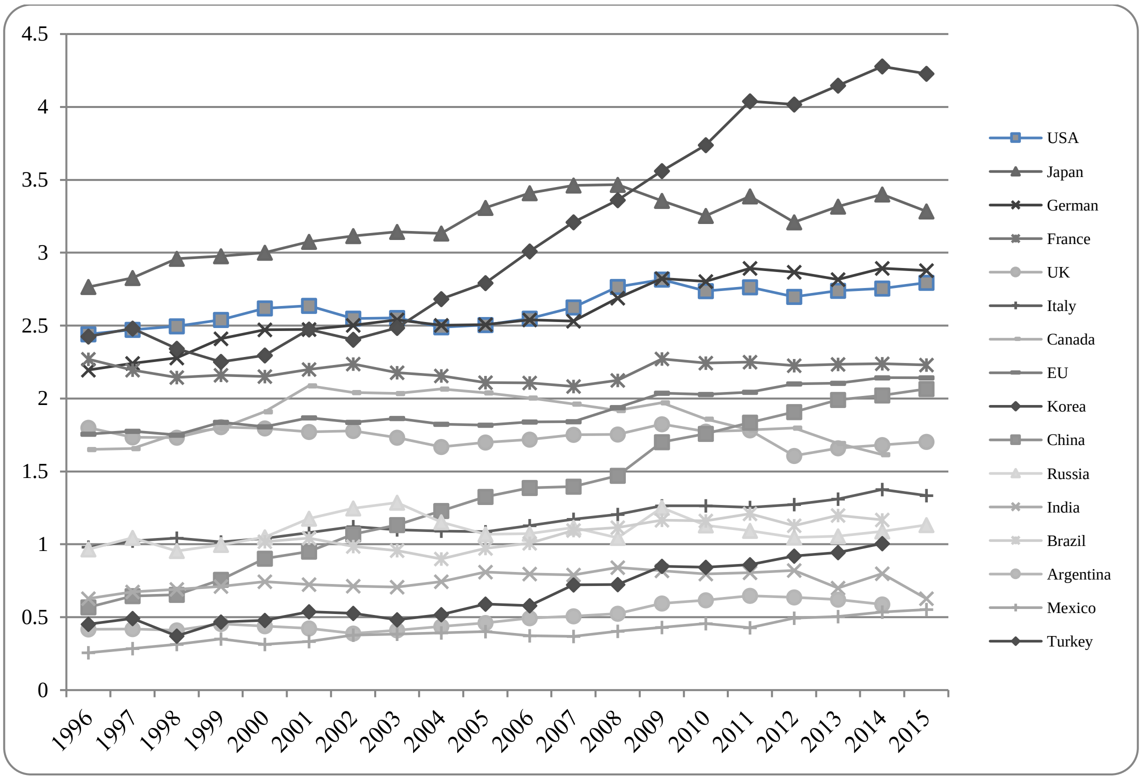

Figure 1-1 R&D expenditure (% of GDP) of the G20 economies, 1996-2015

Source: World Bank (2019)

From the perspective of the patent applicant's countries and regions, as shown in Figure 1-2, PCT applications are mainly from the United States, Japan, Germany, the Republic of Korea, France, the United Kingdom, Switzerland, the Netherlands, and Sweden. Among them, the United States has led in patent applications with an increase from 7,719 in 1990 to 56,674 in 2017. Japan also showed rapid growth from 1,747 in 1990 to 17,415 in 2002 when its surpassed Germany and surged to 48,205 in 2017. The number of patent applications in the Republic of Korea amounted to 7,064 in 2007, surpassing France, Britain, Switzerland, the Netherlands and Sweden. China had no PCT application data before 1990, but its number of PCT applications has increased markedly since 1994, reaching 5,455 in 2007, and surpassing Switzerland, the Netherlands and Sweden; thereafter, China surpassed Britain, France, the Republic of Korea and Germany in 2008, 2009, 2010 and 2013 respectively, ranking after the United States and on a par with Japan.

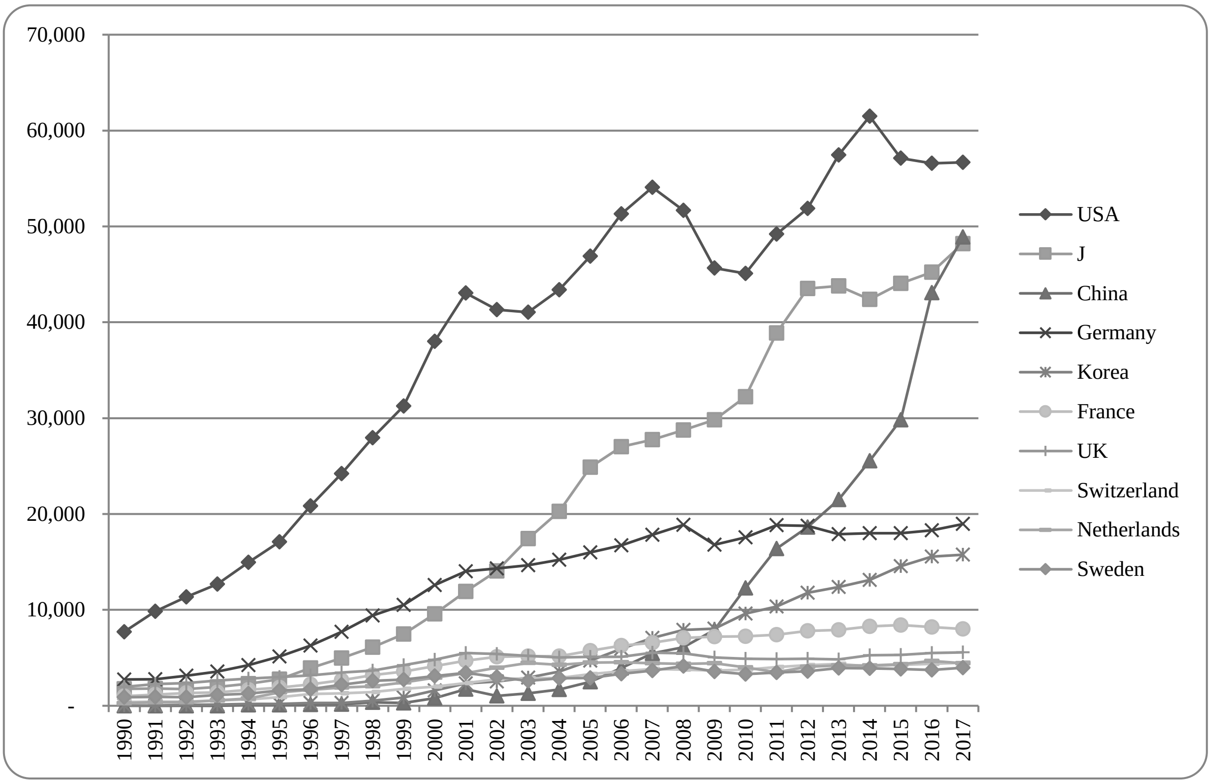

Figure 1-2 PCT applications filed by the top 10 origins, 1990-2017

Source: World Intellectual Property Organization [WIPO] (2019)

After China's reform and opening up, patent application and authorization began with the promulgation of the Patent Law of the People's Republic of China in April 1, 1985. As demonstrated in Figure 1-3, the amount of patent applications accepted by China National Intellectual Property Administration (SIPO) grew slowly from 14,372 in 1985 to 102,735 in 1996; in 2001 when China joined the WTO, the number of patent applications stood at 203,573, after which it reached a record 2,377,061 applications in 2013. Despite a decline in 2014, the number amounted at 3,697,845 in 2017, increasing by 18.16 times and 20.17% year-on-year in 2001-2017. In the same period, the number of granted patents jumped by 16.07 times from 114,251 in 2001 to 1,836,434 in 2017, increasing by 19.78% year-on-year. However, the above increase results from domestic application and authorization. The number of patent applications accepted and granted abroad has shown steady growth with the number of applications increasing from 37,800 in 2001 to 161,512 in 2017, and the amount of grants, from 14,973 in 2001 to 115,606 in 2017, with an average annual growth of 14.95%.

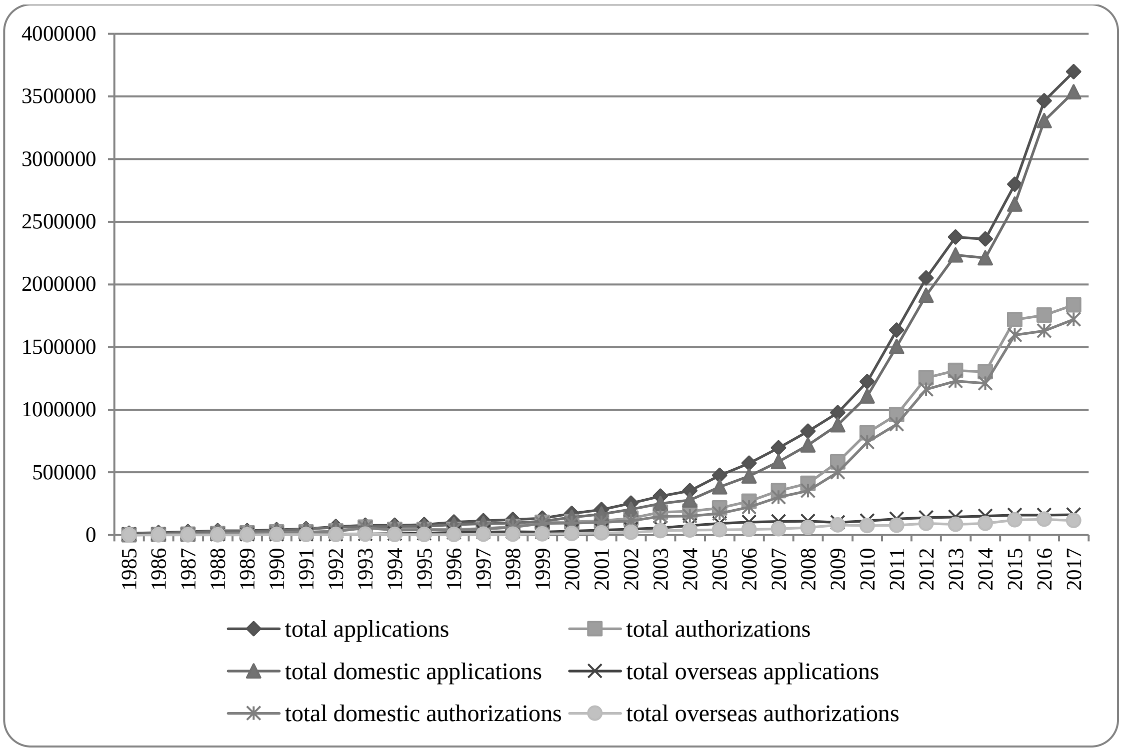

Figure 1-3 Patent applications and authorizations in CNIPA, 1985-2017

Source: China National Intellectual Property Administration [CNIPA] (2018)

Due to the differences in patent systems in various countries, it is difficult to classify the categories of patents. However, the percentage of invention patent applications and authorizations of the total applications and granted is a dominant indicator of the quality of patents. As shown in Figure 1-4, although invention patents have taken up more and more of the total applications in China since 2001, it is still lower than 40%, and the authorized invention patents have accounted for less than 20% of the total authorized patents since 2010. A similarly low rate has also been reported in the percentage of domestic invention patent applications to the total domestic patent applications and in that of domestic invention patent authorizations of the total domestic patent authorizations. The reason is that despite a slight drop in the number of patent applications and authorizations, except that of the design patents since 2012 in China, the amount of utility and design patents has remained high. On the contrary, in other countries, invention patent applications have accounted for above 80% of all patent applications, and the amount of granted invention patents has risen up above 70% of all granted patents since 2001.

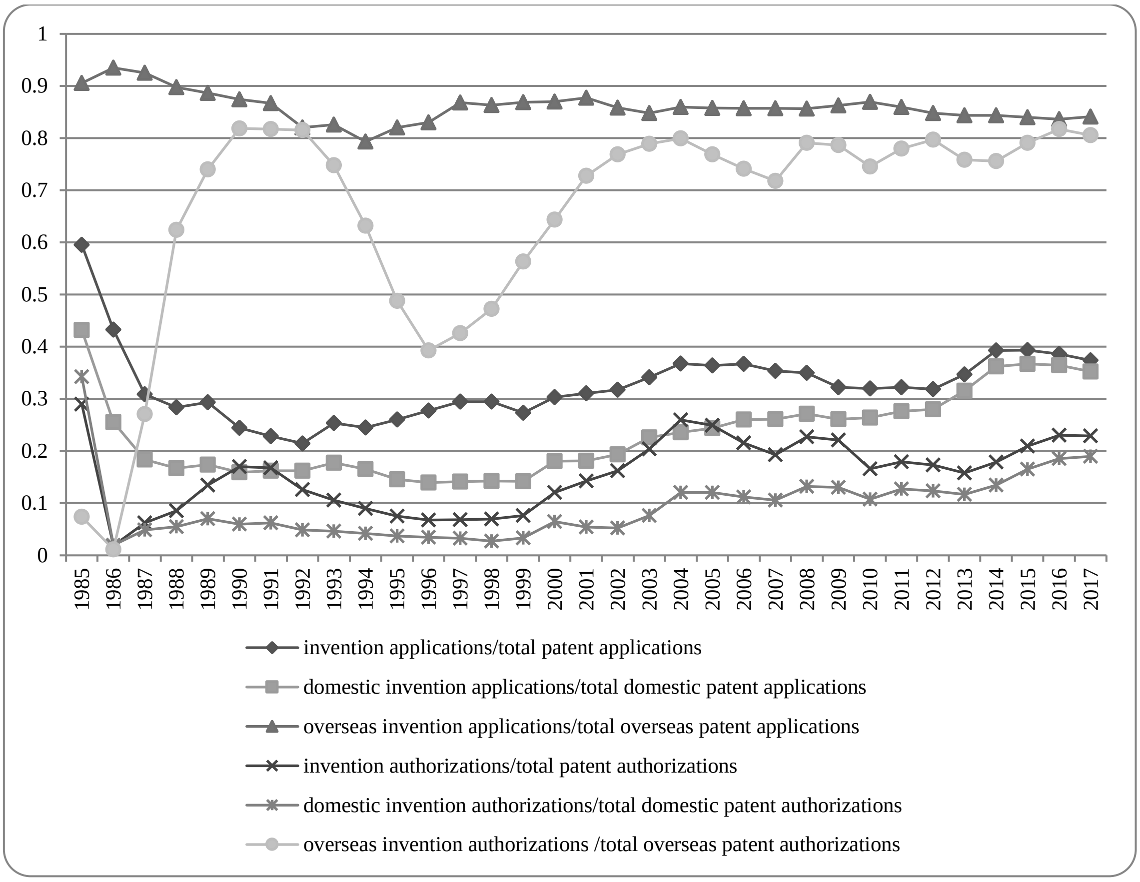

Figure 1-4 Proportion of invention patent applications and authorizations in CNIPA, 1985-2017

Source: CNIPA (2018)

As Appendix 2.5 demonstrates, the top ten countries filing invention patents and obtaining authorizations in China are Japan, the United States, Germany, the Republic of Korea, Switzerland, the Netherlands, Britain, Sweden and Italy, among which the number of granted invention patents filed by Japan, the United States, Germany and the Republic of Korea reached 367,526, 213,720, 94,416 and 72,568 respectively, accounting for 30.14%, 17.45%, 7.71% and 5.92% of the total invention patents filed by foreign countries. In 2017, the amount of granted invention patents was 31,090, 23,673, 11,240 and 7,857 respectively, taking up 33.68%, 25.41%, 12.06%, and 8.43% of the total invention patents filed by foreign countries that year.

(2) The consolidation of an unbalanced growing international licensing with patent value becoming prominent

In recent years, in line with the unbalanced and rapid growth of patents around the world, the value of patents in commercial competition has also become prominent. The enterprises apply their own patents to the products and services, reducing the cost or increasing the value of products and services. As IP represented by patents takes up more and more in the total assets of the enterprises, companies exchange value by transferring or licensing patents, which has spurred the companies to accumulate patents and attach more importance to obtain value from patents.

IPR is a strategic soft resource for companies and countries (Mendonça, Pereira, & Godinho, 2004; Mendonça, Schmoch, & Neuhäusler, 2019; Costa & Mendonça, 2019). The degree of importance attached to it by enterprises directly reflects the value of IP in the enterprises, especially the proportion of IP represented by patents in the total assets of enterprises. According to the longitudinal survey on the asset structure of 500 listed companies in the Standard & Poor's 500 (S&P 500) Index by Ocean Tomo (2015), a well-known IP management group in the United States, over the past 40 years, intellectual capital with IP as the core has accounted for an increasing percentage of the total asset of the enterprises. As shown in Appendix 2.6, in 1975, the intangible asset of the above-mentioned companies took up only 17% of the total asset, but it increased to 32% and 68% in 1985 and 1995 respectively and even jumped to 80% and 84% in 2005 and 2015 respectively.

In order to grasp the flow scale and direction of the exchange value of IP worldwide, in recent years, the International Monetary Fund (IMF) and the World Bank have gathered annual statistics on the international expenditures and income of IP represented by patents in various countries. The statistical specifications used are the annual income and expenditures for the legal use of IP between countries and regions, and the scope of statistics includes annual income and expenses resulting from license agreements, such as patents, trademarks, copyrights, industrial designs, trade secrets and franchise licenses. According to the statistics between 2005 and 2017, the total balance of international payments for the use of IP has been expanding in recent years, indicating an increasing exchange value of IP worldwide, which is consistent with that of international trade in goods. However, the balance of international payments on IP shows a large disparity between developed and developing countries, which is entirely different from that of the international trade in goods. Developed countries such as the United States, Japan, the United Kingdom, Switzerland, and France enjoy IP trade surplus, with both income and expenditure curves having similar slopes, while developing countries, China in particular, has seen a sharp increase in IP trade deficit, with its income and expenditures curves having different slopes, forming the shape of an expanding opening.

As Figure 1-5 and Figure1-6 demonstrate, the United States and Japan enjoyed an increasing IP trade surplus from 2005 to 2017; since 2009, Germany has maintained a surplus. Japan’s surplus in IP trade jumped from USD 3.02 billion in 2005 to USD 20.40 billion in 2017, and the United States, from USD 48.871 billion in 2005 to USD 79.582 billion in 2017. In sharp contrast, China, Russia, and India have suffered an increasing IP trade deficit, especially in China, the deficit jumped from USD 5.164 billion in 2005 to USD 28.001 billion, revealing that behind China's surplus in goods, China has a large deficit in IP trade. The above data not only show to some extent the overall gap between China and developed countries in terms of technical capabilities, but also state the problem for Chinese companies to improve patent quality and strengthen IP patent management.

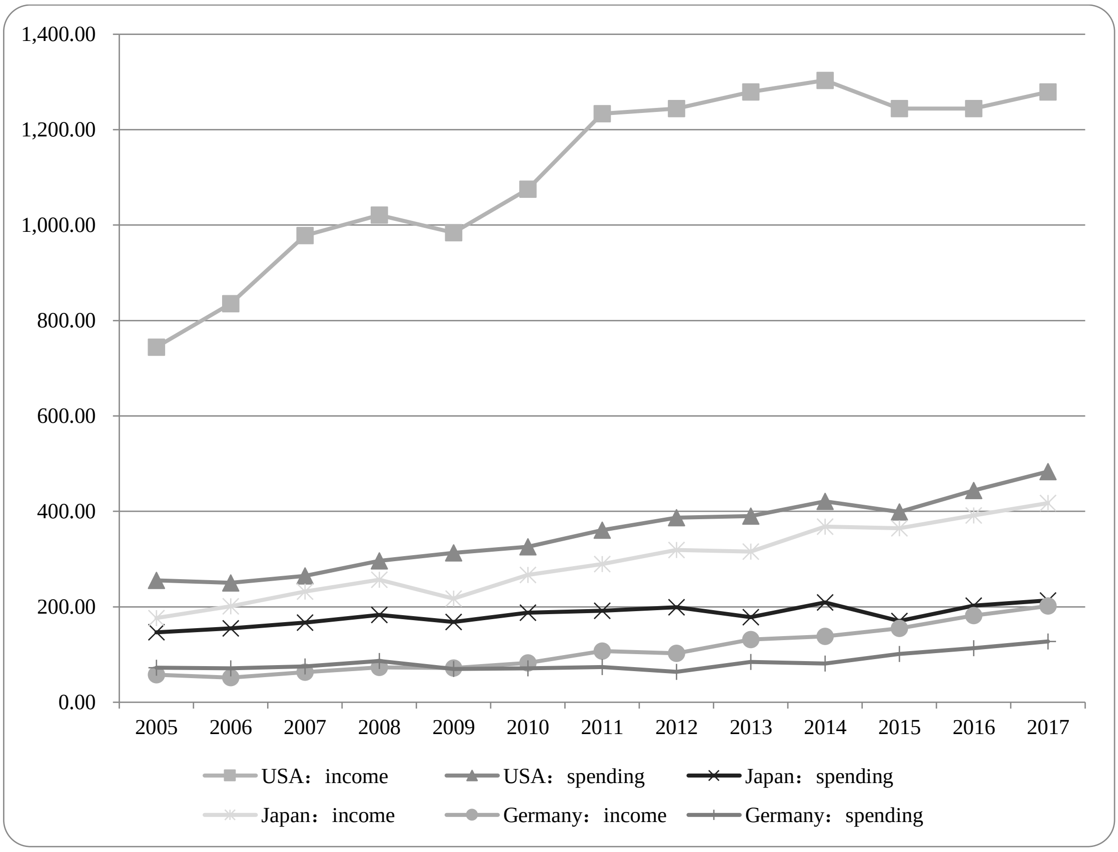

Figure 1-5 Balance of international payments on IP in the United States, Japan and Germany, 2005-2017 (unit: 100 million US dollars)

Source: World Bank (2019)

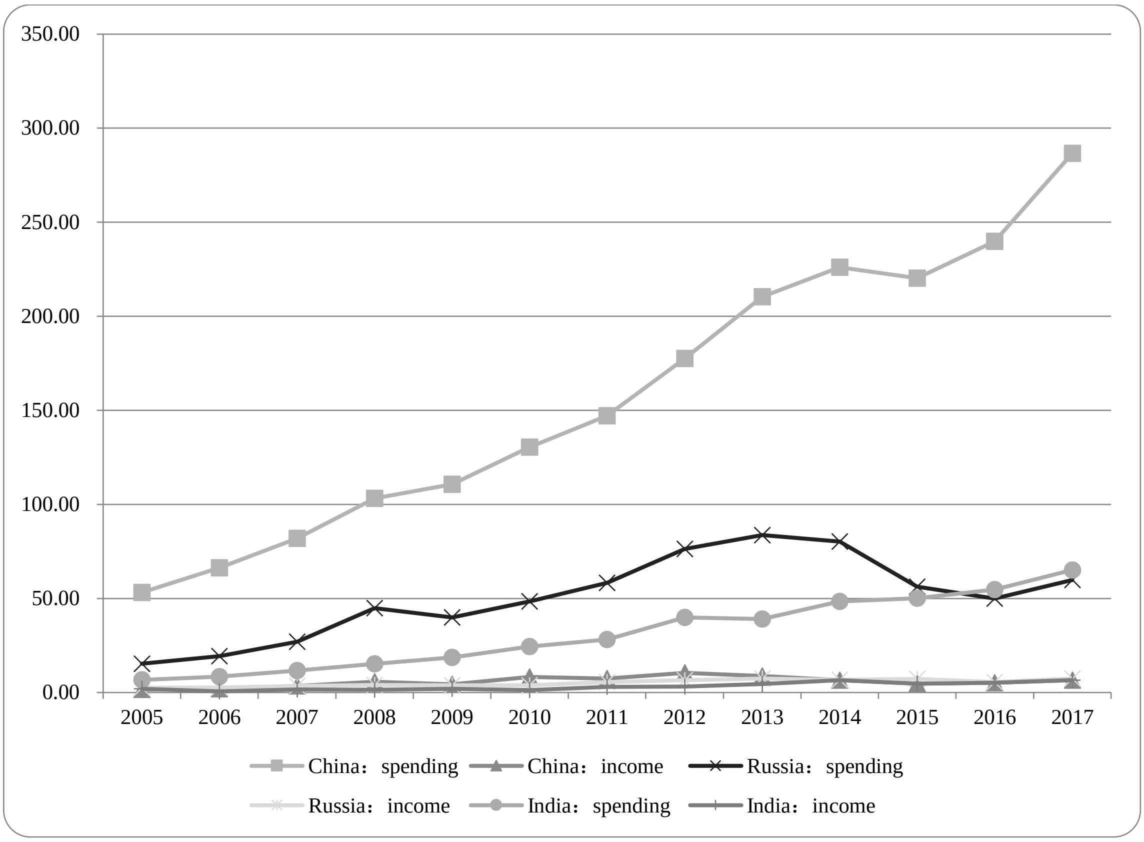

Figure 1-6 Balance of international payments on IP in China, Russia and India, 2005-2017

(units: 100 million US dollars)

Source: Word Bank (2019)

(3) Pressure exerted by patent litigations on Chinese firms

As the number of patents increases and the value of patents becomes prominent, the amount of patent litigations has generally increased with their purposes more diversified. Patent litigation not only becomes an important way for the patent holders to protect innovation achievements and maintain patent income, but is also playing an important role in winning target markets and gaining competitive advantage among competitors. In particular, in recent years, the use of patents as bargaining chips and the emergence of a business model where profits are obtained through litigations or litigation threats, have raised the litigation frequency, resulting in inefficiencies in operating the patent system, for example, the Non-practicing Entities (NPEs) not only increase the cost of innovation and entrepreneurship, but also reduce social welfare, drawing widespread attention from the business circles, government, and academia.

As reported by RPX Corporation, we can see in Appendix 2.7 that NPE litigation filings remained high from 2010 to 2016. Although the volume of NPE-related filings dropped in 2015, it still accounts for half of the total litigations. It has become a new topic in the reform of the U.S. patent system and corporate patent management of how to regularize NPE litigation behavior or litigation threat so as to make the patent system balanced for the sake of innovation and enable the public to access the new knowledge.

According to the Lex Machina database and RPX patent litigation and transaction database, as Appendix 2.8 demonstrates, from 2000 to 2018, China's famous ICT companies, Huawei and ZTE, had 221 and 196 patent lawsuits respectively in the United States, among which 80% were NPE related. It can be seen that NPE is the main opponent of Huawei and ZTE in the United States. The direct reason why NPEs file a patent litigation is to use patent infringement compensation as a threat and to profit through patent licensing.

1.1.2 Research questions

The "patent hold-up" problem was not a serious concern until recent days. It was first proposed by Mark A. Lemley and Carl Shapiro. They find that under the condition that there is no competition between a patent owner and a licensee, the patent owner obtains the actual royalty fees that exceed a benchmark level through threats (usually apply to the court for an injunction, lawsuit or bargaining), and that hold-up problems are magnified "when multiple patents read on a single product" (Lemley & Shapiro, 2007a). Their research has aroused widespread concern in the academic field, and patent hold-up has become a hot topic in the field of patent licensing research.

Since China's reform and opening up, especially since its accession to the WTO, due to the gap with developed countries in patent protection enhancement and patent R&D quality (Zhang, 2016), an increasing number of Chinese latecomer firms (Mathews, 2002) acquire technology from foreign leading firms through patent licensing. As discussed above, China's IP expenditure jumped from USD 5.321 billion in 2005 to USD 28.661 billion in 2017, while IP income rose slowly from USD 157 million to USD 660 million in the same period. The IP trade deficit surged from USD 5.164 billion to USD 28.001 billion. In other words, although the technology gap between Chinese companies and foreign leading companies has narrowed, the IP deficit has not decreased. On the strength of their comparative advantages in patents and based on the needs of globalization and market competition, foreign leading companies carry out patent hold-up on latecomer firms, which has posed a threat to the technological capabilities and market development of developing countries such as China. For example, China's digital TV manufacturers have to bear high patent royalty fee; recently, Google, Microsoft and Apple filed smartphone patents licensing and litigation.

The current start of affairs leads one to wonder why are not catching-up countries not climbing faster up the knowledge ladder. The general issue here being the key conditions that constrain and enable successful strategies by firms by later-comer countries, such as China (Xiao, Tylecote, & Liu, 2013; Xiao et al., 2019). Therefore, it is necessary to analyze the participant and patent structures of patent licensing from the perspective of the latecomer firms, and analyze the patent hold-up problem brought by the foreign leading companies. For instance, what are the inducing factors and characteristics of patent hold-up posed by foreign leading companies to Chinese latecomer firms? Under the condition of different patent structures and participants, what is the mechanism and effects of patent hold-up? Will the bargaining abilities of latecomer firms with different technology strategies and different levels of technological development adversely affect the patent hold-up posed by foreign leading companies? How do latecomer firms adopt effective strategies to reduce or circumvent patent hold-up?

The research questions of this thesis are as follows:

(1) To analyze the inducing factors and characteristics of patent hold-up posed by foreign leading companies to Chinese latecomer firms.

(2) To analyze the mechanism of patent hold-up and its effects on the patent and licensing behavior of latecomer firms under different participant structures: "one-to-one" (assuming a competitive relationship between the licensor and the licensee).

(3) To open the black box of the bargaining abilities of the latecomer firms as a licensee, and analyze the adverse effects of the bargaining abilities of the latecomer firms with different technological capabilities and cost advantages on foreign leading companies.

(4) To verify the reasons for and problems caused by patent hold-up of latecomer firms under the above-mentioned conditions and the adverse impacts of bargaining strategy of latecomer firms on patent hold-up based on questionnaire and case study.

(5) To propose the coping strategies for Chinese latecomer firms under different patent hold-up conditions.

1.1.3 Research methods

The research methods of this thesis mainly include:

(1) Mathematical model based on game theory. This thesis reviews Chinese and Western literature on patent licensing and patent hold-up. Based on the patent hold-up model proposed by Lemley and Shapiro, and considering the characteristics of the latecomer firms, this thesis selects the factors of cost advantage and technology gap to derive the relationship between these two factors and patent hold-up through the revenue function, and build a patent hold-up model from the perspective of latecomer firms. Based on game theory, the thesis proposed strategies against patent hold-up for latecomer firms when the technology gap and the cost advantage vary.

(2) Empirical research method based on questionnaires. Based on the above theoretical model and mathematical derivation, and focusing on the logical relationship between technology gap and cost advantage and patent hold-up, this thesis built the corresponding index system of independent variable and dependent variable, designed the questionnaire by using the 5-point Likert Scale, and applied it to the selected 120 domestic enterprises in Guangdong, Hubei and Sichuan provinces, all of which have registered in CNIPA and have received patent licenses from foreign leading enterprises. The questionnaire is mainly completed by the personnel from relevant departments (such as finance, technology, legal affairs). Through the empirical analysis of the data collected by the questionnaire, the thesis verified the rationality of the above mathematical model and strategies.

(3) Case study. In order to further analyze the patent hold-up problems encountered by Chinese latecomer firms and their anti-holdup strategies since reform and opening up, the thesis selected two cases to discuss the motives and strategies of latecomer enterprises against patent hold-up. The first case focuses on the causes and strategies of Huawei's anti-holdup in the global localization development period. The second case summarizes the phenomenon of patent thickets and hold-up in the development of digital TV patents and the countermeasures of China’s enterprises.

1.2 Main contents and contributions to state of the art

1.2.1 Research contents

The research on patent hold-up was first based on the development of patent licensing, while the practice and theoretical development of patent licensing has always focused on the nature of patents and patent system reform. Therefore, based on the review of Chinese and western literatures on patent licensing and patent hold-up, this thesis builds a patent hold-up model from the perspective of latecomer firms, and further discusses the mechanism of patent hold-up posed by foreign leading companies and anti-holdup strategies taken by latecomer firms under different circumstances from the theoretical, empirical and case perspectives. This thesis consists of six chapters. The main contents and main conclusions are:

In the second chapter, literature review on patent licensing and patent hold-up is presented. Based on the definition and types of patent licensing, this thesis reviewed the research on patent licensing from the perspective of management economics, and summarized the research progress on patent alliance and standard-essential patent (SEP) licensing. The thesis further discussed the patent licensing strategy of latecomer firms, providing theoretical support for follow-up research:

(1) Patent licensing is not only an effective way for innovative entities such as enterprises and universities to profit from innovation and seek competitive advantage, but also an important means for countries to balance international trade revenue and expenditure. Patent licensing is an important research area of management economics and law.

(2) The main patent licensing topics of concern of early industrial organization theory include the relationship between the number of licensees and the industrial structure, the impact of the license agreement between the licensor and the licensee on the distribution of the created value, ex ante and ex post licensing and strategy selection, and the impact of continuous innovation and discontinuous innovation on patent licensing strategies. A number of patent licensing literatures have discussed the dominant licensing strategies with regards to the royalty fee adopted by innovators in different contexts.

(3) From the perspective of patent hold-up, patent licensing ensures patent owners to profit by issuing permanent injunctions, which increases the bargaining power of patent

holders, making the actual license royalty rates much higher than the benchmark or reasonable rate that is determined by the patent value and patent strength. The permanent injunction gives patent owners the right to prevent the infringing companies from designing, manufacturing and selling infringing products, which not only defends and realizes the patent value, but has also become a patent hold-up tool for patent owners to obtain profits higher than the actual value of the patent itself, hindering social innovation. This is why the study of permanent injunction has become one the of the core areas of patent hold-up research.

In the third chapter where a model building is discussed, based on the patent hold-up model proposed by Lemley and Shapiro, the thesis selected the factors of cost advantage and technical disadvantage, built a bargaining decision tree model between a leading enterprise and a latecomer firm, and proposed anti-holdup strategies for latecomer firms in the early stage of technology catch-up and when the technology gap between leading companies and latecomer firms has narrowed.

(1) Patent hold-up occurs in different phases of patent licensing negotiations. In order to effectively reduce the negative impact of patent hold-up, latecomer firms should adopt a technology imitation strategy in the early stage of technology catch-up, which is a wiser choice than ex-ante licensing. When the imitation is perceived by the leading enterprises, the optimal strategy for latecomer firms should be litigation, which is better than direct negotiations.

(2) The degree of patent hold-up is affected by the cost advantage and technology gap. The degree of patent hold-up posed by foreign leading companies will decrease at different stages as the cost advantage of the latecomer firms weakens and the technology gap narrows. In the early stage of technology catch-up, in order to mitigate patent hold-up, the latecomer firms can only reduce the technology gap with the leading companies, thereby enhancing the bargaining power.

(3) If the products of the latecomer firms can be designed in a new way, there are two strategies: when $G^{**} < G \leq G^{*}$, in response to litigations, it is a better strategy to design the products in a new way; when $0 \leq G < G^{**}$, it is a more appropriate strategy to obtain patent license after the litigation.

In the chapter of empirical research, the thesis conducted a survey on the actual royalty rates, cost advantage, and technology gap. The research sample is 120 domestic enterprises located in three provinces of Guangdong, Hubei and Sichuan. The sample companies have all received patent licenses from foreign leading companies and have filed registration with CNIPA. In order to examine the dynamic changes in technology gap and cost advantages of latecomer firms, considering the availability of data, the survey collected data at two points, namely, ten years ago and the recent three years. The results show that:

(1) Ten years ago, the technology gap had a significant positive correlation with the actual licensing royalty rates. As the technology gap between the latecomer firms and the leading companies narrowed, the actual licensing royalty rates decreased, which mitigates patent hold-up. After the regression analysis of every technology gap variable, the results show that the marketing capability gap and R&D capability gap positively affect the actual licensing royalty rates, and that the manufacturing capability gap does not have a significant impact on the actual licensing royalty rates.

(2) In the recent three years, the technology gap has a significant negative correlation with the actual licensing royalty rates, which is contrary to the assumption of this thesis. In further regression analysis, we found that it was because there is a significant negative correlation between the R&D capability gap and the actual licensing royalty rates, revealing that when the technology gap narrows to a certain extent, foreign leading companies will not reduce but intensify patent hold-up. Its reasons and coping strategies should become the concern of latecomer firms. Meanwhile, the manufacturing capability gap and the marketing capability gap have no significant impact on the actual licensing royalty rates. The reason why the marketing capability gap does not have a significant impact may be that the gap between the latecomer firms and leading companies has been significantly narrowed after years of development.

(3) In both periods, the cost advantage of latecomer firms shows a positive impact on the actual licensing royalty rates. The results show that as the cost advantage and patent hold-up weaken, the reasonable licensing royalty fee (rates) are closer to the actual licensing royalty fee (rates). However, the cost advantage of ten years ago had a more significant impact on the actual licensing royalty rates than that of the past three years, which demonstrates that the weakening of the cost advantage of the latecomer firms will not necessarily reduce the actual licensing royalty rates or patent hold-up to the same proportion. In the case of weakened cost advantages, it has become a practical problem faced by

latecomer firms how to enhance their technological and patent licensing negotiation capabilities. In addition, the thesis further analyzed the impact of weakened cost advantage on the reduction of the actual licensing royalty rates and found that the labor cost advantage had less impact than the material cost advantage ten years ago, while the former had a more significant effect than the latter in the past three years, which shows that in the case of weakened labor cost advantage over the past three years, the appeal of the latecomer firms to reduce the actual licensing royalty rates is more urgent.

(4) Through further analysis on the impact of the technology gap on the actual licensing royalty rates, the thesis found that the change in the R&D capability gap was significantly negatively correlated with the actual licensing royalty rates in the past three years, that is, the enterprises that have narrowed the most the technological capability, R&D capability and marketing capability gaps have borne higher licensing royalty rates in the recent three years; the more R&D capability gap the enterprises have narrowed over the past ten years, the more actual licensing royalty rates they have to bear in the recent three years. This result verifies the above-mentioned conclusion that although the technology gap between the latecomer firms and foreign leading enterprises is decreasing, the patent holdup threat posed by the leading companies has not mitigated but increased. The latecomer firms that have narrowed the most the technology gap with the foreign leading companies are facing a more serious patent hold-up.

In the case analysis chapter, the first cases analyzed the motivations and strategies of Huawei against patent hold-up in the context of global localization, and came to a conclusion that Huawei's implementing anti-holdup strategies is derived from the continuous updating of IP concepts, the narrowing of the technology gap, the continuous reduction of cost advantage and the importance attached by China to IP and the continuous improvement of patent related systems. It is an effective strategy for Huawei to successfully implement anti-holdup by identifying the right breakthrough, integrating existing remedies, and making reasonable demands. In the end, the thesis proposed suggestions from the perspectives of Chinese enterprises and western leading companies. The second case summarizes the phenomenon of patent thickets and hold-up in the development of digital TV patents and the countermeasures of China's enterprises.

1.2.2 Objectives and contributions to state of the art

The research approaches of this thesis are as follows: (1) to design the key research questions and construct a theoretical framework based on literature reviews and questionnaire; (2) to analyze the factors that may induce patent hold-up between Chinese latecomer firms and foreign leading enterprises; (3) to open the black box of patent licensing participants and patent structure and to analyze the formation mechanism of patent hold-up under different conditions and its impact on the patent and licensing behavior of latecomer firms; (4) to analyze the bargaining power of the latecomer firms and the adverse effects of the bargaining capability of the latecomer firms with different technology strategies and capabilities on patent hold-up; (5) to design the questionnaire based on the collected data and field research; (6) to organize the required data using literature analysis, questionnaire, and in-depth interviews; (7)to further analyze the collected data and verify the theoretical research proposition; (8) to demonstrate the validity of the proposed theory based on case analysis and from a realistic perspective. The main contributions to the current state of art of this thesis are:

(1) Based on the actual situation in China and existing literature, the thesis studied the relevant factors that affect the Chinese latecomer firms and their characteristics under the circumstances of patent hold-up by foreign leading enterprises. At the same time, on the basis of the characteristics of the latecomer firms, the thesis selected two important variables of the cost advantage and technology gap, and constructed a conceptual model and a mathematical model of patent hold-up from the perspective of the latecomer firms. The theoretical model makes the patent licensing theory closer to the actual situation of the latecomer firms, which is not only conducive to explaining the patent competition that Chinese enterprises have suffered in the local and international competition in the 40 years of reform and opening up, but also instructive for enterprises of other developing countries to participate in global competition.

(2) The thesis opened the black box of the structure and competitiveness of patent licensing participants, and systematically studied the formation mechanism of patent hold-up posed by foreign leading enterprises on latecomer firms and its impact on the patent and licensing behavior of latecomer firms under different conditions. The thesis analyzed the impact of the constant changes in cost and technology gaps on patent hold-up, and discussed the causes of patent hold-up between the patent holders and licensees and related strategies.

These studies can expand the theoretical system of patent hold-up to some extent, and help to enrich the innovation theory from the perspective of latecomer firms.

(3) The thesis further validated and deepened the above theoretical research conclusions through empirical and case studies. For example, the selected factors of technology gap and cost advantage of the latecomer firms are analyzed in different time frames of “ten years ago” and “the recent three years”. One of the important conclusions of the empirical study is that with the cost advantage of the latecomer firms weakened and the technology gap with foreign leading companies narrowed in the recent three years, the leading companies have not mitigated patent hold-up on the latecomer firms. This shows that as the latecomer firms catch up in technology, the advanced firms will not easily give up their existing technology and market advantages. Therefore, in the case of weakened cost advantage and narrowed technology gap, latecomer firms should adopt a corresponding strategy to renegotiate with the advanced firms so as to obtain lower actual licensing royalty rates.

Chapter 2: Literature Review

Patent hold-up research originated from the development of patent licensing practices and theories. A patent license is essentially an agreement in which a patentee transfers part or all of his patent rights and usufruct to a licensee in a specific region and period of time, conferring commercial value to the patent. Patent licensing practice has a long history, but the theoretical research on this area gradually emerged over the past 30 years, and has now become a hot topic in both law and management economics. This chapter starts with a summary of the meanings and types of patent licenses, which is used as a basis for the review of the theoretical origins and dynamics of patent licensing research from the perspective of management economics, allowing in turn to discuss patent licensing strategies from the perspective of latecomer firms, and providing theoretical reference and support for future research.

2.1 Patent license meaning and types

2.1.1 Patent license meaning

According to the Black's Law Dictionary (Black et al., 2014), the definition of a license can be divided into three layers. The first layer indicates that a certain entity pays a certain fee to a country or city, so as to obtain the right to engage in an act, such as driving a car, raising a dog, and conducting tax services. Those who are not permitted may not engage in the above-mentioned activities; the second meaning is the authorization of an act obtained by the licensee, which is a permit relationship established on the basis of the agreement, and implementation without authorization is considered illegal. At the same time, such authorization can be revoked by the licensor. The third layer means having the corresponding certificate or document to prove the above authorization or permission.

Therefore, Gomulkiewicz, Nguyen, and Conway (2014) summarize the nature of the license as Grant of Permission, and point out the root of patent licensing is the exclusive rights granted by the law to the patent holders. Without the permission of the patent owners (except for fair use), no one can enforce the patent, which leads to patent licensing system and management practices. Dong (2008) believe that according to Article 11 of the Patent

Law of the People's Republic of China, it is more reasonable to regard patent rights as negative exclusion rights than to regard them as active use rights. The rights to use the patent are granted by the agreement, which is a contractual claim. Although the patent rights are usually considered as active use rights, the licensed patent rights can only be a contractual claim rather than a real right for usufruct.

Patent licensing refers to the licensor’s act of granting the licensee the right to use his patent in the agreed period and region and in the agreed way. A licensor is a right holder who has the right to grant permission to a licensee to use the patent, while a licensee is the entity that negotiates with the licensor and obtains permission to use the patent. In patent licensing, a licensor transfers part of their right in a patent to another, allowing the licensee to exploit the IP. Thus, patent licensing is an “authorization” act of the licensor to license interest in a patent, namely, a licensor authorizes the licensee to use the patent (Dratler & McJohn, 2016). Both the licensor and the licensee can take what they need through patent licensing. The licensor can recover its investment in technology and market costs, thereby increasing the profits of the company, while the licensee can enter new markets through the authorization of new technologies. A study by Poltorak and Paul (2004) shows that the patent royalty fee jumped from USD 15 billion in 1990 to over USD 110 billion in 2000 in the United States; in general, an effective intellectual property portfolio management can contribute 1% of sales revenue and 5% net revenue to companies; the value of the income from IP licensing fee of 1 USD is four to five times the value of 1 USD business revenue; more than 51% of the interviewed corporate executives believe that IP is an important driving force for mergers and acquisitions. On the whole, patent licensing not only brings cash benefits to the licensor, but also allows the product carrying the patent to enter a new regional or product market, enhancing the market standing of the licensor and patent strength. In addition, patent licensing can also bring more choices and benefits to consumers.

2.1.2 Patent license types

Since the patentee may not have the resources and conditions for maximizing the use of patents to obtain economic benefits, an important way for the patentee to extract commercial value from the patent is to sign a patent license agreement to permit the third party to enforce the patent. Nevertheless, in different types of patent licenses, the rights and obligations of the subjects of the agreement are quite different, so are their behaviors and strategies. At present, patent licenses are divided into Implied License, Contractual License and Compulsory License according to their source of power. They are also divided into Non-exclusive License, Exclusive License, Sole License and Cross License (Zeng, 2015).

(1) Non-exclusive License. It refers to a legal act in which the licensee obtains the permission from the licensor (the licensor here includes natural persons, legal persons or other organizations) to use and retain the patent rights stipulated in the agreement (including the license agreement with a third party based on the patent) within the agreed time period and geographical scope. In non-exclusive licenses, there may be several licensees in the same area at the same time, and the licensor himself may also use the patent. In general, if the agreement does not specify solo license, exclusive license or other special forms of license, it is presumed that the agreement belongs to non-exclusive license. Non-exclusive license has a relatively low royalty fee and weak exclusivity compared with exclusive license and solo license, which is because the licensor retains relatively more rights. When patent infringement occurs, the licensee's right to appeal as a stakeholder is limited, for example, the licensee has to obtain authorization from the patentee.

(2) Exclusive License. It refers to a legal act in which except that the licensor has the right to use the patent, no third party other than the licensee has the exclusive right to exploit the relevant IPRs within a certain period of time and territory. That is to say, exclusive license and solo license prohibit the licensor from signing a licensing agreement with the third party, and the difference between the two is whether the licensor reserves the right to enforce the IPR by himself. In exclusive license, there are two entities who have the right to use the patent within a certain period of time and geographical area, namely, the licensor and the licensee. Any infringement of the patent will result in loss for the licensor and the licensee. Therefore, when a patent infringement occurs, the licensee who has the right to be a stakeholder in a specific period and area will encounter less restriction, for example, the licensee may jointly sue with the licensor for patent infringement or sue on its own if the licensor does not sue.

(3) Solo License. It means that no third party other than the named licensee can exploit the relevant IPRs. The licensor is also excluded from exploiting the IPRs. Under the same conditions, solo license grants more rights to the licensee than the non-exclusive and exclusive licenses. The licensee has the monopoly right, so the royalty fee is higher. According to the data from the Licensing Executives Society International (LESI), compared with non-exclusive license, the royalty fee for solo license is 66% and even 100% higher. As

only the licensee is the legal entity to use the patent, it is the biggest victim when counterfeits of the patented product take up the market share. Therefore, in principle, each country stipulates that the licensee has the right to appeal independently as a stakeholder, that is, the licensee has the right to sue for patent infringement and obtain compensation in its own name.

(4) Cross License. It refers to a legal act in which market entities (two parties or more parties) grant rights to their IP to the other parties and become licensors and licensees of each other. In this case, the right to license can be exclusive or non-exclusive. In international technology trade, cross-licensing is a kind of contractual behavior in which commercial entities use patents of each other because of production needs, which is facilitated through commercial negotiations. Cross license is more and more widely used in business practice, which not only reduces the patent license fee, but also avoids the patent risk of market expansion (Zhu & Yang, 2008).

In addition to the above classifications, some researchers also categorize patent licenses according to the terms of the agreement. Cao (2007) divides the "colored clauses" in the patent license agreement into black, white and gray clauses. The black clause is exclusive, which is a restriction of competition; the white clause aims at reasonable guidance and restriction, and win-win cooperation; the gray clause has the function of reconciliation, which is different from the white and black clauses and is not subject to them. It does not have specific exemption clauses either.

2.1.3 Royalty fee types

The core issue of patent licensing is to determine patent royalty (including Royalty-Fee and Royalty Rate) (Gomulkiewicz, Nguyen, & Conway, 2014; Kong, 2017). In the field of patent licensing, one of the focuses of all parties is the calculation and payment method of royalty fees, which is also an important part of the patent licensing agreement.

(1) Types of IPR royalty fee. According to the calculation and payment method, the royalty fee mainly includes three types: fixed fee, floating fee and entry fee plus commission (Dong, 2013).

A. Fixed fee. A fixed fee refers to the total amount of the royalty fee determined by the parties in the licensing agreement, that is, lump sum fees. After determining the lump sum fee, it can be paid completely or partially. The calculation and delivery of such fees is relatively simple. For the patentee, the fixed fee has nothing to do with the licensee's profit.

The advantage is that the patentee does not need to worry about and care about whether the licensee's financial status is true, how the licensee uses the patent, or the risk of not receiving the royalty fee. For the licensee, if the profits from the licensed patent exceed the royalty fee, the excess is fully owned by the licensee. In addition, the licensor does not have the right to inquire about his accounts, thus reducing the risk of information leakage about the licensee's financial situation and other business information.

B. Floating fee. A floating fee is the most common. During the term of the contract, the licensee pays the royalty fee according to the agreed calculation method based on the actual sales volume of product, the number of uses, and the types and quantity of the patent. Although lump sum payments are easier to operate, in most license contracts, the parties still insist on a floating fee. The floating fee is not the same for each payment, depending on two floating factors: one is the commission fee and the other is the commission period. The calculation formula for the commission fee is:

$$\text{Commission} = \text{commission base} \times \text{commission rate}$$

In the above formula, the base of royalty fee is referred to as commission base, and commission rate is generally calculated as a percentage.

The commission period is the period during which the patentee charges the licensee. In general, the commission period expires when the term of the contract expires or the term of protection for the patent expires. In the case of a special agreement in the contract, the commission period may be terminated before the contract expires. The commission fee is the royalty fee paid by the licensee for each period, regardless of the commission period. In practice, the commission fee is often mixed with the floating fees.

C. Entry fee plus commission. In the process of determining the royalty fee, the parties also often agree to the payment method of agreed commission plus an up-front license fee (referred to as the entry fee plus commission), which is a combination of fixed and floating payments. The so-called entry fee, also known as upfront fees or initial fees, is the fee the licensee pays to the patentee within the period specified in the contract (such as when the contract comes into force or within a certain period of time after the licensee receives the first batch of information), which makes it have the characteristics of fixed fees. However, the entry fee is different from fixed fees in that it is only part of the royalty fee, and the licensee still needs to pay the floating fees. Compared with floating fees, if the floating fee is equal to the entry fee plus the total floating fee, the higher the entry fee, the lower the commission; the lower the entry fee, the higher the commission. Theoretically speaking, the entry fee the commission payment has the dual advantages of fixed fee and flatting fee payments, and should have greater feasibility. However, not all royalty fees can adopt this payment method, which is closely related to the technical perfection of the patent, the stability of the legal status, the economic ability of the parties, and the degree of trust between the parties.

2.1.4 Methods for determining royalty fee

In general, As Figure 2-1 demonstrate, there are many variables that affect the royalty fee, such as the sales revenue of the licensee, marginal profit, patent-related profit margins, technology development stage, product categories (such as general products or specific products), and licensed patent quantity and its combination. There are a number of researches on determining royalty fee (McGavock, Haas, & Patin, 1992; Degnan & Horton, 1997; Finch, 2001; Parr, 2009). As demonstrated in Figure 2-1, the parties in the patent licensing negotiation need to pay special attention to the marginal profit of the licensee and the commercialization risk of the product at different stages of technological development. The royalty rate is not only related to the maturity of the patented technology, but also the expected sales volume and the contribution of the patent. That is to say, on the one hand, the determination of the royalty fee must take into account the stage of technological development; on the other hand, the contribution of patents to the final commercial product or technology must also be considered. The patentees have to bear the risk that the sunk cost of developing the patent will not get market response, while for the licensee, the goal is to assess and minimize the risk of using the patent and bringing the product to market (Manus & John, 2012). The 25% Rule is a typical method for determining royalties in commercial practice, which was proposed by Goldscheider and Marshall (1971) after analyzing a large number of patent licensing cases, and has continued to improve in subsequent business practices and judicial precedent studies (Goldscheider, Jarosz, & Mulhern, 2002; Granstrand, 2006; Goldscheider, 2011, 2012). The rule is based on the “Rule of the Thumb” (a principle with broad application based on experience). Taking the technology-based patent licensing as an example, the rule finds that products manufactured under the licensing of IP, the operating profit can be roughly divided into 75/25, that is, in the operating profit from the licensed product or licensed technology, about 25% will return to the patentee. Nevertheless, in commercial practice, royalty fees usually cannot be determined by profit margins because licensors generally do not have access to the true marginal profit of the product. Therefore, the royalty fee is often determined by a certain percentage of the sales price of the product.

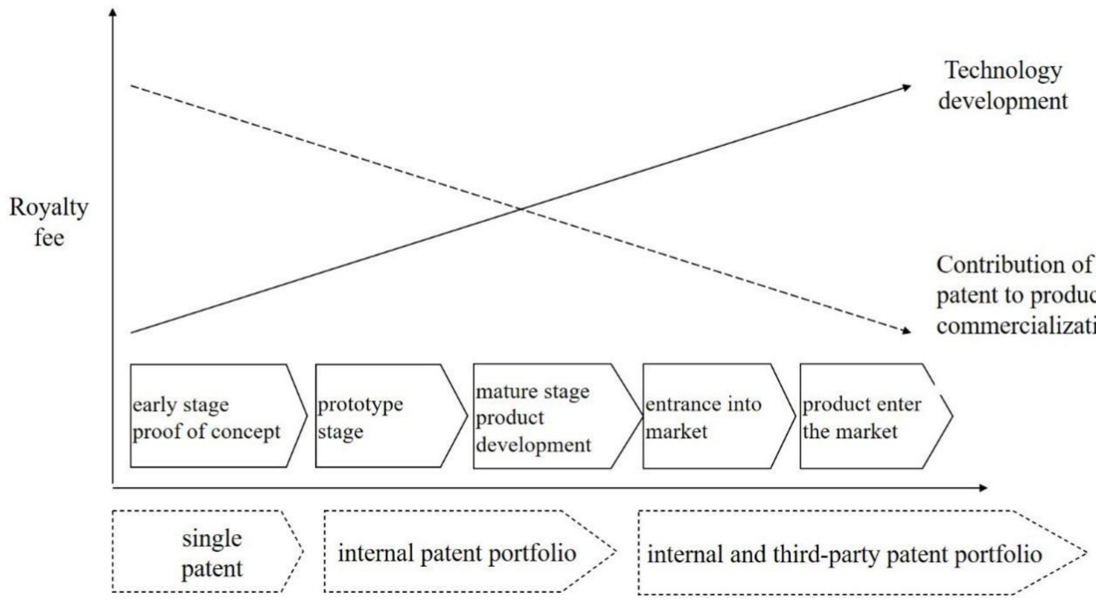

Figure 2-1 Factors affecting royalty rates

The key to the application of the “25% rule” is how to convert the profit ratio into the unit sales price ratio. Thus, in the royalty fee negotiation, the patentee needs to determine the expected cost, and obtain information on the expected market size, product price, manufacturing cost and management cost as much as possible. Usually, if the patentee has difficulty estimating the profit margin of the product, he can compare the similar IP licensing transaction and decide the corresponding royalty fee. If an approximate transaction can be found, the patentee can estimate the expected royalty fee income, calculated as:

Sales revenue × royalty rate % = expected royalty fee income

For the licensee, there is a greater chance of obtaining a reasonable royalty rate, calculated as:

Net sales × profit margin × 25% royalty rate = IP-related profit share

IP-related profit share /net sales = X% royalty fee based on net sales

It should be noted that in the case of Uniloc USA Inc. v. Microsoft Corp. in 2011, the United States Court of Appeal for the Federal Circuit made it clear that it no longer accepts evidence relying on the “25% rule”. In commercial practice, the determination of the royalty rates also depends on the characteristics of the product, such as whether it is a stand-alone Product or a compound product. For a stand-alone product or process, the royalty rates can be based on the unit product cost, unit weight, or unit sales; for a compound product or process, the royalty rates can take into account the contribution of the patented technology to the total manufacturing cost of the final product, or the premium income that the licensed manufacturer can obtain from the patent by comparing to a similar product that does not use the patented technology (i.e. an unmodified product). The entire market value rule cannot be simply applied to the compound product or process. In addition, factors such as inflation rate, interest and the prior investment of the licensee should be taken into an account for the determination of the royalty rates. In order to further promote the market share of the licensee, the progressive reduction of the difference can be used to determine the royalty rates based on the increase in sales revenue.

In fact, the factors affecting the royalty fees in the market are very diverse. Even with the same influencing factors, there are differences in the degree of influence in patent licensing cases between different patentees and licensees. Among the many patent infringement compensation cases, the representative case is the U.S. Georgia-Pacific Corp. v. United States Plywood Corp. Although the Court of Appeal for the Federal Circuit later did not recognize this case served as a method of calculating a reasonable royalty fee and determining the amount of patent infringement compensation, it regarded it as factors to be considered in conducting a reliable economic analysis. In this case, Judge of the United States District Court for the Southern District of New York Tenney listed 15 factors to consider in determining royalty fees for patent infringement, including (1) the existing royalty fees accepted by the patentee in other patent licensing cases; (2) the royalty rates paid by the licensee for the use of other patents; (3) the types and scope of the license, as exclusive or non-exclusive, or as restricted or non-restricted in terms of territory; (4) the patentee’s established policy and marketing program to maintain his patent monopoly, such as not licensing the third party to use the invention or granting licenses under special conditions; (5) the commercial relationship between the licensor and licensee, such as whether they are competitors in the same line of business in the same territory or in different territories; (6) the effect of selling the patented specialty in promoting sales of other products of the licensee; (7) the duration of the patent and the term of the license; (8) the popularity, profitability and commercial success of the product made under the patent; (9) the utility and advantages of the patent property over the old products, modes or design; (10) the commercial embodiment of the patented invention, including the benefits obtained by the licensor or other licensees who have used the invention; (11) the extent to which the infringer has made use of the invention and the value of that use; (12) the proportion of the royalty fees in the profit or selling price when using the invention or similar invention in the same or equivalent business; (13) the portion of the realizable profit that should be credited to the invention as distinguished from non-patented elements, the manufacturing process, business risks, or significant features or improvements added by the infringer; (14) the opinion testimony of qualified experts; (15) at the time the infringement began, the reasonable royalty fee or rate that a licensor (such as the patentee) and a licensee (such as the infringer) would have agreed upon.

As shown in Table 2-1, in non-exclusive license of commercial practice, Poltorak and Paul (2004) suggest that it is common practice for royalty fee to account for about 5% of sales revenue.

Table 2-1 Royalty rates for different industries under non-exclusive license (proportion of royalty fee to sales revenue)

Industry	Average(%)	Median(%)
Cars	4.7	4.0
Chemicals	4.7	3.6
Computer hardware	5.2	4.0
Computer software	10.5	6.8
Consumer goods	5.5	5.0
Electronics	4.3	4.0
Food	2.9	2.8
Internet	11.7	7.5
Health care products	5.8	4.8
Machinery	5.2	4.5
Biomedicine	7.0	5.1
Semiconductor	4.6	3.2
Communication	5.3	4.7

Source: Poltorak and Paul (2004)

2.2 Basic issues of patent licensing theory

2.2.1 The theoretical appeal of patent licensing practice

Early empirical research has shown that patents are only one way to protect technology investments and are often not the most important. One typical research is the Yale Survey (Levin et al., 1987), which shows that in most high-tech industries (excluding chemistry), patents are not as effective as other alternatives such as leading in time, technical secrets and complementary assets. In addition, the purpose of companies using patents is far from being the legal barriers to block the competitors.

Arora (1997) is one of the earliest to propose that patents are one of the mechanisms used by companies to obtain innovative benefits, which stems from the growing size of the technology market over the past two decades (Arora, Fosfuri, & Gambardella, 2001; Athreye & Cantwell, 2007) The growth of the technology market indicates that companies are increasingly considering licensing as an important choice to profit from their IP. Grindley and Teece (1997) find that most companies in the high-tech industry, such as AT&T, IBM, Texas Instruments, and Hewlett-Packard, regard patent licensing and cross licensing as an important part of their business strategy. Many companies such as IBM, Texas Instruments, Hitachi, Dow, Kodak, Eli Lilly, Procter and Gamble have introduced technology licensing policies and have benefited from patent licensing. A study by Degnan (1999) demonstrates that in 1996 US companies charged more than USD 136 billion in royalty fees. Research by Anand and Khanna (2000) suggest that between 1990 and 1993, patent licensing of strategic alliances occur in selected industries: 18% in the computer industry; 24% in the electronic industry; and 38% in the chemical industry. Joint venture licensing has the highest incidence in chemicals, most of which involves some exclusivity clauses; patent licensing is also more common between R&D institutions and manufacturing companies or sales companies, that is, it occurs in the processes of manufacturing and sales. Cross-licensing is the most common in computers and electronics, which mostly occurs after R&D is completed, and litigation is an important way for licensors and licensees to reach licensing agreements.

The practice of patent licensing also plays a pivotal role in the development and improvement of the core competence of IPRs in China. Song, Wan, and Ren (2010) points out that although China’s progress in strategic emerging industries can basically be at the same level compared to those of developed countries, China’s IPR, especially core technology IPRs, faces competition from developed countries. Wang and Ren (2009) conduct a survey on the Patent Demonstration Enterprise in Zhejiang province in 2008, and find that the following situation has a very negative impact on Chinese companies' ability to improve their independent innovation: a large number of Chinese companies have obtained innovation achievements through self-development or introduction of talents, but very few companies conduct secondary development, or purchase patents or technical secrets. Gao and Luo (2014) analyze the dynamics of innovation and transformation in China from the perspective of the total amount, level of distribution and industry distribution of patent license, and suggest that China already began to show signs of innovation and transformation in 2008. Before 2008, the number of patents granted by domestic patent holders in China was extremely small, most of which are low-grade design patents; since 2008, the amount of patents granted by domestic patent owners in China has increased substantially, and most of them are utility patents and are distributed in operation and transportation, mechanical engineering, agricultural light medicine, and electrical industry. In addition, from the perspective of the change in patent holders, foreign patent owners granted most of the patents before 2008; since 2008, patents have been mainly granted by domestic patent holders, revealing that China’s independent innovation capability has improved significantly. Li and Gu (2014), Wang, Liu, and Pan (2011), and Tan, Liu, and Hou (2013) examine university patenting, and suggest that licensing patents to companies is an important way for colleges and universities to realize the value of the patents. Shen, Xiong and, Peng (2011) find that by the use of revenue-and-expense sharing contracts and the coordination of patented-related closed-loop supply chain, the original manufacturer could share the economic benefits of remanufacturing through licensing fee. Obtaining new technology through technology licensing can not only reduce risk, but also increase the profitability of the business. Thus, in recent years, technology licensing has become a common strategy adopted by enterprises in many industries. As mentioned earlier, technology licensing allows companies to acquire external knowledge to enhance manufacturing technology, while also allowing licensors to increase profits through patent rents. Patent-based IP licensing has become an effective way to increase corporate profits and balance international trade balances for countries. Kline (2003)’s research demonstrates that as patent licensing becomes an important way for companies and universities to realize their patent value in business practice, patent licensing has become more and more concerned by academic circles and has become an important research area in management economics and law.

2.2.2 Royalty fee and its strategies

The reason why patent licensing has become an important area of research in management economics is that patent licensing is one of the few ways to observe and characterize technology transfer between firms (Grindley & Teece, 1997). Meanwhile, the structure and motivation of the licensing contract helps to understand the intensity of anti-monopoly and IP protection and its policy adjustments. The main topics of the early theory of industrial organization focusing on patent licensing issues include: (1) the relationship between the number of licensees and the industrial structure (Arrow, 1962; Kamien & Tauman, 1984; Katz & Shapiro, 1986); (2) the impact of the license agreement between the licensor and the licensee on value creation and value distribution (Kamien & Tauman, 1986; Gallini & Wright, 1990); (3) conditions and strategic choices of ex ante and ex post licensing (Gallini, 1984; Gallini & Winter, 1985; Shapiro, 1985; Gallini, 2002; Bessen & Meurer, 2009); (4) the impact of continuous innovation and discontinuous innovation on patent licensing strategies (Green & Scotchmer, 1995).

In many literatures on patent licensing, the central issue of discussion is the optimal licensing strategy adopted by innovators. Arrow (1962) and McGee (2011) introduce the concept of a derived demand for a license, and suggest that licenses may be auctioned considering the royalty method. Kamien and Schwartz (1982) take Arrow's research one step further by comparing the tactical choices of a fixed fee or a per unit royalty in the oligopolistic industry; Kamien and Tauman (1986) analyze the optimal licensing strategy by comparing the fixed fee license contract and the royalty fee license contract. Katz and Shapiro (1985, 1986) study auction licensing methods and find that non-fixed royalties are generally more acceptable than fixed fees in cases where there is a significant risk of commercial failure in innovation. Therefore, most license contracts adopt royalty licensing (Calvert, 1964; Taylor & Silberston 1973; Macho-Stadler, Martinez-Giralt, & Perez-Castrillo, 1996; Jensen & Thursby 2001; Bessy, Brousseau, & Saussier, 2003).

Most of the literature sets different application scenarios when analyzing the innovator's optimal licensing strategy. Overall, most of the literature considers the innovator's optimal licensing strategy in the context of cost reduction. From a subjective status perspective, innovators may be internal innovators or external innovators.

(1) Patent licensing research for external innovators. Early literature such as the research of Kamien and Tauman (1984, 1986), Katz and Shapiro (1986) and Kamien, Muller,

and Zang (1992) show that for external innovators, fixed fee or an auction is more profitable than running royalties. Wang (2002) build a multi-stage non-cooperative game model under the assumption of external innovation. This model discusses the patent licensing strategy of process innovation on the basis of cost reduction, and the conclusion is that for the patentee, compared to fixed fee or an auction, the proposed licensing fee method can bring more benefits, so is the market price and the licensee's payment. Similarly, the auction license will bring more payments to the patentee than the fixed fee. In terms of consumer surplus and social welfare, fixed fee licensing is slightly better than auction licensing, and auction licensing is obviously superior to royalty licensing. Erutku, Freire, and Richelle (2007) study the fixed fees and exclusive licensing contracts in the context of cost reduction. This study assumes that there exist two companies that were in two different product markets, and show that companies rely on three factors to obtain the same revenues as a monopolist in each market: small pre-innovation equilibrium, high degree of substitutability between the goods, and good quality of the innovation. Under such conditions, innovators do not need to adopt the non-linear royalty strategy proposed by Erutku and Richelle (2006, 2007). At the same time, fixed fees and exclusive licensing contracts will reduce benefits. If the innovation cannot reduce the marginal cost of the licensee, the price of the product will increase as a duopoly will develop into a monopoly. On the basis of a Cournot model, Erutku, Freire, and Richelle (2007) came to a conclusion that in both cases, regardless of the innovation size, the number of companies in the industry, the degree of product differentiation, innovative technology will be licensed to all enterprises. Moreover, this study internalized R&D investments and found that the lower (higher) the technical opportunity is, the more (less) the R&D investment is spent by the patentee as an internal innovator. Sen and Tauman (2007) study the optimal combination of royalty with auction for an outsider innovator and an inside innovator in an oligopoly. Different from two-part tariff licensing, in the combination of royalty with auction, the fixed fee is decided by the auction and non-exclusive license is optimal. In addition, Sen (2005), Sen and Tauman (2007) also discussed issues regarding the incentives to innovate and found that for an outsider innovator, innovation forwards and innovation backwards bring more profits, so the outsider innovator is more willing to invest in R&D. Based on the vertical market hypothesis of Kamien and Tauman (1986) and the research by Arya and Mittendorf (2007), Chang, Hwang, and Peng (2013) propose a three-period game model using the subgame perfect Nash equilibrium (SPNE) concept. The model analyzes the case where an outsider innovator licenses his cost-reduction technology to one or two downstream vendors by adopting a fixed fee or a royalty, and the two downstream vendors participate in the homogeneous Cournot competition. The literature finds that for an outsider innovator, the optimal licensing strategy is to adopt non-exclusive royalty contract. In the case of small innovations, the licensing behavior of the outsider innovator leads to low social welfare; in a vertical market, outsider innovators prefer intermediate product manufacturers to adopt uniform licensing prices rather than differential pricing.

Sandonis and Fauli-Oller (2006) analyze when facing a downstream duopoly, whether the upstream external innovator such as a laboratory “prefers to license the innovation as an external patentee or to merge with one of the firms in the industry” so as to achieve vertical integration. Under linear demand and Cournot competition, the literature found that the vertical merger is more profitable for the innovator when the innovation size is small, whereas it “increases welfare only for significant innovations” (Sandonis & Fauli-Oller, 2006). Ali and Gittelman (2016) use patent and licensing data from two famous Academic Medical Centers and analyze whether teams across basic and clinical research are more efficient at licensing than teams composed of inventors from only one domain. The literature adopts the Hazard Model and finds that Teams of clinical researchers (MDs) are more likely to license the inventions than teams of basic researchers (PhDs), whereas teams that include MDs and PhDs are less likely to license inventions. This research has made the translational model of combining experts to bridge different domains very important.

Kamien and Tauman (1986), and Kamien, Muller, and Zang (1992) analyze the licensing strategy of cost-reducing innovations by introducing Bertrand's differentiated duopoly model. Muto (1993) builds a horizontal differentiated duopoly model, compares three methods of licensing, namely, fixed fee, royalty and auction, and concludes that under non-drastic innovation, royalty licensing is the optimal licensing strategy. Poddar and Sinha (2004) propose a spatial framework based on Hotelling linear city model, and find that under drastic and non-drastic innovation, for an external innovator, royalty licensing is always superior to auction and fixed fee licensing.

Under double informational asymmetry and non-drastic innovation, Antelo (2003) studies licensing behavior of the specialized process design and engineering firms (SEFs) that do not have the capacity to produce (that is, they could not rely on their own to realize commercialization of research results) and discusses the licensing scheme adopted by the patentee “owning a new production process whose value is unknown ex ante”. The model assumes that the patentee must license the new technology to those who need to use the patent in order to make a profit, and that all potential licensees have manufacturing costs. Before contracting, the technology is unknown to each potential licensee, and the patentee cannot observe “outputs of the potential licensees”. The research shows that SEFs (external innovators) prefer lump-sum fixed payments to per unit royalties.

Antelo (2009) explores the choice of royalty fee and contract duration of an upstream patent owner without production capabilities and its impact on opportunistic behavior under asymmetric information by building a two-period game model. The conclusion of the study is: in the first period, in the case of obvious differences in production costs, the patentee prefers to adopt a series of short-term contracts instead of a long-term contract, and the high- and low-cost companies pay the same royalty rates; in the second period, the royalty fee for the high-cost companies will decrease, but it will grow for low-cost manufacturers so as to increase the expected the total output and licensing income. Overall, as information evolves from incomplete to complete, unlike the usual understanding, royalty fees will not decrease over time. This strategy helps to improve social welfare.

Erkal (2005) considers “the licensing of cost reducing innovations between firms producing in a differentiated duopoly”. If the companies are horizontal competitors, the licensor is faced with a trade-off between increased competitors and increased license revenue when making licensing decisions. On the one hand, technology diffusion can potentially increase consumers' benefits from using the innovations. On the other hand, licensing agreements that companies use to exchange their technologies may result in anti-competitive result and reduced welfare. Erkal’s study analyzes the optimal licensing strategies for three industries, including industries where imitation is likely to occur and the companies tend to adopt fixed licensing fees, industries where “technology transfer deals are characterized by asymmetric information”, companies tend to have royalty licensing, and industries where the companies do two-part tariff licensing. It is necessary to distinguish between homogeneous products and differentiated product for industry-oriented licensing policies; the antitrust authorities should also distinguish between actual competitors and potential competitors. This literature also discusses collusive licensing, and the author believes that compared to royalty licensing and no licensing, collusive licensing may result in greater social welfare. For collusive licensing between potential competitors, the antitrust authorities should adopt a tolerant attitude. The study reveals that the public is more inclined to encourage technology transfer in the context of innovation breakthrough and product differentiation.

Wang (2011) conducted research on how to choose the optimal patent licensing strategy by comprehensively evaluating the strategies (floating, fixed, and ranging license) the innovators may take, innovation level and the type of network externalities. The study shows that how to choose the optimal licensing strategy is affected by external factors.

Different from the previous research on the optimal per-unit two-part licensing scheme, Colombo and Filippini (2015) discuss an optimal ad valorem two-part licensing within a differentiated Bertrand duopoly where the innovator is a downstream producer and conclude that compared to ad valorem contracts, per-unit contracts are favored by the patentee, because in the case of price competition, the per-unit royalty has a stronger strategic impact than the ad valorem royalty. However, the social welfare under ad valorem contracts is higher than that under per-unit contracts. The literature is based on the generally accepted three-stage game analysis framework constructed by Kamien and Tauman (1984), and compares the incentives for private and social innovation from the use of the inventions by the licensed downstream producers who have an independent research lab.

Alston and Plakias (2014) use the licensing of new apple varieties as an example to study the optimal licensing choice for public universities in the United States. Unlike the past simple maximization of patent income, the literature compares “monopoly licensing and two oligopoly licensing scenarios”, uses the trademark as a product quality signal when constructing a patent licensing model, and considers social welfare objectives at the same time. Through data simulation, it finds that if consumers are insensitive to price but sensitive to brand consumption, exclusive licensing will result in higher consumer surplus and social welfare.

Based on differentiated pricing and remanufacturing patent licensing where competition exists, Tian and Meng (2017) find that: (1) under fixed fee licensing and per unit licensing, as the tendency of consumers to pay increases, the new product output of the producer decreases, and the yield and recycle rate of manufactured products increase. Meanwhile, as the probability of recycle competition grows, the new product output increases and the yield and recycle rate of manufactured products decreases; (2) fixed fee is preferred by the manufacturer to the per unit royalty under differentiated pricing and two licensing strategies, because under the fixed fee, the total market output and recovery rate will be greater, which is more favorable to the environment and consumers, regardless of the consumer's acceptance level of remanufactured products, and the competition between different recycling channels of used products.

From an organizational perspective, Baldini (2010) discusses royalties' incentive mechanism and effect of universities, including the relevance of the sharing mechanism of the inventors and departments to the university's patenting activity. The study of patent behavior of universities by management scholars originates from assessing the impact of academic contributions on the economic development of the host country (Baldini, 2006). In particular, the implementation of the Bayh-Dole Act of 1980 in the United States is seen as the basis for university-industry integration and development (Jaffe, Kamionkowski, & Wang, 2000), which has led to extensive discussions on the university's patent behavior and performance among management scholars. For instance, Henderson, Jaffe, and Trajtenberg (1998) uses the USPTO data from 1965 to 1988 to analyze the impact of the institutional change and finds that when research spending triples, the number of university patents grows 15-fold. Later, the focus of scholars shifts from the amount of university patents to the influential factors of patent behavior. For example, Debackere and Veugelers (2005) reveal that the organizational arrangements of patent-related knowledge creation institutions undoubtedly affect the willingness of different participants to participate in patent activities. The establishment of technology transfer offices (TTO) is undoubtedly a comprehensive reflection of improving university patent behavior and its performance, including the development, diffusion and utilization of patent policies and strategies, industrial linkages and licensing behavior management, as well as the organization of different university entrepreneurship forms (Louis et al., 2001; Jensen, Thursby, & Thursby, 2003; Rasmussen, 2008; Chang, Hu, & Lin, 2013).

Since then, researchers have expanded their research focus to licensing incentives. Given the importance of university research for the long-term economic development, licensing incentive research is valuable for university patent behavior. On the one hand, many studies have shown that royalty incentives are consistent with the university research spending and performance over the long-term (Gomez-Mejia & Balkin, 1992; Makri, Lane, & Gomez-Mejia, 2006). On the other hand, given the diffusion of university science and knowledge, the research results on the effect of royalty incentives are different from the public perception. For instance, based on the patent data of Italian universities from 1988 to 2002, Markman et al. (2004) finds that the higher proportion of universities sharing license fees with inventors and their departments, the more patents the researchers and their departments will create. In addition, some organizational arrangements have positive impacts, such as efficient management processes, the measures taken by the university to use the patent and the effectiveness of TTO.

(2) Patent licensing research for inside innovators. Based on the homogeneous Cournot model, Wang (1998) finds that for a non-drastic innovation, the patentee prefers royalty licensing to a fixed-fee licensing. Kemien and Tauman (2002) extend Wang's study, expanding the number of firms in the market from two to many, and conclude that under fixed fee, royalty and auction licensing, the optimal licensing strategy depends on the number of firms in the industry. Wang (2002) constructed a horizontal heterogeneous Cournot model, and discusses licensing strategies. The conclusion is that when the goods are imperfect substitutes, the licensor may adopt royalty licensing for drastic innovation. Sen (2005) analyzes the optimal licensing strategy for licensor with a given number of licensees. Under fixed-fee licensing contracts and auction licensing contracts, the innovator's revenue is a step function, making royalty licensing a better choice. In the homogeneous Cournot model constructed by Arya and Mittendorf (2007), there is an upstream firm producing intermediate products and two downstream firms producing final products. The patentee is an inside innovator providing cost-reducing technology in the final product market, and the upstream firm can adopt discriminate pricing for downstream firms. The conclusion of the literature is that although the licensor does not prefer fixed-fee licensing, the combination of fixed-fee and royalty licensing is still valuable for the inside innovator to win double marginal benefits.

Filippini (2005) analyzes the optimal licensing contract for revenue maximization for the patentee under two circumstances: one, the patentee is an outsider, that is, the patentee is not a competitor in the product market; the other one, the patentee is an insider, and is a competitor in the product market. Under the full information framework, if the patentee is an external innovator, fixed-fee licensing is superior to royalty licensing (Kamien & Tauman, 1986; Katz & Shapiro 1986; Kamien, Muller, & Zang, 1992). It is more profitable for the external innovator to license cost-reducing inventions to monopolistic industries by auctioning off a certain number of patents (Kamien & Tauman, 2002). Wang (1998) and Kamien and Tauman (2002) analyze the case "where the patentee is an insider and competition in the output market is Cournot", and finds that royalty licensing is superior to fixed-fee licensing, and the license does not affect the consumers but improves social welfare. This analysis examines the optimal linear licensing and social welfare implications of patent holders as Steinberg leaders in the product market when the innovator is an insider, and finds that: 1) the licensing contract that can maximize the patent owner's profit is the royalty licensing contract; 2) the cost reduction brought by the patented technology is less than the optimal royalty rate, and increases with the number of competitors; 3) the optimal licensing maximizes the possibility of technology transfer, but may reduce social welfare and make consumers worse off; 4) the innovators profit from "capacity commitment", and the more competitive is the output market, the greater the license revenue becomes.

The research results of Wang and Yang (1999) show that regardless of whether the innovation is drastic or non-drastic, as long as the difference between products is not too large, royalty licensing is superior to fixed-fee licensing. Poddar and Sinha (2004) reveal that under the condition that the innovation is non-drastic, innovators prefer royalty licensing; in the case of a drastic innovation, innovators are often reluctant to license their technologies. The above studies ignore the fact that the licensor may produce intermediate products in the real world. Arora, Fosfuri and Ronde (2003) build a patent licensing model for an inside innovator to explain the importance of licensing in technology-intensive industries as a means of profiting from the innovations. Due to the exclusive nature of patents, the traditional interpretation of corporate licensing motives is often based on the idea that the firms lack the ability to exploit the innovation compared with the potential licensees, or they intend to establish their technology as a de facto standard, especially in the case of significant network externalities (Teece, 1986). However, Grindley and Teece (1997), Degnan (1999), Anand and Khanna (2000), and Rivette and Kevin (1999) examine the industries and strategic alliances in chemicals, biotechnology, software, computers and electrical machinery, as well as firms such as IBM and Texas Instruments, and find that a large number of licensing in these industries and firms occur between potential competitors. Therefore, this literature considers the interaction between the technology market (manufacturers transfer technology through licensing) and product market (manufacturers sell products), and builds a licensing model to explain the licensing behavior of the firms from a brand-new perspective, especially the fact that the competition in product market provides strategic incentives for licensing, that is, why and how to license. Although licensing leads to revenue reduction due to increased competition, it can increase the licensor's share of the industry's profits. Thus, when there are two or more companies that have alternative proprietary technologies, the relevant companies will find that their respective earnings or common benefits are significantly higher than when there is no licensing.

According to Hausman and Leonard (2007), the patentee as an inside innovator is always faced with a dilemma when considering licensing the patent to a competitor, that is, profit loss because of increased competition. Therefore, obtaining a royalty that is sufficient to cover the loss is a prerequisite for the innovator to license its patent. The minimum acceptable royalty is determined by the competitive impact of the products of the potential licensees on the patentee's products.

Zhang and Kou (2006) analyzes the relationship between the market structure of licensed companies, the costs of accepting patent licenses, and the licensee's innovation ability. The study shows that the patentee licenses the patent to the downstream manufacturers by means of incentives, even if the final products of the licensed downstream producers are competitive with the patentee as long as the licensee has a cost advantage. However, the amount of fees that the downstream producers can accept is decided by their R&D capability. Specifically, assume the value of R&D capability of the downstream producer have a threshold: if the licensee's R&D capability is higher than the threshold, the innovation capability is inversely proportional to the actual royalty fee, that is, the better the innovation capability, the lower the payment. The market structure in this case is also beneficial to the downstream firms. If the licensee's R&D capability is lower than the threshold, the innovation capability will not affect the royalty fee or its market structure.

Su and Peng (2010) analyzes the game generated by patent licensing of duopoly companies and investments in R&D, and compares the performance of royalty licensing according to the output of product with the fixed-fee licensing. The above research is based on the dynamic game approach to analyze how to choose a licensing strategy for a competitive enterprise and the decisions made when investing in a patented technology. Su and Qin (2015) also discusses patent licensing of an inside innovator in a triopoly market, based on which he analyzes the probability of such enterprises in investing in new technology research. It also conducts a game analysis on patent licensing when such companies face two other enterprises with different levels of competitiveness. Under such condition, the inside innovator and the company with strong competitiveness have the same marginal cost. The results show that when patent licensing cannot stop the company with stronger competitiveness from investing in new technology R&D, the total profit of the market and social welfare will decrease. In contrast, the total profit and social welfare is determined jointly by these aspects: the amount of money the stronger company will invest in new technology R&D, and the cost of the weaker company to achieve the marketization of patented technology.

Based on network externalities and innovation level, Xiao, Wei, and Wang (2011) analyzes the three strategies for innovator (including no licensing, running licensing and fixed-fee licensing) to determine the optimal choice. The results show that if the network externalities are relatively weak, fixed-fee licensing is the optimal choice; if the network externalities are moderate, when the innovation degree is high, fixed-feel licensing should be chosen, whereas when the innovation degree is low, running licensing is superior.

Arora, Fosfuri, and Rønde (2013) discuss and compare the impact of centralized business units and decentralized business units on corporate patent licensing decisions from an organizational perspective in the context of internal innovation. This study constructs a three-stage non-exclusive patent licensing decision model based on the monetary benefits and private benefits within large risk-neutral corporations that have patent licensing business unit. They find that when the business unit leads the license, the license incentive is lower than the total production revenue; the higher the total production income is, the weaker the license incentive becomes; when a level of general production income level is defined, the higher the importance of personal income becomes, the weaker the willingness to license will be; licensing gains (including cash income and personal income) will also decrease. The model shows that when the business unit is decentralized, the enterprise adopts a non optimal value maximization incentive method, making the licensing incentive weaker than the production incentive, and the license business unit loses potential profitable transactions. The efficiency problems of the centralized business unit model are different. As it is impossible to assess the rent dissipation potential of a deal, the centralized licensing unit may commit two types of errors, that is, agreeing on unprofitable transactions, or refusing potentially favorable transactions.

Recent research has begun to integrate the above four scenarios. In order to study the impact of patent licensing policies, Rey and Salant (2012) construct a vertical correlation market with one or more upstream patent holders licensing to downstream vendors. Their study concludes that when there is only one upstream patentee's monopoly, the number of licenses will increase, and the downstream competition will be strengthened, thereby weakening the profits of downstream manufacturers. When there are multiple upstream patent holders, the license fee method will not only increase the cumulative license fee, but also reduce the price impact of downstream manufacturers on consumers. Similarly, Layne-

Farrar and Schmidt (2010) discuss different types of licensing contracts in vertically related markets, including cross-licensing agreements and non-linear licensing fees. Kishimoto and Muto (2012) used the Nash bargaining process to build a Cournot duopoly market, verifying that patent owners negotiate with their competitors a cost-reducing innovation strategy. The model considers two licensing methods, fixed fee and royalty fee. The result proves that for both companies, for both drastic and non-drastic innovations and from the perspective of social welfare, the royalty fee is more optimal than the fixed fee strategy. However, it is noticeable that from a welfare perspective, there may be a tendency for consumers to have a fixed license fee.

Ren and Zhang (2016) considers the impact of product price changes on consumer demand, and constructs a three-stage game model based on the Hotelling model. The results of this model show that the main factors affecting social welfare level, consumer surplus and innovation incentives are: competition in the innovation market and the product market, innovation size, and the dynamics of consumer demand. Each one of the common license payment strategies (fixed-fee licensing and royalty licensing) have their own advantages. The former enables licensing fees to help production expansion and technology diffusion, while the latter maximizes the number of licenses offered by licensors. Therefore, the innovator should integrate various options to make the best of the licensing strategy; the organization that exercises the decision-making power should comprehensively study the rules of the countermeasures based on the license itself, striving not to affect the consumer and making efforts to increase the ratio of output and investment in technology in the market so as to enable more people to benefit from the technology.

2.2.3 The impact of patent licensing on innovation

Some studies have shown that the patent system faces the risk of retarding innovation (Jaffe & Lerner, 2004; Merrill, Levin, & Myers, 2004; Bessen & Meurer, 2009). When research is continuous and cumulative, the stronger the patent is, the more it prevents subsequent innovation (Nelson, 1987; Merges & Nelson, 1990; Green & Scotchmer, 1995; Bessen & Maskin, 2000). The most prominent problem is the extent to which patent thickets block innovation. Shapiro (2013) defines the patent thickets as "a state in which enterprises have to navigate through in a heavily overlapping, airtight intellectual property network in order to truly commercialize new technologies." The patent thickets increase the transaction costs of licensing for existing patents, making it difficult to benefit R&D investment. This research was concentrated in the work of Boldrin and Levine (2008) at the University of Washington, St. Louis.

Aoki and Schiff (2008, 2010) construct a licensing model to discuss the impact of a clearinghouse created with the objective of reducing transaction costs on licensing fees and its benefits. The study finds that the use of non-cooperative licensing fees by IP owners can lead to a tragedy of the anti-commons, but the profitability for downstream manufacturers helps offsetting this effect. In downstream markets where higher equilibrium licensing fees are present, the reduction in licensing costs can lead to negative welfare impacts, which can adversely affect the situation of IP owners and consumers.

At the same time, many scholars are concerned about the incentives on technology licensing for corporate innovation (Salant, 1984; Gallini & Winter, 1985; Mukherjee & Mukherjee, 2013). The basic consensus is that a high R&D level motivates more companies to license their innovations. Chang, Hwang, and Peng (2013) construct a three-stage (R&D, technology licensing and output) oligarchy game model to analyze the impact of technology licensing on corporate innovation investment and social welfare in the context of cost-reducing R&D investment. Unlike other insider licensing scenarios (Wang, 1998; Kamien & Tauman, 2002), this study focuses on contract optimization (leading to conclude that licensing is conducive to the promotion of social welfare (Salant, 1984; Gallini, 1984; Gallini & Winter, 1985), and takes the R&D investment as an internal variable. Two basic conclusions are deduced: first, when R&D efficiency is high (low), R&D investment under licensing is lower (higher) than without licensing; second, when R&D efficiency is high (low), the social welfare under the licensing situation is higher (lower) than the non-licensing situation. According to the findings of this study, since licensing is not conducive to innovation and will reduce welfare, it should not be encouraged. Especially when R&D efficiency is high, licensing should be avoided as much as possible. Bao (2004) analyses patent licensing from two perspectives. One is from the perspective of microeconomics, analyzing patent licensing transactions. The conclusions are that the Pareto improvement of economic efficiency is reflected in the patent licensing transaction, and that how to allocate economic resources and choose the optimal licensing strategy should be decided under symmetric information. The other is the use of patent licensing transactions to analyze the incentive mechanism for R&D activities, finding out that the rational use of patent licensing transactions can greatly enhance the ability of the licensors to obtain profits, stimulating technological vitality, all of which are based on a strong patent protection system. Wang

(2011) uses the technology licensing data of 186 local Chinese enterprises from 2000 to 2003 for a quantitative analysis. The results show that technology licensing improves the independent innovation ability of the imported enterprises. Wang (2011) further analyzes and finds that the alienee companies benefit a lot from technology licensing, including new knowledge factors that make the knowledge institutions more diversified and more closely match the market structure; the long-term cooperative relationship with the licensors is established, through which is it easier to obtain knowledge spillovers from the licensor; the transferee promotes R&D investment in technology learning through digestion and innovation. Colombo and Filippini (2014) take linear demand as an example, and find that under medium R&D output levels, non-licensing leads to more R&D consumption and higher social benefits. Correspondingly, when R&D efficiency is high, the license should not only be excluded, but should be encouraged because it increases social welfare. Gilbert and Kristiansen (2018) focuses on the licensing contract enforcement and explores the impact of incomplete enforcement (or weak enforcement) on contract design, competition, and innovation (impact on corporate licensing behavior and market performance). The study assumes that there is an upstream innovator and two downstream companies, and the upstream company has developed a new technology that can reduce the marginal cost of production. There are differences in the end products of the two downstream companies, which makes the upstream enterprises have the power to license two downstream enterprises. The study finds that licensing facilitates technology transfer and innovation. However, the imperfect characteristics of licensing contract execution will affect the company's licensing behavior and market performance. If there exists competition between licensees, a strict licensing fee approach maximizes the licensor's benefits. While imperfect contract execution reduces the profitability of upstream producers, weak execution also lowers product prices, thereby increasing innovation for downstream manufacturers and, in some cases, increasing economic benefits.

Clifford (2016) is concerned with two issues that plague existing patent systems: “the use of ‘haystack’ patent portfolios rather than individual patents and the overwhelming abundance of newly issued patents” (like the needle in a haystack). Therefore, Clifford (2016) suggests classifying the patents into two types: patents derived from progressive inventions and patents doing “more significantly advance knowledge”. The former is termed as a “field-licensed patent” and the latter, “individually-licensed patent”. For mandatory licensing of high royalty rates, the factors that determine the royalty fee include: “1) Rewarding inventors;

2) Encouraging more innovation; 3) Field of innovation; 4) Low value of most patents; 5) Age of the patent; 6) Projected use by the licensee".

Choi (2002) constructs an incomplete contract model of the licensing relationships to analyze the dynamic impact of licensing on R&D competition in the innovation market and to examine the rationale of "grant-back clauses", especially how future competition distorts licensing relationship and how the "grant-back clauses" can mitigate this negative effect. In addition, the study also discusses the effectiveness of grant-back antitrust, that is, the "grant-back clauses" may have an adverse effect on competition because the clauses reduce the incentives for patent holders to invest in R&D and thereby "limit rivalry in innovation markets".

In general, licensing is regarded as a voluntary act by the inventor to allow others to use their superior knowledge to win part of the profits from the innovation (Kamien, Muller, & Zang, 1992). Enterprise licensing is often due to the lack of resources for the commercial exploitation of IP, such as the lack of complementary assets that exploit the potential value of technology (Teece, 1986), or the lack of sufficient financial resources to serve all geographic markets. From the perspective of using other corporate resources, licensing is a mechanism for broadening geography and product markets. Fosfuri (2006) collects 107 product data from 153 large pharmaceutical companies in the United States, Canada, Japan and Europe during 1986-1996, and empirically analyzes the factors affecting the technology royalty rates. The results show a significant inverse U-shaped relationship between the technology royalty rate and the number of potential technology suppliers, and the technology royalty rate is negatively correlated with the market share of the licensor and the degree of differentiation of technology products.

Nevertheless, licensing also poses substantial risks to inventors, such as piracy risks, loss of control over the use of technology, and dependence on the operation revenue of others (Dratler, 1994). In addition, licensing can trigger new competition due to the transfer of know-how ownership to potential competitors. After all, licensing others to use their IP makes it possible for the latter to develop new products, which leads to the elimination of licensed technology, that is, the so-called boomerang effect. Under such circumstances, it is not surprising that a large number of empirical studies have shown that companies usually are not willing to license their cutting-edge technologies because it may provide the knowledge necessary for competitors to develop better technologies (Davies, 1977). In response to this dilemma, a "technical return" clause is added in the licensing contract to requires the licensee to share any progress or improvement of the licensed technology with the licensor, which can compensate the licensor's loss to a certain extent (Shapiro, 1985; Rothstein & Willgohs, 1988). As reported by Caves, Crookell, and Killing (1982), 44% of the licensing agreements contain such license terms.

Comino, Fabio, and Manenti (2011)'s study on the cumulative innovation process highlights the important role of ex ante licensing (i.e, the agreement that has been reached prior to the follow-up innovators' investment in R&D) to mitigate future innovation holdup. Comino focuses on the licensing term negotiation strategies when the patent holder cannot observe the follow-up innovator's investment timing in R&D.

Some scholars believe that the surge in the number of patents authorized by different patent management agencies worldwide in recent years has brought adverse consequences for the innovation process (Jaffe & Lerner, 2004, 2011). This consequence is particularly acute in the field of cumulative innovation industries, as follow-up innovators in these industries need to reach licensing agreements with patent holders for a large number of strong IPRs, which is clearly a heavy burden, resulting in a high risk of holdup for future innovations and severely diminishing research and development incentives. According to Heller and Eisenberg (1998) and Shapiro (2001), when several patents—the so-called patent thickets— simultaneously appear on one technology, the risk of holdup is even more complex. Galasso and Schankerman (2010) conduct further analysis of the patent thickets and related tragedy of anti-commons. Through quantitative analysis and empirical research methods, this paper studies the impact of the establishment of the patent thickets and the United States Court of Appeal for the Federal Circuit on the duration of patent dispute resolutions and the speed of technology diffusion through licensing in 1982. To achieve this research goal, the paper constructs a patent litigation model that predicts the existence of fragmented patents. The model coordinates the interpretation of two patent thicketss, the pro-diffusion view of Lichtman (2006) and the tragedy of anti-commons of Heller and Eisenberg (1998) and Shapiro (2001). Its data source includes almost all patent litigation cases in the US District Court during the period 1975-2000. An important finding of this empirical study is that when the infringer wants to obtain fragmented external rights, the patent dispute at the US District Court can be resolved more quickly, but this effect is greatly weakened after the establishment of CAFC. Another discovery of this study is the large reduction of the dispute resolution cycle since the introduction of CAFC. Jiang, Dong, and

Yi (2016) believes that the “patent thickets” hinders the process of technological innovation and application promotion. This “tragedy of anti-commons” can be eased through a complementary patent pool or an implementation of a form of pareto improvement, vertically integrating upstream patents and downstream manufacturers. When there are potential competitors with high R&D efficiency in addition to the upstream patent holders, the game between patent holders, competitive patent developers and manufacturers is beneficial to achieve efficient market results. Li and Liu (2017) points out that patent speculation is the alienation of patent application, forming the NPEs. By recurring to this methods, even if the patent inventor can obtain the transfer fee from the company faster and maintain the next innovation activity, the negative impact is also significant, such as the accumulation of patent fees, waste of patent resources, increase the burden on the enterprise, and stifle industry innovation.

There has been an agreement on the fact that in the case of cumulative innovation, if different generations of innovators can effectively reach a licensing agreement, the growing number of patents is unlikely to constitute a substantial impediment to subsequent innovations. Following this line of thinking, the theoretical research literature on cumulative innovation focuses on the timing of signing contracts to mitigate the risk of holdup. In particular, some well-known scholars attach great importance to ex-ante licensing or prior agreements (Green & Scotchmer, 1995), arguing that if the negotiating parties agree with the follow-up innovators before investing, R&D incentives can be maintained. Green and Scotchmer (1995) show that with asymmetric information, prior agreements are sufficient to maintain the effect of licensing negotiations and can completely eliminate the risk of holdup.

2.3 Standard essential patent license

2.3.1 The dilemma of standard essential patent license fee

Since the 20th century, the issue of the standard essential patent license has attracted academic attention. After investigating the intellectual property policies of 36 standards organizations around the world, Lemley (2003) finds that although most standards organizations have developed a "reasonable, non-discriminatory (RAND)" policy to guide the negotiation of the standard essential patent license fee, the patentee and the implementer of the standard are still unable to reach an agreement through negotiation. Lemley and Shapiro (2013) research shows that because the fair, reasonable and non-discriminatory

(FRAND) principle is a loose commitment, it makes it difficult for SEP holders and standard implementers Afterwards, an agreement was reached on the issue of standard essential patent (SEP) license fees, which led to the dilemma of standard essential patent license fees. Lerner and Tirole (2015) also found that the loose FRAND commitment would make standard-essential patentees and implementers usually spend a lot of time in court due to licensing fees, resulting in excessively high costs for achieving standard-essential licensing fees. For example, in the Microsoft v. Motorola Standard Essential Patent Licensing Case, Microsoft considered that Motorola's license fee offer was unreasonable and violated the FRAND principle of Standard Essential Patent Licensing, while Motorola argued that Microsoft did not follow integrity when negotiating in principle. As a result, the two companies have been unable to reach an agreement on the SEP license fee, which can only be brought to the court. After the patent inclusion standard becomes a standard essential patent, how to reach the standard essential patent license fee that is satisfactory to both the patentee and the implementer of the standard becomes the core issue of standard essential patent licensing (Qin, 2015). On the one hand, standard-essential patentees hope that after the patent is incorporated into the standard, they will receive a higher license fee than general patents, because there are no other patents that can replace the standard-essential patent; On the other hand, standard implementers believe that the use of standard essential patents means that they must renounce the right to re-develop the patented technology. At the same time, the patentee promises to license the standard essential patents in accordance with the FRAND agreement after the patent is incorporated into the standard, and the license fee should be lower than general patents. The gap between the expected rates of SEP holders and implementers makes it difficult to negotiate patent license fees. The gap between the expected rates of SEP holders and implementers makes it difficult to negotiate patent license fees. In addition, most standard-essential patents involve competition among multinational companies. The issue of patent licensing under international standards is not simply a legal issue, but also an international issue involving multiple disciplines such as law, management, and economics (Liu, 2010).

2.3.2 Judicial Practice on the Formation Mechanism of Standard Essential Patent License Fees

In judicial practice, the determination of standard necessary patent license fees is usually determined by the judge based on the specific circumstances of the case, guided by the FRAND principle, exercising discretion, and choosing an appropriate method to make judgments on standard necessary patent infringement damages. In summary, there are mainly five types of methods for determining standard necessary patent license fees, namely hypothetical negotiation method, patent pool comparison method, allocation principle, proportional principle, and comparative analysis method.

(1) Hypothetical negotiation method. As early as 1946, the United States Patent Law proposed that the "reasonable license fee" (also known as hypothetical negotiation method) could be used to calculate patent infringement damages. This method not only provides a theoretical basis for the calculation of damages for patent infringement litigation in the United States, but also provides a reference for scholars to study patent license fees.

The hypothetical negotiation method applies not only to general patents, but also to standard essential patents. This method was proposed in 1995 in Rite-Hite v. Kelley and is used to calculate general patent license fees. In 2013, Microsoft v. Motorola used this method to calculate standard essential patent license fees. The main point is that a reasonable patent license fee is a license that assumes that the patentee and the defendant infringer are willing to voluntarily license when infringement is found Parties and licensees, the two parties may reach an agreed license fee through negotiation. There are generally two steps to determining a reasonable license fee through a hypothetical negotiation method: ① determining the basis of the license fee (in general, the smallest saleable patent implementation unit should be used as the basis for calculating the license fee); ② determining the reasonable license fee rate.

(2) Patent pool comparison method. The patent pool comparison method is named because it focuses on patent pool comparison. In the aforementioned Microsoft v. Motorola case, the patents involved belong to the H.264 standard and the 802.11 standard, and the patentees under these two standards have established patent pools, namely the H.264 patent pool and the 802.11 patent pool. There are usually four steps to calculate the license fee using the patent pool comparison method: ① find comparable patent pool objects, and check whether the technical standards of the infringing patents constitute a patent pool; ② judge the inductiveness and strength of the patent pool; ③ Simulate hypothetical negotiations to determine the range of patent license rates; ④ Determine the scope of patent license fees through the upper limit of license fees.

(3) Allocation principle. The principle of apportionment means that when determining the basis of the patent license fee rate, the infringement damages shall be "divided" into the patented technical features corresponding to the infringing product, and the non-patented technical features shall not be included, that is, the value of products not related to the patent involved shall be excluded. In Uniloc v. Microsoft, the judge held that if a product contains multiple components, if it calculates patent infringement damages based on the end product, it will cause greater risks, and the patentee will also obtain revenue from non-infringing parts. In subsequent Laser Dynamics v. Quanta Computer and Ericsson v. D-Link, the court affirmed the importance of the principle of apportionment, which is based on the calculation of standard necessary patent license fees based on the smallest saleable unit.

(4) The principle of proportionality. The principle of proportionality is a quantitative calculation method. This principle holds that in determining the basis of the FARND license fee, it can be determined according to the proportion of standard essential patents held by patentees to the total number of standard essential patents in the covered standards. This method was proposed and adopted in a patent lawsuit by In re Innovatio IP Ventures, LLC.

(5) Comparative analysis. The comparative analysis method was first proposed in the case of Huawei v. IDC. In this case, the judge used IDC's standard essential patent license fee as a reference, because the license rate obtained by Apple was determined through equal and voluntary consultation with IDC, and the license fee of IDC's license to Apple was used globally, so the court license fee is considered comparable. The final court ruled that the standard essential patent license fee granted to Huawei by IDC was 0.19% (the license fee rate granted by IDC to Apple was 0.0187%). However, a problem that is easily overlooked in the process of judging license fees through comparable transactions is that the process of confirming patent fees is also the cognitive process of judges. Because judges' decisions are always after disputes, they are subject to hindsight. The effect of prejudice is not conducive to the fairness and rationality of the judgment. In the case of Huawei v. IDC, the court judged that the success of Apple's smartphone was an inevitable event after neglecting the market risk when the license agreement was signed, which typically reflects this cognitive bias. Although it is impossible to completely eliminate the hindsight of prejudice, starting from the existing theoretical research results, through the full reasoning of the judgment and the comprehensive response to the defendant's defense reasons, the adverse effects of the prejudice of the hindsight can be greatly reduced.

The court does not stick to one method when determining the standard necessary patent license fee, and usually uses multiple methods to determine it in a case. These principles and methods for calculating standard essential patent license fees provide judicial reference and practical experience for the pricing of standard essential patent license fees. Ni, Shen, and Hu (2016), Li, Liu, and Luo (2014), Zhao (2017) all believe that the determination of standard essential patent license fees needs to be comprehensively considered based on the actual situation based on a wide range of interests before ruling, and the public interest is the primary purpose.

2.3.3 Management economics analysis of standard essential patent license

Complementing judicial practice, the economic researchers attempts to use economic models or mathematical formulas to characterize and explain the influencing factors of standard essential patent license fees and the optimization of their mechanisms. In summary, there are four mainstream theories and methods, namely the ex-ante bidding model, the ECPR and Shapley method, the proportional contribution method and the Top-Down method, and the baseball rules.

(1) Pre-bidding model. Swanson and Baumol (2005) believed that a reasonable standard-essential patent license rate should be based on the hypothetical negotiations when the standards organization established the standard, and based on this, established an ex-ante auction model to analyze standard-essential patent license fees. The pre-bidding model considers that the reasonable license fee for a standard-essential patent should be the technical value before the standard is established, not the monopoly value obtained by the standard after the standard is established. The core idea is that the license fees for various patents constituting the standard should be determined by the competition between similar technologies before the standard is established, and the similar technology license fee with the lowest quotation is selected as the FRAND license fee for the standard essential patent.

(2) ECPR method and Shapley value method. Layne-Farrar, Padilla, and Schmalensee (2007) proposed two economic models based on FRAND, namely the efficient component pricing rule (ECPR) based on market competition and the Shapley value method based on cooperative game theory and fair distribution of rents. The ex-ante bidding model resolves the value of competing patents, but cannot provide a complementary patent value analysis plan. The ECPR method and the Shapley value rule solve the problem of the distribution of

the interests of all parties in the cooperative game. The patents in the technical standards are complementary. In order to maximize personal benefits, patentees must play games with other standard participants. This is a typical cooperative game process. The ECPR method and the Shapley method solve the problem of the benefits of patentees in complementary patents.

(3) Proportional contribution method and Top-Down method. Sidak (2013) proposed the proportional contribution method and Top-Down method for calculating standard necessary patent license fees, that is, FRAND license fee = end-user product price× (standard contribution / product value) × (patent contribution / standard value), FRAND license fee = (Minimum best-selling component price×Average profit rate×Patent contribution) / Standard value.

(4) Baseball rules. As mentioned earlier, Lemley and Shapiro (2013) proposed the use of baseball rule arbitration to resolve the issue of reasonable licensing fees between standard essential patentees and patent implementers. Under this model, the patent licensor and the licensee each provide a final quotation to the arbitration institution, and the arbitration institution must select one of the two quotations as the final standard necessary patent license fee, and the arbitration institution must not modify the offer. Under the baseball rules, the patent licensor and the licensee can give a near-uniform equilibrium quote for the consideration of maximizing their participation in the game.

2.3.4 Analysis of the causes of the dilemma of standard essential patent license fees

Jin (1979) called the nature and relationship of a thing as the attribute of a thing. Unlike the occasional attributes, the peculiar attributes of a certain type of thing are those attributes that a certain type of thing has, while others do not. The unique attributes of things are divided into essential attributes (the decisive unique attributes of a certain kind of thing) and intrinsic attributes (the derived uniqueness of a certain kind of thing). The dual unique attributes of standard essential patents, such as sharing and private rights, are the root cause of the dilemma of their license fees.

(1) Sharing is the essential attribute of standard essential patents. Samuelson (1954) divided social products into private products and public products, and proposed that public products are significantly non-competitive and non-exclusive compared to private products. Sanders (1972) believes that in essence, standardization is the practice of people's conscious

efforts to make them unified, and its essence lies in the unification and sharing of technology to protect consumer interests and social public interests. In this sense, a standard is a public product and a share of technical resources. From the perspective of rights, standards can be regarded as a kind of "resource sharing right", which is a right for related stakeholders to enjoy social resources, and it is not exclusive or exclusive. For standard-setting organizations, the purpose of standard-setting is to unify and share technology and increase social welfare. In order to successfully implement the standards, the three major ISO, IEC and ITU standards organizations require patentees to sign a license statement to commit to implementing the patent while implementing the standard. Therefore, a standard essential patent is a standard first. After the patent is incorporated into the standard and becomes a standard essential patent, the patentee must give up part of the patent's rights (exclusive rights) and agree to let everyone use the technology together.

(2) Privateness is an essential attribute of standard essential patents. In terms of rights, a patent is a private right that prohibits others from implementing specific patented technologies for profit (Liu, 2014; Lim, 2014). Roman law's "incorporeal" theory and private law concepts provide an important source of ideas for the privatization of patents (Wu, 2003). The privatization of patents is the result of the dematerialization of property since Roman law. In the "Preamble", the Agreement on Trade-Related Aspects of Intellectual Property Rights (referred to as the TRIPs Agreement) affirmed the protection of intellectual property rights. From the perspective of legal form, private right is the legal form of private property (Wu, 2005). The acts targeted by patent rights are directly related to property interests. The control of the implementation of technology is to pursue the property benefits brought by the implementation. A standard essential patent is a patent that has the private property of a patent. Private property is a vesting right, which belongs to the patentee. When the patentee incorporated technology into the standard, although he gave up the exclusiveness (sharing) of the patent, he did not give up his ownership of the right. Therefore, privacy is an inherent attribute derived from standard essential patents.

The dual attributes of a standard-essential patent indicate that it has both dual attributes of sharing and private rights, both of which are opposite and unified. Among them, the shared attribute accounts for the main aspect of the contradiction, and the private property attribute belongs to the secondary aspect of the contradiction. The conflict of interest caused by the transfer of rights is the reason why the standard necessary patent license fee is difficult to achieve. Therefore, the fundamental difference between standard essential patents and general patents is that social welfare can be maximized on the basis of maximizing the interests of both parties. This is the fundamental solution to the dilemma of standard-essential patents.

(3) The looseness of FRAND's promise is the direct cause of the dilemma of SEP licensing fees. The FRAND principle is an intellectual property license policy of the standardization organization for many years, and it is also a core principle in judicial and law enforcement processing of standard necessary patent license rates. FRAND's commitment is to promote the widespread use of technology by protecting standard-essential patent implementers from patent hijacking, while giving reasonable returns to standard-essential patent owners who invest in research, development, and commercialization of standard technology. The FRAND commitment should be regarded as a reasonable compulsory license agreement in essence, that is, Standard-Setting Organizations (SSOs) participants are obliged to provide any technical standard implementer with an offer that complies with the FRAND principle, as long as the latter is willing to follow the principle of payment standard essential patents license fees, it can constitute a standard essential patents license agreement. Many literatures also try to use the FRAND principle to build a mechanism to solve the problem of standard necessary patent license fees. Such as Swanson and Baumol (2005) hypothetical negotiation method, Layne-Farrar, Padilla, and Schmalensee (2007) effective component pricing rules and Shapley value method, and the incremental value of the US Federal Trade Commission's second-best alternative standard. The FARND principle is often adopted in judicial jurisprudence, and it is difficult to effectively exercise its binding force in commercial negotiations between the two parties, because the FRAND principle is a loose commitment (Lerner & Tirole, 2015), and it is difficult to restrict and guide the parties to achieve a balanced license fee. Since 2011, Samsung and Apple have conducted at least 50 patent lawsuits in 10 countries until a settlement agreement was reached in August 2014; as of 2014, Apple and Google remained trapped in about 20 mutual legal proceedings. In these 20 cases, Google and Apple partner Rockstar Consortium are not counting ongoing lawsuits. Many patent lawsuits are related to FRAND commitments made by companies when they enter a standardization organization. Therefore, the court usually uses the FRAND principle to judge cases in litigation.

(4) Imperfect information disclosure system is the institutional cause of the dilemma of standard essential patent license fees. The patent information disclosure system is the core and foundation of the standards-related patent system. All standards organizations encourage

all parties involved in their standardization work to disclose necessary patents as soon as possible. Lemley conducted research on the intellectual property policies of 36 SSOs in 2002 and found that most standards organizations have expressed or implied patent disclosure obligations; the American National Standards Institute encouraged them in the "Guidelines for the Implementation of ANSI Patent Policies" in 2012 Standard essential patent holders disclose the patent information they consider necessary before the standard is adopted; On April 1, 2015, the "Revised Draft of the Patent Law of the People's Republic of China (Draft for Examination)" (referred to as "Patents" "Law Amendment for Review" added) Article 85, which specifies the implied license liability of standard essential patentees for breach of information disclosure obligations.

2.4 Patent hold-up

2.4.1 Background of patent hold-up

The basis for the commercial effect of patents is that patent holders can prove in court that their patents are valid and infringed, and obtained compensation accordingly. In many countries, the patent laws have similar provisions, that is, the patentee will receive compensation based on the profits they have lost due to the infringement or the “reasonable royalty fee” the infringer should pay. In addition, once the patent is found to be valid and infringed, the court usually issues an injunction, requiring the infringer to stop selling the infringing products.

Although such permanent injunctions are essential for patent-related property rights, many of the facts have proved that they are controversial. For instance, RIM, a wireless email device provider of Blackberry, was claimed by NTP to infringe several NTP patents. When the jury found that NTP’s patents are valid and infringed by RIM, NTP requested the court to issue an injunction to prohibit the sale of infringing Blackberry cellphones. Since the injunction can force RIM to stop infringing NTP’s patents, RIM was faced with huge reconciliation pressure to prevent the Blackberry service from being shut down. In March 2006, RIM paid USD 612.5 million to NTP to settle the case, which reflects the strong bargaining power of NTP given by the injunction because it derives from the ability of threatening to shut down the Blackberry service rather than the potential value of NTP’s patented technology.

At the beginning of the patent system design, a new device or machine was often protected by a single patent. Over the past several decades, it has begun to change dramatically. Patents in chemicals, biotechnology, hardware and software inventions have surged; more and more products are not just a single new invention but a combination of many different components, each of which may be the subject of one or more patents. Particularly, in the field of information technology, modern products such as microprocessors, mobile phones or memory devices are easily covered by dozens or even hundreds of different patents. An obvious example is that thousands of patents are considered essential in the 3G mobile phone systems. A large number of patents can be seen on one product in some key industries, which brings many practical problems to the operation of the patent system. Under the current patent system, the patentee has the right of compulsory injunction that can force downstream producers who infringe the patent to withdraw their products from the market. This threat can greatly affect licensing negotiations, especially when the injunction is issued based on a small part of the complex products with high margin and high sales volume. Injunction threats are often associated with patent holdup. For example, when the downstream producers have invested heavily in the design, manufacture, and sales of the suspected infringing products, the threat of a mandatory injunction enables the patentee to negotiate a royalty fee that is much higher than the patentee's actual economic contribution. The excessive royalty fee is equivalent to taxing new products that use the patented technology, which hinders rather than promote innovation.

It is the concern about the injunction that has resulted in many complaints about the so-called "patent hooligans" by the advanced firms in in the information technology industry. Patent trolls on markets for technology–An empirical analysis of NPEs' patent acquisitions. Research Policy, 2012, 41(9): 1519-1533.). Most of the patents owned by the "patent hooligans" have little innovation value, but based on which the "patent hooligans" can always obtain huge royalty fee from companies with considerable revenues because the patent infringement case filed by the "patent hooligans" can affect the sources of income of these companies. Once the defendant in a patent infringement case is found to have infringed a valid patent, the patentee automatically obtains a court-ordered injunction to prevent the defendant from continuing to sell its infringing product. Even if the patent only involves a small feature of the product, the injunction will be routinely approved. With this rule, even weak patent owners who only involve a small feature of the product will remain in a strong negotiating position. Therefore, the injunction gives the patentee the right to prevent the infringing company from designing, manufacturing and selling the infringing product, which can not only become a means of defending and realizing the value of its patent, but it can also become a tool to obtain benefits higher than the actual value of the patent itself through patent holdup.

Many scholars (Cary et al., 2008; Jiang & Zhao, 2012; Wen, 2014; Wang, 2015; Zhong, 2015) base on the research on patent holdup in countries and regions such as the United States, Japan and South Korea to explore the reasons for patent holdup from both macro and micro levels.

The reasons of patent hold-up from a macro perspective are as follows:

1) "Pro-patent" policy. As more and more countries attach importance to technological innovation, the role of patents in protecting corporate technological achievements is gradually recognized by society, regardless of whether the country is developed. Therefore, an increasing number of countries encourage companies to apply for patents by improving relevant IPR policies, which may increase the number of patent applications within a certain period of time, but at the same time it also brings many negative effects. Due to the lack of perfect supporting policies and facilities, the large number of questionable patents has become a source of patent holdup.

2) Free issue of injunctions. The method most commonly used by US courts was to issue a permanent injunction, which occurs before the Ebay case. As long as the court issues a permanent or temporary injunction, it will have a very large impact on the producers or the infringing companies, even making the previous efforts in vain. As the business opportunities in the market fleet, and the litigation duration is long, it is impossible to wait for the product cycle. Therefore, the injunction is the most powerful weapon for patent holders, and also the strongest shock to “infringing” companies.

3) The system of infringement damages is not sound enough. Under the influence of the “pro-patent” policy, the punitive damage system is more often used. For infringers, if they choose to sue, they may not only have to bear high punitive damages, but it also greatly affects the sales of products, resulting in investment losses. After weighing the pros and cons, they can only choose to settle out of court and be forced to accept a high royalty fee.

4) The cost of litigation is high, including the cost of response to suits, the cost of proof, the cost of time and the cost of lawyer. In particular, the cost of time is very high because

the litigation may continue for several years, greatly exceeding the product life cycle.

5) Information asymmetry. For infringers, if both sides negotiate, the royalty fee is always higher than the value of the patent itself because the specific value of the patent cannot be assessed.

The reasons of patent hold-up from a micro perspective are as follows:

1) Sunk costs. Patent holders often claim patent protection when the products of “infringing” companies are about to enter or have entered the market. The investment of “infringing” enterprises at this point is usually irreversible, thus, from the strategic point of view, they can only respond to suits, negotiate with the patentee or withdraw from the market. If they respond to suits, it may result in high recompense; if they withdraw from the market, the previous investment cannot be recovered. Therefore, for infringing companies, the best choice seems to be negotiation, which is a powerful weapon for the patent owners.

2) The cost of patent substitution is high. The patented technology involved in patent holdup is generally a key technology or has high value. If the infringing company wants to redevelop this technology, they are faced with difficulties of technology threshold, long development cycle and high cost.

Shapiro (2001) analyzes in the discussion of “patent thickets” the reasons why there is patent holdup:

1) Vagueness in patent. Lemley and Shapiro's research suggests that the actual use of patent rights is not as clear as the "claims" but rather vague, especially the time lag between the court's determination of the invalidity of the problem patent and the payment of the royalty fee. This is because the ambiguous problem patent can profit before the court rules that it is invalid, and the infringing company may have come to an agreement with the patent holder out of court before the court’s decision comes out and have paid the royalty fee for the questionable patent.

2) Sunk costs. “Infringing” companies will balance the high royalty fee and the costs already invested (such as production materials and equipment, plant, manpower.), and often choose pay the royalty fee so as to avoid that the investment cannot be recovered.

3) Injunction threat. There is a permanent injunction on US law. Therefore, patent owners can request the court to issue a permanent injunction on technology infringement

through litigation. The "infringer" has to either stop the infringement or pay the corresponding royalty fee. For the "infringing" company, even if the infringement involves a very small portion of the product, in order to continue the production and sales of the product, it has to pay the high fee. This is when the patent holdup occurs.

Based on the above research, we can see that the reasons why patent holdup occurs are the injunction system and the possible sunk cost. It is not affected by whether the patent holder is the subject for patent enforcement.

2.4.2 The definition and composition of patent holdup

The concept of holdup is derived from the transaction costs and contract theory proposed by Coase (1937, 1960). Williamson (1974, 1979, 1985), Klein, Crawford, and Alchian (1978) reveal that the formation of patent holdup must meet three conditions: information is asymmetric, the party involved has motive to profit, and assets have a specific nature.

Shapiro (2001, 2003) finds that there is a complementary nature in patent thickets, and discovers the existence of patent holdup. He argues that the downstream patent users pay a higher royalty fee because of the threat posed by the upstream patent holders (usually in the form of litigation or injunction threats), sometimes with other unreasonable conditions, which is called patent holdup. Since then, patent holdup has become one of the concerns of the academic circle. Based on the relevant US judicial system and economic environment, Lemley and Shapiro (2007a) study how patent holdup comes into being and finds that: 1) there is a permanent injunction in US law, which undoubtedly becomes the trump card for patent holders. It makes the actual royalty fee higher than the reasonable baseline rate that is calculated based on the strength and value of the patent. This is particularly prominent in weak patents (patents whose value is only a small part of the value of the product and is less than the marginal price or cost). Under this circumstance, if the party involved wants to circumvent patent holdup, it needs to make new modifications to the products, and the time window requires a delay in permanent injunction; 2) when many patents are applied to the same category of product at the same time, the holdup effect will magnify; 3) policy suggestions are proposed based on theoretical and empirical research, including improving the quality of patent to reduce related expenses and to postpone the injunction. Lemley points out that when patent holdup occurs in "multi-patent" products, its effects will magnify, leading to royalty stacking. Scholars usually classify patent holdup as opportunism, or monopolistic behavior, and consider such behavior to be an excessive use of rights.

Attention should be paid to the difference between patent holdup and patent troll. Although the definition of patent troll has many controversies, it has several common features: 1) the patent owner does not produce the patented product, and belongs to non-patent exercise entities; 2) the main methods of the patent holder to operate and profit are litigation, licensing and transactions; 3) the patent holder obtain high recompense through litigation; 4) the patent owner occupies a favorable position by using the permanent injunction and obtain high fees through threats; 5) the patent holder choose cleverly the timing for patent holdup, usually when the investment of the "infringing" company cannot be recovered. We can see that the patent troll strategies consist of patent holdup strategies. In market practice, patent holdup is often accompanied by patent troll because most of the "infringing" companies have to compromise due to the long litigation duration and high cost, except for weak patents.

2.5 The basic contents of the Lemley and Shapiro patent holdup model

2.5.1 Lemley and Shapiro patent holdup model hypothesis

The Lemley-Shapiro model can be applied on the conditions when a downstream company is ready to sell the product, and at the same time the patentee claims that the product infringes the patent, how can the individual patentee use the threat of an injunction to negotiate with the downstream companies. This game process develops as follows: First the patentee and the downstream company negotiate the royalty rate. According to the Nash equilibrium theory, the outcome of the negotiations depends on the benefits that the parties receive after the breakdown of the negotiations, that is, the threat point of each party in the negotiations. If the negotiation breaks down, the patentee will sue the downstream company, which will cause both parties to bear certain legal fees and sue for some time, and the result is uncertain at the time. If the patent is invalidated or not infringed, the downstream company does not need to pay any license fee for the patentee and can continue to sell his product. If the court rules that the patent is valid and there exists an infringement, the downstream company must pay a reasonable license fee for the infringement and cannot continue to sell the infringing product until it is licensed. At this point, the two sides can restart the renegotiation. Obviously, the patentee is in a very favorable position. If the negotiations break down at this time, the downstream company must stop selling the product and withdraw from the market until it can produce a product that does not contain the infringing patent, or until the patent expires. The relevant parameters of the model are as follows:

1) The unit value of the patent V, that is, the value of the patent characteristics per unit compared with the sub-optimal substitute technology of the downstream enterprise. For example, if the characteristics of a patent make the value of the product to the consumer higher than the suboptimal choice, then V = 1. Similarly, if it reduces the manufacturing cost of $1, then V = 1.

2) The profit per unit earned by the downstream company from its products M. For example, if the product is sold for $40, the marginal cost is $30, then M = $40-$30 = $10.

3) The strength of the patent, that is, the possibility that the patent is judged to be valid. Suppose that no lawsuit is filed, there is no way to determine whether the patent is valid and infringed. Therefore, downstream companies cannot fully resolve the uncertainty of effectiveness and infringement before making investment decisions.

4) The cost C of the downstream company to redesign its products to avoid patent infringement, measured as a percentage of the value of the patent. For example, if the value of a patent per unit is V = $1, and the downstream company expects to sell 10 million units of this product, the total value of the patent is $10 million. If the cost of redesigning the product is $2 million, then C equals $2 million / $10 million, or 20%. If C exceeds 100%, it may be because the cost of redesign is high, or because the patent value V is too small.

5) If the downstream company is forced to withdraw from the market due to the injunction, the reduced sales volume during the term of the patent is defined as L. These sale losses reflect to a certain extent the time lag required by downstream companies to redesign non-infringing products and bring them to market. In addition, it depends on the ability of downstream companies to successfully resell the product after redesigning it. For example, due to the strong network effect, downstream companies lag behind competitors in building user bases, and may not be able to return to the market after the damage caused by the injunction.

6) The patentee's negotiation skill B is measured by the percentage of the total income that the patentee obtains from reconciliation rather than litigation. This variable is between 0 and 1. If the negotiation skills are the same, then B = 0.5, which is a common assumption.

Negotiation skills B and threat points are not the same. Lemley cites an example: suppose a buyer evaluates a new product for $100, and the marginal cost of the seller producing the product is $40. If the buyer does not have a viable alternative, the buyer’s threat is not to buy the product, and the seller’s threat is not to sell the product. Achieving an agreement in a deal of $100 - $40 = $60 will bring benefits compared to the threat points. If the negotiation skills are the same, these benefits will be distributed evenly, with a final price of $70 and the buyer and seller receiving a surplus of $30 respectively. If the buyer has the option to purchase an older, less attractive product, and the product lacks certain features of the new product, suppose the price of the old product is $40, but the buyer only sets the value of the old product to $80. The buyer's threat now is to buy the old product, which will generate a remaining 80 - 40 dollars = 40 dollars of the buyer. The seller’s threat point remains unchanged. Now the trade income between buyers and sellers is only 20 US dollars (the total surplus of 60 US dollars brought by new products minus 40 US dollars brought by old products), which reflects the increase of the value of new products compared with the old ones. With the same bargaining skills, these gains are evenly divided and the final price is $50. The seller receives a $10 surplus from the transaction with the buyer ($50 price minus $40 marginal cost) and the buyer receives a $50 surplus ($100 value, $50 price), of which $10 comes from trading with the seller and $40 is obtained through the purchase of old products. Introducing an old product will change the buyer's threat point (from $0 to $40 of the buyer's surplus), which allows the buyer to negotiate a lower price ($50 instead of $70) at a given level of negotiation skill (B = 0.5).

In this example the bargaining skill remains the same, and the bargaining result is changed by changing the buyer's threat point. Similarly, for a given set of threat points, changing negotiation skills will also change the outcome of the negotiations. Going back to the situation where there is no old product at first, now assume that the seller is a better bargainer (the seller’s negotiation level B = 0.6), so the seller gets 60% of the revenue from the transaction, which is a surplus of $36. This means that the price is $76; the buyer's surplus will be 40% of $60, or $24, which is in line with the $100 price. Because the Shapiro-Lemley model examines how an injunction affects threat points in royalty fee negotiations, a neutral assumption is used assuming negotiation skills B do not change as threat points change.

2.5.2 Lemley and Shapiro patent holdup model content

(1) Benchmark Royalty Level

First, it is necessary to establish a benchmark level for patent licensing fees, that is, a reasonable, predictable royalty fee without any holdup factor in the ideal patent system. Assuming that the patentee and the downstream company have the same negotiation skills, they share the benefit of the agreement evenly, which is B = 0.5. If the value of the patent is valued at V = $1 per unit for downstream companies, the two companies will share a $1 per share benefit from the patented technology if the patent is absolutely valid and there are no holdup factors. The result is that the royalty fee is $0.50 per unit. Therefore, the benchmark royalty fee for a patent is equal to the negotiation skill multiplied by the patent value, which is BV. Lemley and Shapiro consider this to be the appropriate benchmark for a “reasonable royalty”.

Since the royalty fee negotiation is conducted before the final decision is made by the court, the benchmark royalty fee must be discounted to reflect the patent strength. Suppose there is a 40% chance of finding that the patent is valid and infringed, if there is no patent holdup, the benchmark royalty rate will be 40% of the time when the patent is absolutely valid. In the example above, the benchmark royalty fee for an absolutely valid patent is $0.50 per unit of product, so the benchmark royalty fee for the same patent with a patent strength of 40% is $0.20 per unit. Therefore, considering the patent strength, the benchmark royalty rate is θ*B*V.

(2) Negotiated Royalty Rates

Negotiated royalty fees depend on the best strategy for downstream companies in the event of a breakdown with the patentee. Under the above assumption, there are two optimal strategies: one, if the negotiation breaks down, the best strategy for the downstream enterprise is to defend the patent litigation. Only if the patent litigation is lost and the license cannot be negotiated after losing the case, then the product is redesigned. This is called the “Litigate Strategy”. The second scenario occurs when the downstream company's best strategy is to develop a non-infringing version of its products while the patent litigation is pending, so that in the event of a patent litigation failure and an injunction, a backup plan is formulated in a timely manner. This strategy is called "Redesign and Litigate Strategy”. In both cases, the formula for calculating the negotiated royalty fees depends on the amount of the “reasonable royalty fee” that the court will apply. It is optimistic to assume that “reasonable” royalty fees should be at the B*V benchmark level.

① Litigate strategy: In this case, the percentage difference between the negotiated royalty fee and the benchmark royalty level is $C+\frac{M-V}{V}\cdot L$. The first item C reflects the costs of redesigning the products that the downstream company will have to bear if it loses the patent lawsuit. The second component $C+\frac{M-V}{V}\cdot L$ reflects the loss of the downstream company when it redesigns the product after losing the patent lawsuit and withdrawing from the market. In this percentage gap calculation, we can see that if the value of the patented property is small relative to the total value of the product, the negotiated patent fee for a single patent is often much higher than a reasonable benchmark. If the infringer is prohibited from selling infringing products and has to redesign the product to avoid infringement, he will lose the full value of his product, not just the value of the patented part. Therefore, he will be willing to accept a royalty fee higher than the value contributed by the patentee's patent, but lower than the negotiated royalty fee for the expected loss of the product when it is banned from selling the product.

② Redesign and litigate strategy: In this case, the percentage difference between the negotiated royalty fee and the benchmark license fee is $\frac{C}{\Theta}$. For an absolutely valid patent, $\theta=1$, so the difference is equal to C, which is the same as the first element in the case where the "litigate" strategy is optimal. However, for weaker patents, this number is magnified: if the patent strength is $\theta=0.5$, the additional cost associated with the redesign cost will double. Although the alleged infringer has to spend money in redesigning, if the patent is invalid or not infringed, the money will become a sunk cost. Therefore, it is willing to accept a royalty fee higher than the value contributed by the patentee's patent, but lower than the negotiated royalty fee for the cost of redesigning the product during the lawsuit.

③ Discussion of some special cases: A special case occurs if the patent does not have special value, or there are other ways to achieve the same product performance without infringing the patent, that is, V=0. Correspondingly, the downstream company inadvertently designs a patent feature that allegedly infringes the patent. However, even if the patent is known in advance, the downstream can use an equivalent alternative. In this case, because the benchmark royalty level is zero, the patent feature does not add any value. Therefore, all negotiated royalty fees represent excess fees based on holdup. If the "litigate strategy" is the optimal strategy, the optimal royalty rate in this case is $\theta\cdot B[M\cdot L+K]$, where K is the redesign cost per unit of product. This is a function of risk, that is, if the patent is deemed to be valid and infringed, the alleged infringer will redesign the product to avoid infringement and bear part of the sales loss. In the redesign and litigate strategy, the negotiated royalty fee will be $B \cdot K$, indicating that although the patent does not have an actual economic contribution to the products of downstream companies, it is able to obtain some of the redesign benefits that could have been avoided.

④ Ex-ante Licensing: Lemley and Shapiro also discuss the early negotiations between patent holders and downstream companies prior to product design. In the case of ex ante licensing, the percentage difference between the negotiated royalty fee and the benchmark royalty level is $(1-\theta)/\theta$. For an absolutely valid patent, that is, a patent of $\theta = 1$, there is no overcharge, because the negotiated royalty fee is equal to the benchmark royalty level at this time, and there is no factor of holdup. However, if downstream companies have the opportunity to win the patent litigation, which is not equal to 1, some excessive charges are inevitable. For example, if $\theta = 0.5$, the percentage difference between the negotiated royalty fee and the benchmark royalty level is 100%. If it is a weak patent and $\theta = 1/3$, the excess ratio is 200%, that is, the negotiated royalty fee is three times the benchmark level. This reveals that early negotiations cannot solve completely the problem of holdup.

2.5.3 Interpretation of royalty stacking

The second focus of Lemley's research is how patent holdup magnifies royalty stacking. When a product contains multiple patents, downstream companies have to pay royalty fees to multiple patent holders. A large amount of empirical data shows that royalty stacking is not a theoretical problem and has accelerated the patent holdup problem. Royalty stacking is not a simple addition of multiple royalty fees, but the combination royalty fee among multiple patentees that affect each other. Lemley explains three reasons for this phenomenon from an economic perspective: rent splitting, shutdown and Cournot payment. The rent splitting occurs when downstream companies have to pay more royalties to the patented, lowering the profit of the product and the threat of an injunction. The shutdown occurs when a product can be judged to encounter holdup problems before it is developed, the manufacturer may think that the product is not worthy of being developed, manufactured and sold. When Cournot complement occurs, higher royalty fees will increase the marginal cost of the product, thereby increasing its price and in turn reducing the production, raising the price of the product to a value even higher than the price of the joint monopoly (a manufacturer with all patents), thus causing more additional losses. In addition, patent holdup and royalty stacking will lead to lead to serious problems under the private standard setting, that is, enterprises jointly set a non-statutory standard for the purpose of standard work or licensing. In the privatization standard environment, companies need extremely high redesign costs to bypass standard patents, resulting in an injunction threat that can lead to excessive royalty fees, especially for weak patents. It is quite common for companies to have patents covering the basic aspects of the products, especially in the areas of telecommunications and computers. The process of selecting standards is often a consensus and compromise, which in turn leads to product standards involving patents of many companies. According to Rysman and Simcoe (2008), the number of “basic patents” disclosed to standards-setting organizations has increased significantly over the past 15 years, making the problem of royalty stacking more and more serious

Lemley takes 3G communication as an example. There are two important standards in the field of 3G communication technology: 3GPP, known as WCDMA; and 3GPP2, known as CDMA. According to ETSI's report, in early 2004, WCDMA identified 6,872 key patents and patent applications. These patents can be divided into at least 732 "patent families", each of which is a patent obtained for an invention in different countries before January 1, 2004. According to the ARIB and TTC reports, CDMA2000 has received 924 basic patents before February 5, 2004. It can be divided into at least 527 patent families. Among them, there are 327 patents applicable to WCDMA and CDMA2000. The patents were distributed to 41 different companies, four of which have three-quarters of key patents: Qualcomm, Ericsson, Nokia, and Motorola. The severity of the whole problem may be more serious than what these numbers show. These data only include essential patents of the companies that participate in the standard-setting organizations, international standards organizations (SSOs). For example, Nortel has claimed to the Telecommunications Industry Association (TIA) that it has the necessary patents for CDMA2000 which have not yet listed on SSOs in Europe and Japan. Similarly, Lucent has not identified its key patents. In addition, this list does not include patents that are critical to early standards (GSM, TDMA, CDMA) that may also be critical for WCDMA or CDMA2000. On the other hand, not all patents are necessary; some may be commercially valuable and some may not have commercial importance. Although it is not possible to calculate the total cost of patents for these patents, Lemley estimates that it is up to 30% of the total price per handset, but these estimates are based on the sum of the royalty fees before the start of the cross-licensing negotiations. After the cross-licensing offset, the licensing cost of the mobile Internet function is 20% of the entire mobile phone price. However, access to Internet is only one factor in the cost and value of mobile phones. Nokia has tried to limit the cost of access to Internet to 5% of the mobile phone price, but failed. The key is that these are only the royalties of companies that have already established their basic patents, and do not include the fees paid to important patent holders such as AT&T. In addition to the case of 3G communication, Lemley also lists WIFI, DVD and other fields as a case, proving that there are similar royalty stacking problems in these areas.

2.5.4 Discussion on the Lemley & Shapiro model

Sidak (2007) raises the following questions about Lemley & Shapiro model: 1) when Lemley and Shapiro prove the royalty stacking problem, the empirical data and cases used do not represent the overall situation. The assessments on the literature in this field indicate that Lemley and Shapiro's concerns about the holdup and royalty stacking may be wrong. 2) According to Sidak, the Lemley-Shapiro model does not accurately account for "the relevant error costs associated with weakening the presumption of injunctive relief". In particular, Lemley and Shapiro do not consider how the lifting of injunctive relief can reduce dynamic efficiency. In addition, even if their model is correct, Lemley and Shapiro rely on deviation parameters that favor their results, which are caused by two reasons: first, when the patent holders make sunk investments in new technologies or products, Lemley and Shapiro fail to explain the real options granted on potential users of the patent, which biased their reasonable royalty fee. Second, the results of the Lemley-Shapiro model are not from deriving the general game model, but by assigning all the bargaining power to the patent owner and claiming a general result. Both factors bias Lemley and Shapiro's results toward the infringer. Sidak believes that a more effective market should be the primary consideration for IP policy reform.

Elhauge (2008) shows that the baseline royalty rate predicted by the holdup models is lower than the true optimal rate. Therefore, the predicted royalty rate is the true optimal rate. In addition, the assumptions of constant demand, one game and informational symmetry in the model are not correct or do not conform to the actual situation, so the royalty fee is overstated. When there is competition in the downstream product market or the upstream invention market, the predicted royalty fee by the holdup models cannot apply. Under such condition, royalty stacking will not result in a royalty rate higher than the optimal rate, but usually equal to or lower than the optimal rate. If the conclusion of Lemley and Shapiro is correct, it indicates that the present patent compensation measures result in an excess royalty fee. However, the current patent laws often lead to a royalty rate that is too low to adequately reward the outstanding inventions in society.

(1) Golden (2007) considers that the use of the benchmark royalty rate βθv as the basis for measuring patent holdup is not fully confirmed. In this regard, Lemley and Shapiro (2007b) explain that the benchmark royalty rate βθv is equal to the absence of patent holdup. For example, before the patentee's patent is judged valid and infringed, the downstream company can quickly transfer to the royalty rate where other non-infringing patents do not form a sunk investment. It can also resolve the issue of the validity of the patent and negotiate the expected royalty rate when infringement occurs before it makes any specific investment in the patented technology. Lemley and Shapiro argue that Golden's suspicion of the validity of the benchmark royalty rate is primarily due to its inclusion of a variable that reflects the patentee's negotiation skills. However, when buyers and sellers obtain unique benefits from the transaction, the market outcomes often depend on negotiation skills. Their benchmark royalty rates only reflect market outcomes in the absence of known market failures (i.e. holdup). By determining the key underlying economic factors that decide the gap between the negotiated royalty fee and the benchmark royalty fee, we can separate and study the impact of a permanent injunction on patent holding rate. By segregating one type of market failure and developing a model of equilibrium, we can better understand the implications of specific public policies in the face of market failures. This approach is a standard practice in the field of economics.

(2) Golden (2007) criticizes Lemley and Shapiro's reasonable royalty fee by the court and argues that the data may not represent a large licensing system. Lemley and Shapiro agree at this point. The data show the reasonable royalty fee judged by the court rather than the agreement reached by the two parties when resolving the lawsuit. However, the data are useful because the damage to be awarded by the court will affect the parties' choice of strategy to resolve the suit. Lemley and Shapiro believe that their result is a relative result, that is, there is no need to know whether the average reasonable royalty rate of 13.1% in the empirical data is "high", "low" or "just right". Only through group comparison we can know whether the court change the reasonable royalty fee according to the relative proportion. The empirical data provided in the article demonstrates that in the case of complex products, judicial decisions on reasonable royalty fees may systematically over-compensate the patent owners.

A. For the statement that the benchmark royalty rate is too low in Lemley & Shapiro's patent holdup model and that it lacks a practical basis, Shapiro responds that they adopt traditional economic methods and only investigate the holdup problems. The holdup part of the patentee's gains is not obtained from the value of the patented technology, the cost and delay of redesigning borne by downstream enterprise has almost no benefit to increasing the profit of the patentee. For the patent holder, holdup is indeed a good choice because the revenue obtained by the patentee under normal licensing is always lower than the expected one. If the patentee's remuneration is indeed systematically low, the patent system should be adjusted in other ways to increase their returns, rather than inefficiently allowing patents holdups. Holdup-based royalty fee is not purposeful, because weak patent holders, namely, those that are least likely to represent true innovation, obtain more benefits from the holdup than the holders of strong patent. Critics believe that the benchmark royalty rate is θv instead of $\beta\theta v$, however, Shapiro argues that this rate deviates from the principle of ex ante independent negotiations. Even if the social contribution of the patent holder is θv per unit, it is impossible for each innovator to invest 100% of its marginal contribution in innovation when complementary innovations exist and no subsidies are available. When complementary innovations exist, the sum of marginal contributions exceeds the total sum innovation costs. Also, if the downstream company independently develops a patent with similar patent characteristics, the patentee expects that the contribution to the downstream product is not θv per unit. If the patent independently developed by the downstream company does not plagiarize the patentee's patent characteristics, the patentee's contribution to downstream enterprise products may be zero.

B. For the issue whether denying injunctive relief is discrimination against NPEs adopting a specific business model, Shapiro responds that the patent damage laws have distinguished between infringement claims based on profit loss and those based on reasonable royalty fees. His analysis and policy recommendations apply only to cases involving reasonable disclosure fee claims, in which the patentee can request a reasonable royalty fee without an injunction. In addition, the court of first instance has usually established a reasonable royalty fee in order to make a retroactive decision on damage compensation. Forward-looking reasonable royalty fees are the same as retroactive reasonable royalty fees because they are based on prior independent negotiations between the patentee and the infringer. Although it is more difficult to determine the loss of profits on a forward-looking basis, this alone needs to be treated differently.

C. Responding to the problem of the model being too simple to be questioned and being unable to become the basis of a policy advice because it ignores the asymmetry of information and considers only one patent and one downstream company, Shapiro argues that the model is a beneficial step forward. This model identifies some of the basic aspects of probabilistic patent holdup. Further research will certainly help to understand how some of the complex factors listed above affect the negotiation of royalty fees, but there is no reason to believe that these factors will fundamentally change the basic findings of the model. In addition, patent policies must be based on empirical and theoretical findings.

D. Shapiro's response to the claim of the model being too simple to be used as a basis for policy advice because it does not include legal errors in determining reasonable royalty fees, is that interpreting legal errors may be important, but only paying attention to the possibility of legal errors and using the error cost framework do not change the basic conclusions of the model. As long as the reasonable royalty fee determined by the court is fair, the model's results will not cause significant errors in determining the reasonable royalty fee. In reality, negotiations sometimes break down, but they are still carried out within the litigation, therefore the expected value of reasonable royalties remains the most important.

E. Commenting on the criticism claiming that injunction lifting and granting a reasonable royalty fee undermines the "property" nature of the patent system, Shapiro argues that the restricted use of an injunction and related policy suggestions are limited to cases where non-competitive patent holders file a patent damage case against the downstream companies that do not plagiarize patent features from patent holders. The presumption of the right to injunctive relief is an important part of the patent law. In most cases, the right of the patentee to obtain an injunction is not a problem. However, the model analysis is clearly limited to the case where the patentee's main commercial interest in filing a patent infringement lawsuit is to obtain licensing revenue. In this case, restricting the use of an injunction means that once the patent is found to be valid and infringed, a hybrid system containing the elements of responsibility can be used. There is no universal presumption in the academic world that the pure property system is superior to the hybrid system or the pure liability system. Kaplow and Shavell (1996) specifically point out that if negotiations are always successful, the distribution of after-the-fact resources generated by the two systems is the same: both parties can obtain the benefits from the trade under any one of the systems.

2.5.5 Summary and shortcomings

Based on the discussion of the scholars mentioned above, it can be seen that the discussion of the Lemley & Shapiro model mainly focuses on three points: whether the determination of the benchmark royalty rate is correct, whether the model's assumptions are in line with the reality, and whether the conclusion of the model's response to the restriction of injunctive relief is reasonable. Lemley and Shapiro believe that the basic framework of the injunction holdup model is based on the classical economic method. Some scholars have raised questions from special circumstances and added more hypotheses and conditions, helping to study how some complex factors affect patent licensing negotiations, but these additional factors do not fundamentally change the basic findings of their model, because the Lemley-Shapiro model is based on the prevalence of injunction hole-up. Therefore, although the Lemley-Shapiro model does not fully explain the problems of patent holdup, it constructs a basic analytical framework and is widely cited by later scholars, who try to improve the hypothesis of the Lemley-Shapiro model by introducing new variables to analyze patent holdup under different situations.

Literature shortcomings: (1) The factors affecting holdup are not only external, but also the internal factors of the enterprise. (2) There is no explanation for the high royalty fees between leading companies and latecomer firms.

Chapter 3: Patent Holdup Model from The Perspective of Latecomer Firms

According to Hobday (1995) and Mathews (2002), taking the leading companies in developed countries as reference, latecomer firms in developing countries have the following characteristics: cost advantage, relatively weak technical capabilities, late entry to the industry and determination to catch up, among which the key feature is the technology gap and cost advantage. This chapter will first introduce these two features as variables and set relevant parameters based on the L&M model. Taking a leading company and a latecomer firm as research objects, this chapter proposes relevant hypotheses, and constructs a bargaining decision tree model between them. This chapter will also verify the patent holdup through empirical and economic approach and put forward corresponding strategies against patent holdup. In addition, since the cost advantage and technology gap will change dynamically, and will gradually narrow with the development of time, this chapter will propose anti-holdup strategies targeted at situations after change for latecomer firms.

3.1 Model assumptions and parameter selection

3.1.1 Research hypotheses

Compared with the leading companies in developed countries (hereinafter referred to as F), latecomer firms (hereinafter referred to as L) often enter the market late, resulting in lack of sufficient technical capacity for product development, and lack of market channels. However, they have the intention to catch up. With the advantage of low cost, the improvement of technical capabilities plays an important role the company’s success. Therefore, technology gap and cost advantage are two key factors for latecomer firms.

This thesis proposes assumptions based on Shapiro’s model (2010):

(1) Set F as a leading company and L as a latecomer firm, and they are competitors.

(2) The products that L plans to manufacture may involve many patents. The model in this thesis assumes that the product involves only one patent.

(3) Before F poses patent holdup on L, L has started production and invested in land

and other resources.

(4) In the model created in this thesis, it is assumed that the patents granted by F to L are only enforced in emerging markets.

(5) This thesis only analyzes the degree of patent holdup from a micro level, and downplays the macroscopic reasons such as injunctions and litigation.

Based on the above assumptions, the thesis puts forward two important factors, namely technology gap and cost advantage. Considering the dynamic changes in technical capabilities, the thesis adds relevant assumptions:

In the initial stage of technology catch-up, there are two cases. One is to assume L is weaker in technology than F and does not have the ability to circumvent F's patent. When the technology gap between them keeps narrowing, L is able to circumvent F's patented technology. The other case is that L has the cost advantage of land and manpower, but F cannot fully grasp the advantage of L due to information asymmetry.

3.1.2 Parameter selection

Based on the Lemley-Shapiro model, this thesis selects two key influencing factors of technology gap and cost advantage, and makes assumptions about the relevant parameters:

1) S_L refers to L's technical ability of L, correspondingly, S_F refers to F's technical ability; G is the technology gap between S and L. From a mathematical point of view, G=$(\mathrm{D}_F - \mathrm{D}_L)/\mathrm{D}_F, G \in [0,1]$.

2) *F* and *L* are in their respective markets (developed markets and emerging markets); the unit costs of the products are C_L , C_F respectively, with the costs including patents. The cost advantage is $\varphi \in [0,1]$, and *F*'s understanding of *L*'s cost advantage is α . Then, from a mathematical point of view, the advantage of C_L is φ=$(\mathrm{C}_F - \mathrm{C}_L)/\mathrm{C}_F$; F's actual understanding of the advantage of C_L is $\alpha\varphi$.

3) The price per unit by *F* is *p* (the patented technology included); the revenue per unit of *F* is *w*. From a mathematical point of view, $w = p - C_F$. Since L has cost advantage such as land in the early stage, the revenue per unit of L is $w + \varphi$.

4) v is the additional value because L uses F's patented technology. If v is excluded, the revenue per unit is $w-v(w-v\geq 0)$.

5) β is F's ability to earn revenue, $\beta\in[0,1]$; β is also the cost of L to avoid patent holdup. It is assumed that F and L have carried out the Nash bargaining.

6) θ is the infringement possibility of F's valid patents. From a mathematical point of view, in the negotiation between L and F, L's winning probability is $(1-G)(1-\theta)$, and F's winning probability is $1-(1-G)(1-\theta)$.

7) M is the production quantity of L's patented product; $\bar{b}$ is the patent licensing benchmark rate $\bar{b}=(\bar{b}-\beta\theta v)$, $\bar{\pi}$ is the patent licensing benchmark rate that F should obtain. From a mathematical point of view, $\bar{\pi}=\bar{b}X=\beta\theta vM$

8) $s=\beta\theta v$ is the patent licensing fee. Assume that L is the infringer by court ruling**,** from a mathematical point of view, $\theta=1$, $s=\beta v$.

9) Setting the time frame of L's patent infringement as t, $t\in[0,1]$ is the percentage of the litigation time between F and L to the term of the patent; $t'\in[0,1]$ is the percentage of the time period before F discovers L's infringement to the term of the patent.

10) When L has the technical ability to circumvent patent holdup, $f<vM$ is the fixed cost that L has to pay; $l<t$ is the proportion of the time L needs to circumvent the holdup with respect to the period from L's beginning of infringement to the end of the term of the patent.

3.2 Patent holdup model based on technology gap and cost advantage

3.2.1 Basic model construction

According to the research results of Xiao, Wei, and Wang (2011), when the technology track is established, latecomer firms have two choices in the early stage. The first one is ex ante licensing strategy, in which latecomer firms produce and sell products with licensed patents from foreign leading companies in emerging markets and the production technology or facilities of such products are introduced through patent licensing. The second is technology imitation strategy, that is, to produce or sell similar products through learning and imitation. Such products do not involve licensed patents. When the infringement of the latecomer firms is noticed by foreign leading companies, two possibilities may occur. The first is that the negotiation goes smoothly and the former pay the fees to the latter. The second possibility is the breakdown of the negotiations where the two sides resolve the dispute by litigation. In this case latecomer firms may also file a defense against the validity of the patent. The court's judgment of whether the patent is valid or not is very important under this situation. It determines whether the firm infringes the patent and whether follow-up negotiations are needed or not. If the dispute is settled through negotiations, and the latecomer firms and the leading companies come to a patent licensing agreement, the latecomer firms will pay the licensing fees. If the negotiation fails, the latecomer firms have to withdraw from the market and compensate the leading enterprise for the infringement. Based on the above game process, the patent licensing decision tree of the latecomer firm and the leading enterprise is shown in Figure 3-1.

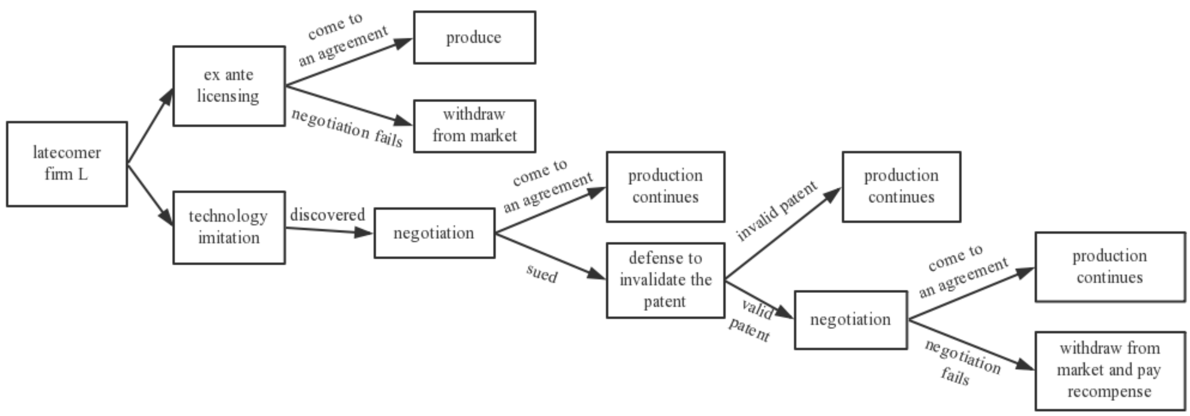

Figure 3-1 Patent licensing decision tree of the latecomer firm L

Analyzing the case of the latecomer firm taking the second strategy, namely technology imitation, when the first negotiation with the leading company breaks down and the second leads to an agreement, assume that the leading company is F and the latecomer firm is L, the litigation duration is *t*, the duration before F notices L's "infringement" is t', $1-t-t'$ is the remaining validity period of F's patent, w is the marginal revenue of the product per unit, $\alpha\varphi$ is the advantage of unit product cost. According to the game theory and deducing backward from the end of the decision tree, if the second negotiation can lead to an agreement, the revenue will be $(w+\alpha\varphi)M(1-t-t')$. However, if the second negotiation breaks down, L will have to withdraw from the market, resulting in zero return. Based on the Nash equilibrium, the revenue difference is $(w+\alpha\varphi)M(1-t-t')$.

The profits that F and L obtain are $\beta(w+\alpha\varphi)M(1-t-t')$ and $(w+\alpha\varphi)M(1-t-t')-\beta(w+\alpha\varphi)M(1-t-t')$ respectively. The probability of patent validity is $1-(1-G)(1-\theta)$ and $(1-G)(1-\theta)$. If the court rules that the patent is invalid, the benefit that L can obtain at this point is $(w+\alpha\varphi)M(1-t-t')$, and the revenue that L obtains from the start of production to the cessation of litigation is $(w+\alpha\varphi)M(t+t')$. If the court rules that the patent is valid, L will have to compensate the leading enterprise for the infringement, and the amount of compensation of the product per unit is s=βv. Thus, because of the infringement, L will have to pay F $[1-(1-G)(1-\theta)]\beta vM(t+t')$. It can be seen from the formula 3-1 that if the first negotiation breaks down, the revenue that L can obtain is:

$$[1-(1-G)(1-\theta)][(w+\alpha\varphi)M(1-t-t')-\beta(w+\alpha\varphi)M(1-t-t')]+(w+\alpha\varphi)M(t+t')$$
$$+(1-G)(1-\theta)(\mathrm{w}+\alpha\varphi)M(1-t-t')-[1-(1-G)(1-\theta)]\beta vM(t+t') \quad (3\text{-}1)$$

It can be seen from the formula 3-2 that:

$$(w+\alpha\varphi)M-[1-(1-G)(1-\theta)][(w+\alpha\varphi-v)\beta M(1-t-t')]-\beta vM(1-\theta)G-\beta\theta vM \quad (3\text{-}2)$$

if the first negotiation breaks down, the revenue that L can obtain can be simplified into $(w+\alpha\varphi)M-\pi_{\mathrm{dis}agree1}$. In this case, the compensation that F can obtain after the second settlement of negotiation is $\pi_{\mathrm{dis}agree1}$. From the formula 3-3, we can see $\pi_{\mathrm{dis}agree\ 1}$

$$\pi_{\mathrm{dis}agree1}=[1-(1-G)(1-\theta)][\beta \mathrm{m}M(1-t-t')+\alpha\beta\varphi M(1-t-t')+sM(t+t')]$$
$$=[1-(1-G)(1-\theta)][\beta(w-v)M(1-t-t')+\alpha\beta\varphi M(1-t-t')]$$
$$+\beta vM(1-\theta)G+\beta\theta vM \quad (3\text{-}3)$$

From the formula 3-3 we can see that when the court rules that the patent is valid, F obtains the value of the unpatented part of the product and understands the cost advantage, that is, $[1-(1-G)(1-\theta)]\beta(w-v)M(1-t-t')+\alpha\beta\varphi M(1-t-t')$; when the court rules that the patent is invalid, $\beta vM(1-\theta)G$ is the patent profit that F obtains from L, and it is also the time when L's defense against the validity of patent fails.

As the formula 3-4 shows, assuming that the basic licensing royalty rates is $\bar{\pi} = \beta\theta vM$, when the first negotiation breaks down and the second leads to an agreement, the ratio of the extra profit that F can obtain to the basic royalty rates is:

$$f(\mu,\varphi) = \frac{\pi_{\text{disagree1}} - \bar{\pi}}{\bar{\pi}} = \frac{1-(1-G)(1-\theta)}{\theta} * \frac{(w-v+\alpha\varphi)}{v} * (1-t-t') + \frac{(1-\theta)G}{\theta} \quad (3\text{-}4)$$

In the formula, $[1-(1-G)(1-\theta)]/\theta$ is the ratio of L's possibility of winning the litigation to the patent strength; in $[(w-v+\alpha\varphi)/v](1-t-t')$, the profits obtained from the unpatented technology are divided by those obtained from the patented technology, and the result obtained is multiplied by the validity period of this patented technology. Here refers mainly to product per unit. In $(1-\theta)G/\theta$, the impossibility of defending against the validity of the patent is divided by the patent strength when the court may rule that the patent is invalid. This is due to the weak technological and negotiation capabilities of L in the early stage of technology catch-up.

When the latecomer firms adopt the second strategy, namely technology imitation, during the first negotiation, the focus of both sides is whether F's patent will be validated, which is the best entry point. If the court rules that F's patent is valid, L cannot obtain the permission for the use of the patent but can only withdraw from the existing market. If the court rules that F's patent is invalid, the threat can be expressed in the following formula 3-5:

$$(1-G)(1-\theta)(w+\alpha\varphi)M(1-t-t') \quad (3\text{-}5)$$

$(w+\alpha\varphi)M(1-t')$ is the profits that L will obtain if L gets the permission to use the patent after the first negotiation between L and F. If both sides come to an agreement, the profits are shown in the formula 3-6:

$$(w+\alpha\varphi)M(1-t') - (1-G)(1-\theta)(w+\alpha\varphi)M(1-t-t') \quad (3\text{-}6)$$

Thus, the profit that F can obtain is:

$$\beta[(w+\alpha\varphi)M(1-t')-(1-G)(1-\theta)(w+\alpha\varphi)M(1-t-t')] \tag{3-7}$$

$(w+\alpha\varphi)Mt'$ is L's profits before the first negotiation. If L comes into an agreement with F after the first negotiation, that is, L admits the validity of F's patent, s, namely βv is the amount of compensation of the product per unit that L has to pay due to the infringement; $\beta vMt'$ is the total amount of compensation for this period of time, therefore, the profits that L can obtain if the patent is granted to L after the first negotiation are shown in the formula 3-8:

$$(w+\alpha\varphi)M-(w+\alpha\varphi-v)\beta M(1-t')+\beta(1-G)(1-\theta)(w+\alpha\varphi)M(1-t-t')$$
$$-\beta vM(1-\theta)-\beta\theta vM \tag{3-8}$$

From another point of view, if L and F can come to an agreement after the first negotiation, we can infer from the formula 3-9 that $\pi_{\text{dis}agree1}$ is the licensing royalty rates that F can obtain:

$$\pi_{\text{agree1}}=\beta[(w-v+\alpha\varphi)M(1-t')-(1-G)(1-\theta)(w+\alpha\varphi)M(1-t-t')]$$
$$+\beta vM(1-\theta)+\beta\theta vM \tag{3-9}$$

In the formula 3-9, if both sides come to an agreement after the first negotiation, $(w-v+\alpha\varphi)M(1-t')$ is the value after removing the patented part and cost advantage of L. If the first negotiation breaks down, $(1-G)(1-\theta)(w+\alpha\varphi)M(1-t-t')$ is the threat point for L. In this case, according to the Nash equilibrium, the profits that F obtains are demonstrated in the formula 3-10:

$$\beta[(w-v+\alpha\varphi)M(1-t')-(1-G)(1-\theta)(w+\alpha\varphi)M(1-t-t')] \tag{3-10}$$

In the formula 3-10, if the court rules that F's patent is invalid, $\beta vM(1-\theta)$ is the amount of the patented technology that L has to pay F. If both sides come to an agreement in the first negotiation, $\beta vM(1-\theta)$ has nothing to do with the technology gap between both sides.

If *L* obtains the license from *F* before production, there are two possibilities. If the ex-ante licensing negotiation is successful, L obtains the license from F to produce patented products. Since there is no production and sales activity before, there is no infringement compensation, and the revenue is $(w+\alpha\varphi)M$. If the negotiation breaks down, private patent infringement and suing for patent invalidity are the hidden threat points, that is, $(1-G)(1-\theta)(w+\alpha\varphi)M(1-t-t')$, and withdrawal from the market is the obvious threat point, which will lead to zero revenue and cannot earn the trust from F. Thus, the profit that F can obtain is shown in the formula 3-11.

$$\beta[(w+\alpha\varphi)M-(1-G)(1-\theta)(w+\alpha\varphi)M(1-t-t')] \tag{3-11}$$

L's profit if it obtains ex-ante licensing is presented in the formula 3-12:

$$(w+\alpha\varphi)M-\beta[(w+\alpha\varphi)M-(1-G)(1-\theta)(w+\alpha\varphi)M(1-t-t')] \tag{3-12}$$

The license fee that F can obtain is $\pi_{\text{ex-ante}}$, as shown in the formula 3-13:

$$\pi_{\text{ex-ante}}=\beta[(w-v+\alpha\varphi)M-(1-G)(1-\theta)(w+\alpha\varphi)M(1-t-t')]$$
$$+\beta vM(1-\theta)+\beta\theta vM \tag{3-13}$$

In the formula 3-13, if F and L come to an agreement after the first negotiation, removing the patented value of the product and cost advantage, it is $(w-v+\alpha\varphi)M$; if the first negotiation breaks down, based on the Nash equilibrium, the profits that F can obtain are shown in the formula 3-14:

$$\beta[(w-v+\alpha\varphi)M-(1-G)(1-\theta)(w+\alpha\varphi)M(1-t-t')] \tag{3-14}$$

In the formula 3-14, if the court rules that F's patent is invalid, $\beta vM(1-\theta)$ is what L should pay F for the patented technology. If both sides come to an agreement after the first negotiation, $\beta vM(1-\theta)$ has nothing to do with the technology gap.

As the formulas 3-3, 3-9 and 3-13 demonstrate, the technology gap and cost advantage between F and L have a direct impact on the licensing fee that F can obtain. From the formulas we can see that there exists patent holdup between F and L, and that L has paid a licensing fee much higher than the benchmark royalty level $\beta vM\theta$. Therefore, we can have the following propositions:

Proposition 1: Patent holdup exists and occurs in the patent negotiation between F and L.

According to the law, F as the patent owner has the right to exclude others to a certain degree. As a latecomer firm, F is often weak in terms of technology and negotiation. In order to avoid its product from being banned, L has to pay high licensing fees with the premise that L's cost advantage can make up for the loss of profits.

Based on the above formulas we can see that the result of the formula 3-9 is smaller than that of 3-13, so the countermeasure 1 is as follows:

Countermeasure 1: in the early stage, due to poor technological capabilities, latecomer firms have to adopt imitation to catch up. In this case, those who adopt technology imitation suffer less patent holdup than those obtaining prior agreement for the use of patent.

If licensing negotiation is conducted before R&D, the latecomer firms will expose the shortcomings of their technological capabilities, making themselves at a disadvantage in negotiations. There are different situations. If a latecomer firm has cost advantage, although its technological capabilities are weaker than the leading enterprises in the industry, it has accumulated technology and market in the early stage of development through learning and imitation, and obtained a relatively strong bargaining power and the right of speech in the market. In this phase, even if the leading companies notice the possible "infringement" of the latecomer firm, the latecomer firm can still adopt cross-licensing and strive for win-win cooperation, reaching an agreement with the leading company.

Since the result of the formula 3-3 is smaller than that of 3-9, the countermeasure 2 is as follows:

Countermeasure 2: In the early stage of development of the latecomer firms, the latecomer firms will adopt imitation due to weak technological capabilities, which will be found out by the leading enterprises in the industry at a certain stage. In order to effectively mitigate patent holdup, latecomer firms should employ litigation instead of direct negotiation.

In fact, because of cost and relevant regulations, latecomer firms are usually passive once they face litigation. However, based on the model, the best strategy should be active response to the litigation. Although the technology gap between the latecomer firms and leading companies is big, latecomer firms must learn to protect themselves, especially using IPR to defend their own rights. Figure 3-2 demonstrates the advantages and disadvantages of the different countermeasures adopted by the latecomer firms.

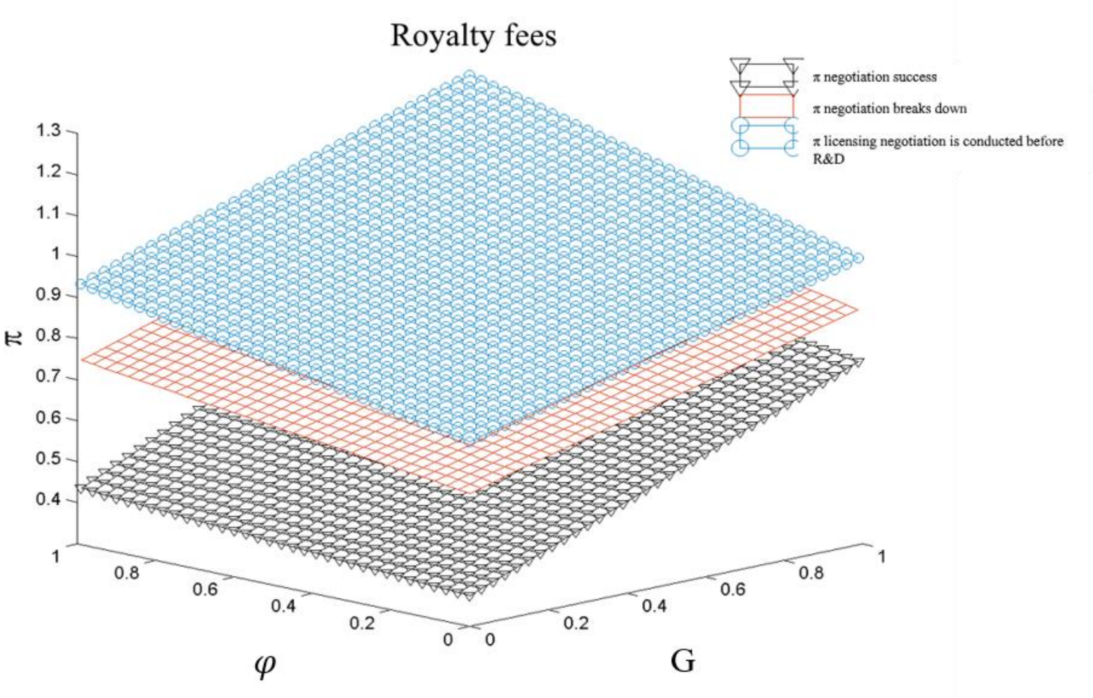

Figure 3-2 The royalty fees paid by latecomer firms under different strategies

Therefore, latecomer firms should judge based on the actual situation and the stage of development to determine a better countermeasure. For instance, in the early stage of development when the company adopts imitation to catch up, it may be more sensible to resort to litigation. However, this approach is also dynamic and relatively appropriate at this stage, that is, litigation can mitigate patent holdup at this stage, but it does not get to the root of the problem, which can be seen from the comparison of formulas 3-3, 3-9 and 3-13.

After a comprehensive analysis of countermeasures 1 and 2, in the case of technology imitation, we can see that it is more sensible for latecomer firms to resort to litigation at the early stage of development, which will mitigate the patent holdup by the leading companies. Formula 3-9 demonstrates the countermeasure model for latecomer firms at the early stage of development. We then combine the factor of technology gap G, calculate the partial derivative, and get formula 3-15, in which we can see the change in patent holdup as the technological capabilities of the latecomer firms improve the technology gap with the leading companies narrows.

$$\frac{\partial f}{\partial G}=\frac{(1-\theta)}{\theta}[\frac{(w-v+\alpha\varphi)}{v}*(1-t-t')+1] \tag{3-15}$$

As the result of the formula 3-15, a monotonically increasing function, is greater than 0, we can see that the smaller the technology gap is, the weaker the patent holdup posed by the leading companies to the latecomer firms will become.

Based on the formula 3-9, we calculate the partial derivative and get formula 3-16, which shows the impact of the change in the cost of the latecomer firms on patent holdup.

$$\frac{\partial f}{\partial \varphi}=\frac{[1-(1-G)(1-\theta)]}{\theta}*\frac{\alpha}{v}*(1-t-t') \tag{3-16}$$

Because the result of the formula 3-16, a monotonically increasing function, is greater than 0, the dynamic impact of the change in cost advantage on patent holdup is that the greater the cost advantage, the more serious the patent holdup faced with the latecomer firms.

In order to clearly present the evolution of patent holdup caused by stacking changes such as higher cost and the technological development of the latecomer firms, based on the formula 3-9, we selected the special parameters and obtain Figure 3-3.

Figure 3-3 shows clearly the proposition 2.

Proposition 2: The technological development of the latecomer firms has narrowed the gap with the leading companies, but the cost increase has reduced the advantages of the latecomer firms, all of which help to mitigate patent holdup posed by leading companies to varying degrees.

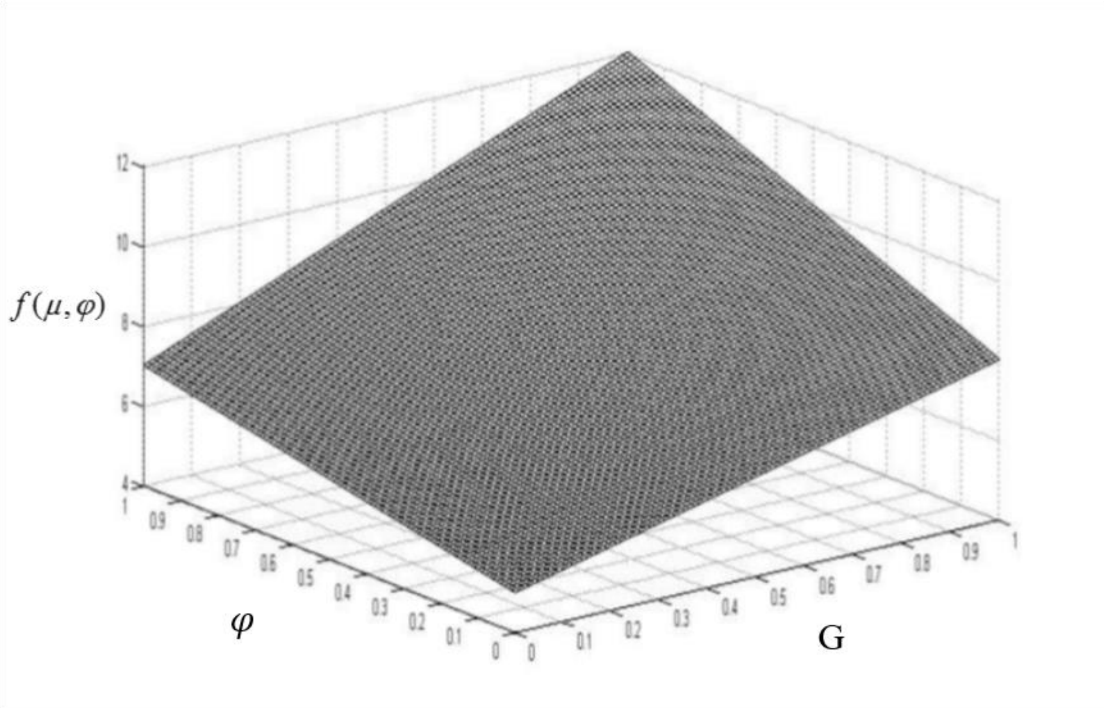

Figure 3-3 The evolution of patent holdup brought by the stacking change in technology and cost

In the early stage of development, due to the huge technology gap, latecomer firms have to bear patent holdup posed by the advanced firms, namely, a licensing fee higher than the benchmark fee. There are two reasons why the latecomer firms can bear high licensing fees. One hand, the technical strength is weak but it is urgent to occupy the market, especially to profit by entering emerging markets. On the other hand, there is still room for profit increase due to cost advantage, which has not been fully grasped by leading companies. In fact, with the development of global economy, the costs are also increasing, leaving little profit margins for the latecomer firms. In addition, high licensing fees will further squeeze the profits of the latecomer firms. Therefore, if the technology gap is not considered, the weakening cost advantage of the latecomer firms will mitigate patent holdup to a certain extent. However, latecomer firms will not be able to win profits under this situation, which will hinder the development of the company and result in withdrawal from the market. While the cost advantage is continuously decreasing, if the technology gap can be gradually narrowed, latecomer firms will have the conditions to re-initiate the negotiations in order to mitigate patent holdup.

In summary, countermeasure 3 is: in the early stage of development, because of poor technological capabilities, latecomer firms are relatively passive in market game, especially in patent licensing negotiations. Under this circumstance, in order to mitigate patent holdup, latecomer firms must strive to improve technological capabilities and further narrow the gap with the advanced firms.

3.2.2 Dynamic impact of technology gap and cost advantage on patent hold-up

Assume that the cost advantage of the latecomer firms weakens, and the technology gap G^* gradually narrows, in order to circumvent patent holdup, the latecomer firm L makes new modifications to the product, leading to a new round of game between the latecomer firm and leading companies. When $0 \le G \le G^*$, L either modifies the products or resorts to litigation without modifying the product. Since G^* is a change value, it cannot be expressed by formulas. In addition, the strength of the patented technology determines when the latecomer firms are able to develop alternative products. Thus, G^* is used in this thesis.

In the countermeasure tree shown in Figure 3-1, $wM(1-t-t')$ is the profit that L can obtain if it comes to an agreement with F in the second negotiation. $(w-v)M(1-t-t'-l)-f$ is the profit that L can obtain if the second negotiation breaks down and L makes new modifications to the product.

According to Nash equilibrium, $\beta vM(1-t-t')+\beta[(w-v)Ml+f]$ is the profit that F can obtain, in which $\beta vM(1-t-t')$ is the benchmark licensing fee, and $\beta[(w-v)Ml+f$ is the profit obtained by F after posing patent holdup. Thus, if the court rules that F's patent is valid, the profit that F can obtain after posing patent holdup on L is $[1-(1-G)(1-\theta)]\beta[(w-v)Ml+f]$. If L makes new modifications to the product before facing the lawsuit, the profit that L can obtain after circumventing patent holdup is the sum of $[1-(1-G)(1-\theta)]\beta[(w-v)Ml+f]-f$ and the profit it can obtain by resorting to litigation, as shown in the formula 3-17:

$$(w+\alpha\varphi)M(1-t-t')-\beta vM(1-t-t')+\beta[(w-v+\alpha\varphi)Ml+f] \tag{3-17}$$

The formula 3-17 shows the profit L can obtain if the court rules that F's patent is valid. In this case, the validity probability of the patent is $1-(1-G)(1-\theta)$. If the court rules that the patent is invalid, which means that L does not need to pay anything for the technology, the profit it can obtain is $(w+\alpha\varphi)M(1-t-t')$, and probability of the patent being ruled invalid is $(1-G)(1-\theta)$. The sales revenue that L can obtain before the court decision comes out is $(w+\alpha\varphi)M(1+t)$. If the court rules that the patent is valid, which means that L infringes the patent, the amount of compensation L needs to pay per unit is $s=\beta v$. The profit that L can obtain before the court decision comes out is presented in the formula 3-18.

$$[1-(1-G)(1-\theta)]\beta vM(1+t') \tag{3-18}$$

Therefore, in the first negotiation, if L does not admit the infringement, the profit it can obtain is shown in the formula 3-19:

$$(w+\alpha\varphi)M-\beta[1-(1-G)(1-\theta)]f-\beta[1-(1-G)(1-\theta)]Ml(w-v+\alpha\varphi)$$

$$-\beta(1-\theta)vMG-\beta\theta vMM \tag{3-19}$$

The formula 3-19 can be examined from another perspective, that is, the profit obtained from the production before the expiration date of the patent minus the licensing fee that L pays to F after the second negotiation when both sides come to an agreement, as shown in the formula 3-20:

$$\pi^{*}_{\mathrm{non}-redesign}=\beta[1-(1-G)(1-\theta)]f+\beta[1-(1-G)(1-\theta)]Ml(w-v+\alpha\varphi)$$

$$+\beta(1-\theta)vMG+\beta\theta vM \tag{3-20}$$

If the latecomer firm L chooses to resort to litigation rather than circumvent patent infringement by making new modifications to the product, L will face patent holdup, and the degree of patent holdup is shown in the formula 3-21:

$$f(G,\varphi)=\frac{1-(1-G)(1-\theta)}{\theta}[\frac{f}{vM}+\frac{(w-v+\alpha\varphi)}{v}*l]+\frac{G(1-\theta)}{\theta} \tag{3-21}$$

In the formula 3-21, the success probability of L in litigation divided by the patent strength is $[1-(1-G)(1-\theta)]/\theta$; if L can make new modifications to the product to avoid patent holdup posed by advanced firms, the cost of the new product divided by the sum of the revenue generated by the patented technology is f/vM. Multiply the revenue of L generated by the unpatented technology per unit by the time it takes to modify the products; and then the obtained result divided by the sum of the revenue generated by the patented technology is $(w-v+\alpha\varphi)l/v$. In the case that F's patent may be judged invalid, since L is weak in technology at the early stage of development, it cannot invalidate the claims in

F's patent. This value divided by the patent strength is $G(1-\theta)l/\theta$. $[1-(1-G)(1-\theta)]\beta[(w-v)Ml+f]-f$ plus, the possible benefits brought by litigation is the profit L obtains after making new modifications to the product. Thus, the profit F can obtain is shown in the formula 3-22:

$$\pi^{*}_{\text{redegisn}} = \beta f + \beta vM(1-\theta)G + \beta\theta vM \tag{3-22}$$

In the formula 3-22, the benchmark licensing fee is $\bar{\pi} = \beta\theta vM$; when F's patent may be judged invalid and L fails to invalidate the patent in the early stage, the benefits that F obtains from the patented technology is $\beta vM(1-\theta)G$.

If L makes new modifications to the product, the degree of patent holdup posed by F to L is:

$$f(G) = \frac{f}{\theta vM} + \frac{G(1-\theta)}{\theta} \tag{3-23}$$

In the formula 3-23, the fixed cost of making new modifications to the product of L divided by the term of the patented technology is the sum of the profits $f/\theta vM$. The value when F's patent may be judged invalid and L fails to invalidate the patent in the early stage divided by the patent strength is $G(1-\theta)/\theta$. If L chooses to modify the products, there is little relevancy between the patent holdup faced with L and its cost advantage. This is because L will not adopt F's technology once deciding to modify the products, minimizing or mitigating patent holdup. If the negotiations between both sides break down, the latecomer firm will still encounter patent holdup posed by the advanced firm.

During the litigation at the court, whether L makes new modifications to the products will directly affects the amount of licensing fee paid to F. Figure 3-4 exhibits the dynamics of these strategies.

As shown in Figure 3-4, the intersection indicates the point when the formula 3-21 is equal to the formula 3-23, L encounters the same degree of patent holdup regardless of whether L makes new modifications to the products or resorts to litigation without modifying the products, from which we can see that the formula 3-24 is valid:

$$G = G^{**} = 1 - \frac{1}{1-\theta} + \frac{1}{(1-\theta)\beta} * \frac{f}{(w-v+\alpha\varphi)Ml+f} \tag{3-24}$$

When the result of the formula 3-23 is smaller than that of 3-21, it indicates that if L chooses to modify the products, it will suffer less patent holdup and the licensing fee to be paid to F will be less. From this perspective, we can obtain countermeasure 4.

Countermeasure 4: When facing litigation and $G^{**} < G < G^{*}$, if L has the ability to modify the products, making modifications is the most sensible countermeasure.

In Figure 3-4, if $G < G^{**}$, L decides not to modify the products but resort to litigation. It will encounter less patent holdup and the licensing fee to be paid to F will be less. Thus, we can obtain countermeasure 5.

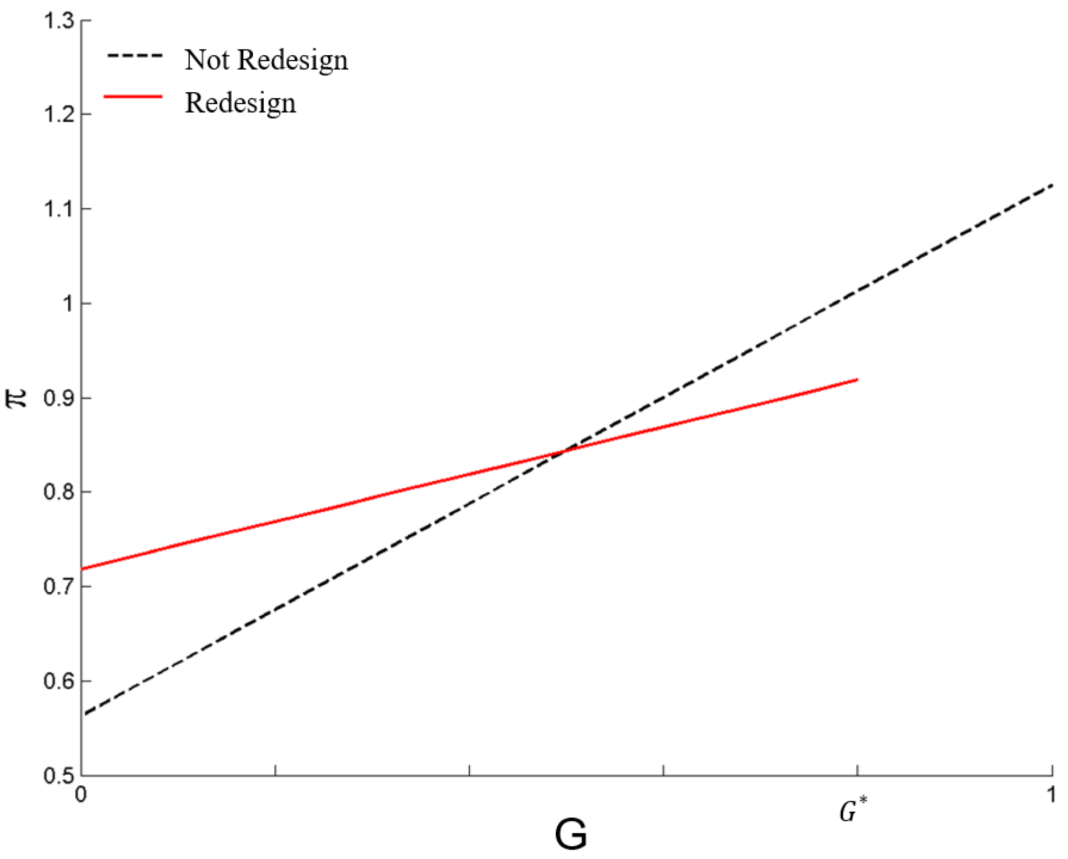

Figure 3-4 Redesigned and not redesigned patent licensing fees

Countermeasure 5: when faced with litigation and $0 \le G < G^{**}$, it is the most sensible countermeasure for L not to modify the products but resort to litigation.

A prerequisite for this countermeasure is that the latecomer firm has the ability to modify the product and circumvent the existing technology. The benefits of modifying the products are to improve technological capabilities, circumvent patent holdup posed by leading companies, and increase market share, while the drawback is that R&D may take a long time. If the technology gap between both sides is huge, the latecomer's right to speak is limited. In this case, modifying the products is better than negotiations. If the technology gap is small, the right to speak of the latecomer firm will strengthen, which is conducive to patent game and mitigate patent holdup. Under this circumstance, if L chooses negotiation, it can obtain the patent license to occupy the market as soon as possible.

Based on the injunction system of the Lemley-Shapiro patent holdup model and from the perspective of the latecomer firms, this chapter built a patent holdup model by introducing two variables of the technology gap between latecomer firms and advanced firms and cost advantage, and analyzed the impact of the dynamic changes of these two variables on the patent hold faced with the latecomer firm. In addition, this chapter also analyzed what reasonable strategies latecomer firms should adopt in a certain situation. Through analysis, this chapter came to two propositions and proposed five strategies:

Proposition 1: Patent holdup exists in the negotiation between latecomer firms and leading companies, namely, patent licensing fee higher than the reasonable fee.

Proposition 2: The development of technological capabilities of the latecomer firms has narrowed the gap with the leading companies, while the cost increase has weakened the advantage of the latecomer firms, all of which will help to mitigate patent holdup posed by the advanced firms to varying degrees.

Countermeasure 1: In the early stage of development, due to weak technological capabilities, latecomer firms should adopt imitation to catch up with the advanced firms in technology. In this case, those adopting technology imitation encounter fewer holdup problems than those obtaining ex-ante licensing.

Countermeasure 2: In the early stage of development, the technology imitation employed by the latecomer firms will be perceived by the leading companies in the industry. In order to mitigate more effectively patent holdup, latecomer firms should resort to litigation instead of direct negotiations.

Countermeasure 3: In the early stage of development, due to poor technology, latecomer firms are relatively passive in market game, especially in the licensing negotiations. In order to mitigate patent holdup, latecomer firms must strive to improve technological capabilities so as to further narrow the technology gap between them and the leading companies.

Countermeasure 4: When faced with litigation and $G^{**} < G \leq G^{*}$, if the latecomer firm

L has the ability to modify the product, it is a wiser strategy to make new modifications to the product.

Countermeasure 5: If the latecomer firm L has the ability to modify the product, when facing litigation and $0 \le G < G^*$, it is more sensible for L to resort to litigation instead of modifying the product.

Chapter 4: Empirical Research

4.1 Research hypotheses and key variable identification

Based on the data collected from the questionnaire, this chapter will empirically analyze the relationship between the technology gap and cost advantage of the latecomer firms and patent hold-up through regression analysis.

4.1.1 Hypotheses

Based on the research results of Fransman (1984), Katz and Shapiro (1986), Lall (1987), and Yam et al. (2004), this chapter will establish an analytical framework of technological capabilities from three aspects: R&D capability, manufacturing capability and marketing capability. R&D capability refers to the combination of capabilities to integrate various innovative resources inside and outside the enterprise to support the company to actively carry out independent design, independent manufacturing and structural innovation with an aim to enhance its comprehensive competitiveness. Manufacturing capability refers to the comprehensive capabilities of the company in terms of process, equipment, planning, and quality control. Marketing capability is the ability of companies to enter the market, increase market share.

Based on the above research results on technology gaps, this thesis proposes the following hypotheses:

H1: The technology gap between the latecomer firms and the foreign leading companies is positively correlated with the actual licensing royalty rates, that is, the smaller the technology gap, the fewer the actual licensing royalty rates. The technology gap consists of gaps in R&D capability, manufacturing capability and marketing capability, therefore:

H1a: As the R&D capability gap narrows, the actual licensing royalty rates will also decrease.

H1b: As the manufacturing capability gap narrows, the actual licensing royalty rates will also decrease.

H1c: As the marketing capability gap narrows, the actual licensing royalty rates will also decrease.

Another notable feature of latecomer firms is the cost advantage. Dollar (1993)'s research shows that the competitiveness of enterprises lies on producing high-quality and low-cost products. Scott and Lodge (2010) believed that the methods used to effectively allocate human and material resources to ensure the sustainable development of enterprises is very important for the improvement of corporate competitiveness. Wright, Kroll, and Parnell (1998) put forward that human resources, organizational resources and material resources constitute the sum of resources of enterprises, among which the material cost includes organizational resources and material resources. Xiao, Wei, and Wang (2011) analyzed the patent licensing model from the perspective of latecomer firms and found that latecomer firms can improve the bargaining power in patent licensing negotiations by virtue of cost advantages.

Based on the literature review on cost advantage, this thesis proposes the following assumptions:

H2: The cost advantage of latecomer firms is positively correlated with the actual licensing royalty rates. The weaker the cost advantage is, the fewer the actual licensing royalty rates are.

In addition, the cost advantage is composed of the labor cost advantage and the material cost advantage, thus:

H2a: As the cost advantage of the latecomer firms on manpower becomes weaker, the actual licensing royalty rates will become fewer.

H2a: As the cost advantage of the latecomer firms on material resources becomes weaker, the actual licensing royalty rates will become fewer.

4.1.2 Classification indicators of technology gap

Guo and Liu (2011) divide measurement indicators of R&D capabilities into R&D investment, R&D speed, innovation patents creation, and economic performance. Dahlman, Ross-Larson, and Westphal (1987) use indices including manufacturing equipment, manufacturing processes, product quality, and energy and environment to characterize manufacturing capabilities. Zheng (2006) adopts domestic and international market share, new local market development and brand influence development as measurement indexes of marketing capability. Based on the above research results, the indicators for measuring the technology gap in this thesis are shown in Table 4-1.

Table 4-1 Summary of variables influencing the technology capabilities of latecomer firms

Factor	Dimension	Measuring indicator	References
Technological capabilities gap	R&D capability gap	R&D investment: Ratio of R&D investment to the total revenue of the company. R&D speed: New product development cycle; number of new products developed in one year. Patent invention: ratio of invention patents to the total number of patents of the company. Economic performance: Contribution of the new product to the company's performance.	Guo and Liu (2011)
	Manufacturing capability gap	Manufacturing equipment: Equipment generation differences and update frequency. Manufacturing processes: Automatization and optimization degree and efficiency of the manufacturing process. Product quality: product passing rate and repair rate Energy and environment: Energy consumption and environment contamination indicators.	Dahlman, Ross-Larson, and Westphal (1987)
	Marketing capability gap	Market share: Domestic and international market share New local market development: imitation strategy or innovation strategy Global market share increase: product price, produce quality	Zheng (2006)

	Brand influence development: Trademark and product reputation.

4.1.3 Classification indicators of cost advantage

Based on the study of Chen and Ren (2011) and Wei, Yao, and Shi (2015), the variables of cost advantage in this thesis consist of the manpower and material resource\ advantages. Table 4-2 shows the indicators for measuring cost advantage in this thesis.

Table 4-2 Latecomer firms cost advantage indicators list

Variable	Dimension	Indicators	References
Cost advantage	Manpower cost advantage	Employee salary spending	Zeng and Ren (2011); Wei, Yao, and Shi (2015)
		Social insurance spending	
		Education and training spending	
	Material resource advantage	Raw material costs	
		Land costs	
		Energy costs	
		Environmental costs	

4.2 Survey design, reliability and validity tests

4.2.1 Questionnaire survey and recovery

The questionnaire adopted the 5-point Likert Scale and investigated the technology gap and cost advantage of latecomer firms and the actual licensing royalty rates of foreign leading companies. In order to examine the dynamic changes in technology gaps and cost advantages of latecomer firms, and considering the availability of data, the questionnaire collected data at two points, namely, ten years ago and the recent three years.

The questionnaire was distributed from October 1, 2017 to November 30, 2017 (see Appendix 1). In order to ensure the scientific and representativeness of the sample selection, this study downloaded the 12,627 patent license records between foreign enterprises (patent licensor) and domestic enterprises (patent licensee) from 2002 to 2016 from the official website of The State Intellectual Property Office (SIPO). The above statistics are used to understand and analysis the feature of time distribution, regional distribution, patent distribution, and industry distribution of patent licenses between leading foreign companies and China's latecomer enterprises, and provide a basis for further selection of samples. Considered the feasibility of distribution and collection of questionnaires, this study has selected 120 Chinese companies in Guangdong, Hubei, and Sichuan which have accepted patent licenses from leading foreign enterprises for empirically studying the dynamic impact of technological gap and cost advantage on patent hold-up. The three provinces were chosen as sample sources because Guangdong represents the developed areas of the southeast coast of China, Hubei represents the rising areas of central China, and Sichuan represents the developing areas of inland western China. A total of 120 questionnaires were handed out to 120 companies, and 94 questionnaires were able to be recovered with a recovery rate of 78.3%. 88 valid questionnaires out of the collected 94 questionnaires were qualified, a pass rate of 73.3%. The questionnaire was mainly completed by the company's legal, R&D/technical, IP or financial department heads and related personnel.

4.2.2 Questionnaire reliability and validity tests

This thesis used Cronbach α coefficient to test the overall reliability of the questionnaire. The acceptable minimum value factor is between 0.65 and 0.70; between 0.70 and 0.80 is acceptable; between 0.8 and 0.9 is good, and above 0.9 is ideal. Table 4-3 demonstrates the reliability test results of this questionnaire.

Table 4-3 Cronbach α reliability test

Variable	Reliability (Cronbach α)	reference
Actual royalty rate	0.876	$\alpha>0.7$
R&D capability	0.792	
Manufacturing capability	0.792	
Marketing capability	0.783	
Labor cost	0.861	
Material resource cost	0.874	
Total	0.891	$\alpha>0.8$

This research also adopted exploratory factor analysis to analyze the reliability and validity of the questionnaire. The indicators for measuring reliability and validity were composite reliability (CR), Average Variance Extracted (AVE) to verify the convergence validity of the variables and Kaiser-Meyer-Olkin (KMO) to verify the correlation between variable subproblems.

If the load factor for each variable is greater than 0.5, and KMO is greater than 0.6, it indicates a strong correlation between the questions used to form the variables. If the CR calculated by the load factor is greater than the threshold of 0.7, it indicates that the variables have good combination reliability. If AVE is greater than 0.5, it indicates that the variables have good convergence validity. If AVE is greater than the square of the correlation between the structure and other factors, it indicates that the variables have good discriminant validity.

(1) Technological capability

Table 4-4 presents the results of the reliability and validity tests for the technology capability variables. The load factor, KMO, CR and AVE for each variable and dimension are greater than the threshold requirement, indicating that the questionnaire has high reliability and validity for the variables of technological capabilities and related issues.

Table 4-4 Reliability and validity analysis of the technology capability variable

Variable	dimension	Measuring items	Load factor
Technology gap over the recent three years CR=0.9514 AVE=0.6416 KMO=0.697	R&D capability gap CR=0.8796 AVE=0.7091 KMO=0.697	Ratio of R&D investment to sales revenue compared with foreign leading companies	0.858
		The number of new products developed by your company compared with foreign leading companies	0.863
		The number of patent applications by your company compared with foreign leading companies	0.804
	Manufacturing capability gap CR= 0.8657 AVE= 0.6173 KMO=0.671	The production process efficiency of your company compared with foreign leading companies	0.771
		Production equipment update rate of your company compared with foreign leading companies	0.759
		Repair rate of your company compared with foreign leading companies	0.828
		Energy consumption per unit product of your company compared with foreign leading companies	0.783
	Marketing capability gap	The degree of competition between similar products of your company and foreign leading companies in the market	0.758

	CR= 0.8633 AVE= 0.6151 KMO=0.727	the competitiveness of similar products of your company compared with foreign leading companies	0.873
		the share of similar products of your company in the domestic market compared with foreign leading companies	0.839
		the share of similar products of your company in the international market compared with foreign leading companies	0.648
Technology gap ten years ago CR=0.8073 AVE=0.5845 KMO=0.603	R&D capability gap	when your company was founded, your company's R&D capabilities gap with foreign leading companies	0.766
	Manufacturing capability gap	when your company was founded, your manufacturing capability gap with foreign leading companies	0.840
	Marketing capability gap	when your company was founded, your marketing capability gap with foreign leading companies	0.679

In the questionnaire, for some questions such as "the ratio of R&D investment to sales revenue of your company compared with foreign leading companies", the higher the value in the 5-point scale, the smaller the gap in R&D investments. Thus, in the regression analysis, the value for this type of questions is calculated by "6 minus the original value". The higher the calculated value is, the greater the gap in R&D investments becomes.

(2) Cost advantage

Table 4-5 shows the results of the reliability and validity tests for the cost advantage variable. The load factor, KMO, CR and AVE for each variable and dimension are greater than the threshold requirement, indicating that the questionnaire has high reliability and validity for the variables of cost advantage and related issues.

Table 4-5 Reliability and validity analysis of the cost advantage variable

variable	dimension	Measuring items	Load factor
Cost advantage	Manpower advantage	The ratio of employee compensation to cost of your company compared with foreign leading companies	0.891

over the recent three years CR=0.955 AVE=0.7525	CR= 0.9158 AVE= 0.7838 KMO=0.736	The ratio of social insurance spending to the cost of your company compared with foreign leading companies	0.878
		The ratio of education and training spending to the cost of your company compared with foreign leading companies	0.887
	Material resource advantage CR= 0.9147 AVE= 0.7289 KMO=0.798	The cost of raw materials for your company compared to foreign leading companies	0.871
		Land cost of your company compared to foreign leading companies	0.834
		The energy consumption cost of your company compared to foreign leading companies	0.916
		The environmental costs of your company (such as pollution control and waste disposal costs) compared to foreign leading companies	0.789
Cost advantage ten years ago CR=0.7589 AVE=0.6115	Labor cost advantage	when your company was founded, your company's labor cost advantage compared to foreign leading companies	0.782
	Material resource advantage	when your company was founded, your company's material cost advantage compared to foreign leading companies	0.782

(3) Actual licensing royalty rates

In the questionnaire, the actual royalty rates have two dimensions: the rate in the recent three years and the rate ten years ago. As shown in Table 4-6, the load factor, KMO, CR and AVE for each dimension are greater than the threshold requirement, indicating that the questionnaire has high reliability and validity for the variables of actual licensing royalty rates and related issues.

Table 4-6 Reliability and validity analysis of the actual royalty rate variable

variable	dimension	Measuring items	Load factor
Actual royalty rate	Actual royalty rate over the recent three years	The actual royalty rates your company have accepted from foreign leading companies compared with the rate between foreign leading companies	0.904
		The actual royalty rates your company have accepted from foreign leading companies compared with the rate foreign leading companies offer other domestic	0.910

CR=0.8244 AVE=0.8031 KMO=0.735	companies	
	The actual royalty rates your company have accepted from foreign leading companies compared with the rate between domestic companies	0.874
Actual royalty rate ten years ago CR=0.9301 AVE=0.8163 KMO=0.662	when your company was founded, the actual royalty rates your company accepted from foreign leading companies compared with the rate between foreign leading companies	0.900
	when your company was founded, the actual royalty rates your company accepted from foreign leading companies compared with the rate foreign leading companies offer other domestic companies	0.952
	when your company was founded, the actual royalty rates your company accepts from foreign leading companies now	0.856

4.3 Descriptive statistics

Table 4-7 presents the descriptive statistics analysis of each of the items. R1 represents the difference between the actual royalty fees charged by the foreign leading enterprises and the reasonable royalty fees with a mean value of 2.69. R2-R4 measures the royalty fees accepted by Chinese latecomer firms from foreign leading enterprises 10 years ago. R5-R7 measures the royalty fees accepted by Chinese latecomer firms from foreign leading enterprises in the recent three years. The reported values of R2 and R4 are higher than the royalty fee in the recent three years. RD1-RD3 are items related to the R&D capability gap of latecomer firms in the recent three years, and RD4 is items related to the R&D capability gap of latecomer firms ten years ago. MC1-MC4 measure the manufacturing capability gap of the latecomer firms in the past three years, while MC5 measures the manufacturing capability gap of the latecomer firms ten years ago. MD1-MD4 measure the marketing capability gap of latecomer firms in the recent three years, and MD5 measures the marketing capability gap of latecomer firms one decade ago. As Table 4-7 shows, the average values of the R&D, manufacturing and market capability gap are lower in the recent three years than the corresponding scores ten years ago. It can be seen that the technological capability gap between latecomer firms and foreign leading enterprises in the recent three years is narrowing.

Table 4-7 Descriptive statistical analysis of the items related to each variable

Items	Average	Standard deviation	Skewness	kurtosis
R1	2.69318	1.206857	0.095	-0.9
R2	2.78409	1.19817	0.01905	-0.81007
R3	2.61364	0.99922	-0.00285	-0.19248
R4	3.46591	1.12392	-0.1119	-0.83036
R5	2.64773	1.09376	-0.01043	-0.74413
R6	2.65909	1.09215	-0.03957	-0.7305
R7	2.65909	1.16349	0.119	-0.64388
RD1	3.00000	1.00573	0.20811	-0.45821
RD2	3.02273	0.93437	0.04066	0.24647
RD3	2.97727	0.93437	-0.04066	0.24647
RD4	3.42045	1.21032	-0.46632	-0.60812
MC1	2.97727	0.95865	-0.19421	-0.03801
MC2	2.875	0.95668	0.09445	0.49612
MC3	2.55172	0.9494	-0.15181	-0.49176
MC4	2.82955	0.83352	-0.27736	0.13599
MC5	3.63636	3.45474	7.93811	70.418
MD1	2.72727	0.95565	0.17241	-0.21217
MD2	2.55682	0.86911	0.03641	-0.13278
MD3	2.63636	1.03036	0.01066	-0.93607
MD4	3.09091	0.96652	-0.18538	-0.23962
MD5	3.23864	1.12438	-0.23943	-0.7273
LC1	3.04598	0.88801	-0.29509	0.22758
LC2	3.22989	0.87206	-0.14647	-0.07809
LC3	3.27586	0.92371	-0.31038	-0.08189
LC4	3.43678	0.99652	0.0342	-1.03269
LC5	3.36782	0.90367	-0.31972	-0.10554
LC6	3.52874	0.91294	-0.69691	0.61144

MR1	3.06977	0.86488	-0.02489	1.28018
MR2	3.25581	0.9354	0.16901	1.09116
MR3	3.09302	0.76124	0.8242	1.86176
MR4	3.38372	0.92251	0.25881	0.12199
MR5	3.15294	0.9575	-0.06443	-0.38748

LC1-LC3 and LC4-LC6 measure the labor cost advantages of the latecomer firms in the recent three years and ten years ago respectively. LC4-LC6 descriptive statistics are higher than the corresponding statistics of LC1-LC3, indicating that the labor cost advantage of the latecomer firms is weakening compared with that ten years ago.

MR1-MR4 measure the material cost advantage of the latecomer firms in the past three years while MR5 measures the material cost advantage of the latecomer firms ten years ago. The average values of MR1-MR4 and MR5 are similar, indicating that the material cost advantage of the latecomer firms has not changed significantly during the past ten years. Since the absolute value of the skewness coefficient of each variable is lower than 3 and the absolute value of the kurtosis coefficient is lower than 10, it can be assumed that it obeys a normal distribution.

Table 4-8 shows the correlation coefficient matrix between the variables.

Table 4-8 Matrix of correlation coefficients

	1	2	3	4	5	6	7	8	9	10
Actual royalte rate over the recent years	1									
Actual royalte rate 10 years ago	.558**	1								
Company Type	-.018	-.171	1							
Company industry	-.110	.138	-.232*	1						
Company product or service distribution area	-.104	.111	.167	-.082	1					

License company residence	.020	.063	-.154	-.025	.338**	1				
Technology gap over the recent three years	.141	.209	-.275**	-.034	.034	.163	1			
Cost advantage over the recent three years	.001	-.013	.057	.042	-.019	.058	.138	1		
Technology gap ten years ago	-.206	-.118	-.067	.167	-.064	.009	-.097	.035	1	
Cost advantage ten years ago	.089	.076	-.294*	.040	-.017	-.061	.139	.063	.102	1

Note: * indicates P < 0.1, ** indicates P < 0.05, *** indicates P < 0.01

From a general analysis of the table, it can be observed that there is a significant positive correlation between the technological capability of the latecomer firms and the actual royalty rates ten years ago. However, in the case of the recent three years the correlation is inverted, existing a significant negative correlation between the technological capability and the actual royalty rates. There is also a significant positive correlation between the cost advantages the actual royalty rates both ten years ago and the past three years. As can be seen from the table, since the absolute values of the correlation coefficients between the dependent variable and the independent variable are much lower than 0.5, there is no problem of multicollinearity.

4.4 Empirical analysis of the factors affecting royalty fees

4.4.1 Regression analysis of the technology gap and actual royalty rates

Table 4-9 presents the regression analysis of the technology gap and the actual royalty rates of both time periods (Model 1 and Model 2).

Model 1 demonstrates that the technological capability ten years ago is positively correlated with the actual royalty rate ten years ago with a significance level of 0.05; However, Model 2 shows there is a negative correlation in terms of technological gap during the recent three years with a significance level of 0.05, that is, the smaller the technology gap, the higher the actual royalty rate.

Table 4-9 Regression analysis results of the technology capability and actual royalty rates ten years ago and over the past three years

	Actual royalty rate ten years ago	Actual royalty rate over the recent three years
	Model 1	Model 2
Control variable		
Company type	-0.296** (-2.123)	-0.31** (-2.197)
Company industry	-0.052 (-0.419)	-0.185 (-1.461)
Company product or service distribution area	0.126 (1.129)	0.018 (0.157)
License company residence	0.031 (0.221)	0.108 (0.766)
Independent variable		
Technology gap ten years ago	0.240** (2.34)	
Technology gap over the recent three years		-0.236** (-2.234)
F	3.131	2.405
R^2	0.160	0.128
Adjusted R^2	0.109	0.075

In order to explore the specific differences between the technology gaps and the actual royalty rates of the two different time periods analyzed, we conducted a dimensional regression analysis. Table 4-10 presents the regression analysis result of three different technology gaps and the actual royalty rates ten years ago. The standardized regression coefficient of R&D capability ten years ago was 0.197, with a t value of 1.869, indicating that it has a positive correlation with the actual royalty rate with a significance level of 0.1; the marketing capability gap standardized regression coefficient was 0.206, and the t value was 1.999 with a significance level of 0.05, demonstrating that the marketing capability gap can significantly and positively affect the actual royalty rate. The standardized regression coefficient of manufacturing capability gap was 0.149, but did not show significant statistic correlation (t value = 1.404).

Table 4-10 Regression analysis results of the R&D capability, manufacturing capability and marketing capability, as well as actual royalty rates ten years ago

	Actual royalty rates ten years ago			
	Model 3	Model 4	Model 5	Model 6
Control variable				
Company type	-0.339** (-2.392)	-0.285** (-1.996)	-0.321** (-2.274)	-0.337** (-2.425)
Company industry	-0.06 (-0.474)	-0.059 (-0.476)	-0.027 (-0.213)	-0.089 (-0.707)
Company product or service distribution area	0.114 (0.996)	0.123 (1.091)	0.125 (1.097)	0.112 (1.001)
License company residence	0.031 (0.216)	0.018 (0.126)	0.054 (0.378)	0.014 (0.099)
Independent variable				
R&D capability gap		0.197* (1.869)		
Manufacturing capability gap			0.149 (1.404)	
Marketing capability gap				0.206** (1.999)
F	2.415	2.689	2.349	2.801
R^2	0.104	0.141	0.125	0.146
Adjusted R^2	0.061	0.088	0.072	0.094
Sig.(F)	0.055	0.027	0.048	0.022

Note: * indicates P < 0.1, ** indicates P < 0.05, *** indicates P < 0.01, the coefficients in the table are all standardized coefficients

As can be seen from Table 4-11, the R&D capability of the companies with a significance level of 0.01 in the past three years has a significant negative correlation with the actual royalty rate (t = -2.658). However, the standardized regression coefficients for manufacturing capability and marketing capability are 0.036, 0.131 respectively, and the t values are 0.313 and 1.208 respectively, both of which are not in the confidence interval.

Table 4-11 Regression analysis results of R&D capability, manufacturing capability, marketing capability with actual royalty rates over the recent three years

	Actual royalty rates over the recent three years			
	Model 7	Model 8	Model 9	Model 10
Control variable				
Company type	-0.335** (-2.331)	-0.343** (-2.467)	-0.33** (-2.269)	-0.323** (-2.241)
Company industry	-0.151 (-1.174)	-0.221 (-1.743)	-0.143 (-1.085)	-0.183 (-1.396)
Company product or service distribution area	0.022 (0.191)	-0.002 (-0.016)	0.029 (0.242)	0.004 (0.037)
License company residence	0.106 (0.733)	0.076 (0.544)	0.115 (0.776)	0.089 (0.611)
Independent variable				
R&D capability gap		-0.277*** (-2.658)		
Manufacturing capability gap			0.036 (0.313)	
Marketing capability gap				0.131 (1.208)
F	1.677	2.853	1.347	1.641
R^2	0.075	0.148	0.076	0.091
Adjusted R^2	0.03	0.096	0.02	0.036

Sig.(F)	0.163	0.02	0.253	0.158

Note: * indicates P < 0.1, ** indicates P < 0.05, *** indicates P < 0.01, the coefficients in the table are all standardized coefficients

By comparing the differences of the impact of the technology gaps on the actual royalty rates for the two time periods, we can see that the R&D capability gap has different impacts, that is, while the R&D capability gap was significantly positively correlated with the actual royalty rate ten years ago, there is a significant negative correlation in the last three years. The reason for this change may be that during the early stage of patent licensing when the gap between the latecomer firms and the foreign leading companies in terms of R&D capabilities was relatively large, due to the differences in competition areas and product performance, the patented technologies received by the latecomer firms were not advanced or key technologies. Also, impelled by the need of expanding the market and diffusing the technology, leading companies may reduce the royalty fees to the companies owning relatively strong R&D capabilities in order to reduce the risk of imitation or design modifications of peripheral or utility patents from the latecomer firms. However, when the technology gap between the latecomer firms and the foreign leading companies narrows to a certain extent, for example, when the leading company licenses a core technology to the latecomer firm, or even when the foreign leading company and the latecomer company have products of similar performance in the same competition area, the smaller the technology gap becomes, the higher the royalty rate is, which is why foreign leading companies try to stay privileged, and suppress the latecomer firms.

Based on the analysis of the data of ten years ago and the recent three years, it can be seen that a decade ago, the difference in marketing capability positively affected the actual royalty rate. However, in the recent three years, the marketing capability gap has not had a significant impact on the actual royalty rate. This difference may be due to the fact that after several years of development, the marketing capability gap between leading companies and latecomer firms has narrowed significantly. Today, the main factor affecting the actual royalty rate is the gap in R&D capabilities.

4.4.2 Regression analysis of cost advantage and actual royalty rates

Based on the regression results shown in Table 4-12, it can be observed that the cost advantages are significantly positively correlated with the actual royalty rate during the two time periods. However, the significance level at both time periods is different. In Model 11, the regression coefficient of cost advantage ten years ago was 0.272, and the t value was 2.687 with a significance level of 0.01, and the model's R^2 was 0.177. In Model 12, the regression coefficient of the cost advantage in the recent three years is 0.244, and the t value is 2.289 with a significance level of 0.05. The R^2 of the model is 0.13, which is smaller than the corresponding parameter of the Model 11. This reflects that to a certain extent, in comparison with the last three years, the positive impact of the cost advantage of the latecomer firms on the actual royalty rate was stronger ten years ago.

Table 4-12 Regression analysis results of the cost advantage and actual royalty rate ten years ago and over the recent three years

	Actual royalty rate ten years ago	Actual royalty rate over the recent three years
	Model 11	Model 12
Control variable		
Company type	-0.327** (-2.397)	-0.334** (-2.378)
Company industry	-0.094 (-0.768)	-0.154 (-1.23)
Company product or service distribution area	0.103 (0.934)	-0.007 (-0.063)
License company residence	-0.014 (-0.101)	0.05 (0.351)
Independent variable		
Cost advantage ten years ago	0.272*** (2.687)	
Cost advantage over the recent three years		0.244** (2.289)
F	3.521	2.458
R^2	0.177	0.13
Adjusted R^2	0.127	0.077
Sig.(F)	0.006	0.04

Note: * indicates P < 0.1, ** indicates P < 0.05, *** indicates P < 0.01, the coefficients in the table are all standardized coefficients

In order to explore the specific difference in the impact of the cost advantage of two different time periods on the actual royalty rate, the thesis conducts regression analysis on the labor cost advantage and material cost advantage. As presented in Table 4-13, both the labor cost advantage and the material cost advantage have a significant positive impact on the actual royalty rates in both time periods.

Table 4-13 Regression analysis results of the labor cost, material cost and actual royalty rates ten years ago and over the recent three years

	Actual royalty rate ten years ago		Actual royalty rate over the recent three years	
	Model 13	Model 14	Model 15	Model 16
Control variable				
Company type	-0.37*** (-2.622)	-0.312** (-2.261)	-0.36** (-2.548)	-0.311** (-2.186)
Company industry	-0.088 (-0.7)	-0.081 (-0.657)	-0.157 (-1.246)	-0.151 (-1.188)
Company product or service distribution area	0.109 (0.966)	0.105 (0.945)	-0.026 (-0.222)	0.021 (0.186)
License company residence	0.051 (0.36)	-0.024 (-0.172)	0.085 (0.597)	0.043 (0.294)
Independent variable				
Labor cost advantage ten years ago	0.179* (1.719)			
Material resource cost advantage ten years ago		0.246** (2.394)		
Labor cost advantage in the recent three years			0.233**	

			(2.164)	
Material resource cost advantage in the recent three years				0.200* (1.857)
F	2.569	3.189	2.338	2.071
R^2	0.135	0.163	0.125	0.112
Adjusted R^2	0.083	0.112	0.071	0.058
Sig.(F)	0.033	0.011	0.049	0.077

Note: * indicates P < 0.1, ** indicates P < 0.05, *** indicates P < 0.01, the coefficients in the table are all standardized coefficients

4.5 Further discussion and summary

4.5.1 Further analysis

The results from the empirical research reflect that the impact of the technology gap on the actual royalty rate is significantly different in the two different time periods. To further explore the dynamic differences, this section builds five new variables shown in Table 4-14.

Table 4-14 Regression analysis results of changes in actual royalty rate and technological capability gap in the past three years

Variable	Calculation method
Change in technological capability gap	Technological capability gap in the recent three years/technological capability gap ten years ago, the negative result indicates that the technology gap has narrowed, and the greater the absolute value, the greater the reduction
Change in R&D capability gap	R&D capability gap in the recent three years/ R&D capability gap ten years ago
Change in manufacturing capability gap	manufacturing capability gap in the recent three years/ manufacturing capability gap ten years ago

Change in marketing capability gap	marketing capability gap in the recent three years/ marketing capability gap ten years ago
Change in actual royalty rate	Actual royalty rates in the recent three years/actual royalty rates ten years ago, the negative result indicates that the actual royalty fees are higher over the past three years; the greater the absolute value, the greater the disparity.

Table 4-15 presents the regression analysis results of the impact of the dynamic change in the technology gap on the actual royalty rate over the recent three years.

It can be seen that the change in the R&D capability gap is negatively correlated with the actual royalty rate in the past three years with a significance level of 0.01. It should be noticed that a negative value of the technology gap change indicates that the gap has narrowed in the past three years compared with that ten years ago.

Furthermore, the larger the absolute value, the larger the gap reduction. The positive values indicate that technology gap has expanded over the last three years, and the greater the absolute value is, the greater the degree of expansion becomes. Therefore, the negative correlation between the change in the R&D capability gap and the actual royalty rate in the past three years reveals that the companies that have caught up the most in R&D capabilities have a higher royalty rate. This result is an important complement to the empirical results of last section.

Moreover, the change in technological capability gap and marketing capability gap over the past three years are negatively correlated with the royalty rate with a significance level of 0.1, but its R2 value and significance level is lower than that of the model 18. Therefore, the gap in R&D capacity is the main factor that leads to the dynamic impacts of technological capability gap on the actual royalty.

Table 4-15 Regression analysis results of changes in actual royalty rates and technological capacity gap in the past three years

	Model17	Model 18	Model 19	Model 20
Control variable				
Company type	0.034 (0.281)	-0.006 (-0.053)	-0.008 (-0.069)	0.017 (0.148)

Company industry	-0.096 (-0.849)	-0.09 (-0.825)	-0.118 (-1.036)	-0.119 (-1.069)
Company product or service distribution area	-0.138 (-1.149)	-0.112 (-0.957)	-0.131 (-1.074)	-0.142 (-1.189)
License company residence	0.042 (0.348)	0.002 (0.021)	0.059 (0.483)	0.049 (0.408)
Independent variable				
Change in technological capability gap	-0.192* (-1.695)			
Change in R&D capability gap		-0.300*** (-2.783)		
Change in manufacturing capability gap			-0.032 (-0.283)	
Change in marketing capability gap				-0.205* (-1.87)
F	1.039	2.040	0.465	0.167
R^2	0.061	0.113	0.028	0.068
Adjusted R^2	0.042	0.058	0.002	0.010
Sig.(F)	0.401	0.082	0.801	0.333

Note: * indicates P < 0.1, ** indicates P < 0.05, *** indicates P < 0.01, the coefficients in the table are all standardized coefficients

A positive change value of the actual royalty rate indicates that the actual royalty rate in the past three years is higher than that of ten years ago. The greater the absolute value is, the greater increase of the actual royalty fee will be. A negative value indicates that the actual royalty rate is lower in the past three years. Likewise, the greater the absolute value is, the greater the reduction in actual royalty fees. It can be seen from the table 4-16 that the change in the R&D capability gap is negatively correlated with the actual royalty rate gap at the 5% level, that is, the companies that have narrowed more the R&D capability gap over the past three years are faced with an actual royalty rate higher than that of ten years ago.

Table 4-16 Regression analysis results of changes in actual royalty rates and technological capability gap

	Model 21	Model 22	Model 23	Model 24
Control variable				
Company type	0.118 (1.016)	0.101 (0.924)	0.081 (0.700)	0.121 (1.075)
Company industry	-0.209** (-1.904)	-0.195** (-1.84)	-0.228* (-2.079)	-0.218** (-2.041)
Company product or service distribution area	-0.261* (-2.238)	-0.242* (-2.13)	-0.254* (-2.17)	-0.267** (-2.319)
License company residence	0.076 (0.65)	0.038 (0.330)	0.085 (0.735)	0.075 (0.658)
Independent variable				
Change in technological capability gap	-0.097 (-0.879)			
Change in R&D capability gap		-0.245** (-2.340)		
Change in manufacturing capability gap			0.048 (0.446)	
Change in marketing capability gap				-0.173 (-1.638)
F	2.303	3.080	1.902	2.457
R^2	0.113	0.161	0.106	0.133
Adjusted R^2	0.057	0.109	0.050	0.079
Sig.(F)	0.083	0.014	0.103	0.040

Note: * indicates $P < 0.1$, ** indicates $P < 0.05$, *** indicates $P < 0.01$, the coefficients in the table are all standardized coefficients

4.5.2 Empirical research result summary

Based on the Lemley-Shapiro patent holdup model, this thesis collected 88 questionnaires from companies in several Chinese provinces, all of which have received patent licenses from foreign leading companies. Through empirical research, this thesis explores the technology gap and cost advantage between latecomer firms and leading companies. The differences and advantages dynamically influence the actual royalty rates between them. Table 4-17 presents the regression analysis for hypothesis verification:

Table 4-17 Verification of the regression analysis results

		10 years ago	Recent three years
HypothesisH1	The technology gap between latecomer firms and foreign leading companies is positively related to the actual royalty rate; the smaller the gap, the smaller the rate.	True	Opposite
HypothesisH1a	The R&D capability gap of latecomer firms is positively related to the actual royalty rate; the smaller the gap, the smaller the rate.	Valid	Opposite
HypothesisH1b	The manufacturing capability gap of latecomer firms is positively related to the actual royalty rate; the smaller the gap, the smaller the rate.	False	Opposite
HypothesisH1c	The marketing capability gap of latecomer firms is positively related to the actual royalty rate; the smaller the gap, the smaller the rate.	True	False
HypothesisH2	The cost advantages of latecomer firms and foreign leading companies are the influencing factor of the actual royalty rate, and there is a positive correlation between and cost advantage and the actual royalty rate; the smaller the cost advantage, the lower the rate.	True	True
HypothesisH2a	The labor cost advantage of the latecomer firms is positively related to the actual royalty rate; the smaller the advantage, the smaller the rate	True	True
HypothesisH2b	The material resource cost advantage of the latecomer firms is positively related to the actual royalty rate; the smaller the advantage, the smaller the rate	True	True

The research reported above shows that:

(1) Ten years ago, the technology gap had a significant positive correlation with the actual royalty rate. As the technological gap between the latecomer firms and the leading enterprises continues to shrink, the actual royalty rate decreases, and patent holdup also weakens. Based on the regression analysis of the technology gap variables, the results show that the actual royalty rate is significantly positively correlated with the R&D capability gap and marketing capability gap, while the manufacturing capability gap does not have a significant impact.

(2) In the past three years, the technology gap has a significant negative correlation with the actual royalty rate, which is contrary to the assumptions of the thesis. In further regression analysis, it is found that the main factor leading to this result is a significant negative correlation between the R&D capability gap and the actual royalty rate, indicating that the leading foreign companies exert more patent hold-up pressure to the latecomer firms when they the technology gap between them narrows to a certain degree. The reasons for this situation and the development of coping strategies are highly important for latecomer firms. In the recent three years, the manufacturing and marketing capability gaps have no significant impact on the actual royalty rate. The reason why the marketing capability gap does not have a significant impact may be that after years of development, the gap between the leading companies and latecomer firms has been significantly reduced in comparison with that a decade ago.

(3) In both time periods, there is a significant positive correlation between the actual royalty rate and the cost advantage of the latecomer firms, which proves that the weakening cost advantages of the latecomer firms contributes to the reduction of patent holdup posed by leading companies, making the actual royalty rate for latecomer firms more closer to the reasonable royalty rate. However, the influence of the cost advantage ten years ago is more significant than that of the past three years on the actual royalty rate, showing that the cost advantage of the latecomer firms has weakened, but it will not certainly bring down the actual royalty rate or patent holdup to the same proportion as it would in the past. In the case of weakened cost advantages, how to enhance their technological capabilities and patent licensing negotiation capabilities is a practical problem faced by latecomer firms. In addition, through further analysis of the impact of the weakened cost advantage on the reduction of the actual royalty rate, the thesis finds that the labor cost advantage ten years ago has less

impact than the material cost advantage, while the impact of the labor cost advantage in the past three years is more significant than the material cost advantage. It can be seen that in the past three years, it has become more urgent for latecomer firms to reduce the actual royalty rate in the case of weakened labor cost advantages.

(4) Based on further analysis of the dynamic impact of the technology gap on the actual royalty rate, the thesis finds that the change in the R&D capability gap is significantly negatively correlated with the actual royalty rate over the recent three year, that is, the companies that have narrowed more the gaps of technological capability, R&D capability and marketing capability over the recent three years have to bear royalty rates higher than those a decade ago, revealing that as the disparity in technology between the latecomer firms and leading companies, the leading enterprises exert more patent hold-up instead of reducing it. Companies with smaller technology gap with the leading companies will encounter more serious patent hold-up.

Chapter 5: Case Studies

This chapter selects two typical cases of patent hold-up and anti-holdup in China, and combines with the milestones of patent license management to discuss the confusion and solution of the patent licensing practice of Chinese enterprises under different industry backgrounds and different enterprise life cycles. The first case focuses on the causes and strategies of Huawei's anti-holdup in the global localization development period. The second case summarizes the phenomenon of patent thickets and hold-up in the development of digital TV patents and the countermeasures of China's enterprises.

5.1 Huawei Patent Licensing Case

This chapter selects the patent holdup and anti-holdup case of one of the typical enterprises in China, and aims to discuss the confusion on patent licensing and practices of Chinese enterprises from different industries and with different life cycles based on the landmark events of patent licensing management. The focus is to analyze the motivations and strategies taken by Huawei to fight against patent holdup under the background of global localization.

In February 2015, the National Development and Reform Commission (NDRC) of China officially launched the investigation against Qualcomm, attracting domestic and international attention. World famous business newspapers such as "Wall Street Journal" and "Financial Times" have given long reports and comments, most of which mention: why China's ICT companies like Huawei can crack the existing one-way licensing model and game rules in the name of antitrust, especially under the background that these rules have been implemented between European and American multinationals and Chinese companies for more than two decades.

This question has commercial historical value. For the industry in the West, the case of Huawei can be regarded as the turning point of patent competition between China's ICT enterprises and leading European and American companies. Chronologically, Huawei's case includes three cases: Huawei's response and counterclaims to IDC's Standard Essential Patents (SEPs) (including four wholly-owned subsidiaries of InterDigital Inc), monopolistic civil infringement (including InterDigital Inc. and its two wholly-owned subsidiaries), and NDRC's antitrust investigation against IDC. Table 5-1 shows cases that Huawei and other Chinese ICT companies sued IDC and Qualcomm in China.

Table 5-1 Huawei and other Chinese ICT companies v. IDC and Qualcomm case in China

Period	Party	Cause of action	Judge	Result
Dec. 2011-Oct. 2013	Huawei sued IDC	standard essential patent license fee dispute	China Shenzhen Intermediate People's Court and Guangdong Higher People's Court	The court ruled that the FRAND licensing rate of IDC's Chinese Standard Essential Patents ("SEPs") should be no more than 0.019 percent of sales revenue of Huawei's involved products. (IDC requires a royalty rate of about 2%).
Dec. 2011 to Oct. 2013	Huawei sued IDC	Huawei sued IDC over its abuse of SEP market monopoly	China Shenzhen Intermediate People's Court and Guangdong Higher People's Court	The court ordered IDC to cease its unlawful practices of unreasonable licensing terms and pay Huawei 20 million CNY (approximately 3.2 million USD) in damages, and rejected other claims from Huawei.
Dec. 2013 to -March 2014	Huawei reported IDC	Huawei reported that IDC abused SEP market monopoly	NDRC	NDRC suspended the investigations against IDC after receiving a formal application. IDC adopted specific measures to eliminate the consequences of suspected monopolistic behavior, including: not charging Chinese companies for discriminatory high-priced license fees, and not binding non-SEPs with SEPs.
Nov. 2013 to Feb. 2015	Chinese and American companies reported Qualcomm	Chinese and American companies reported Qualcomm abuse market monopoly in SEP licensing and baseband chip	NDRC	NDRC issued an administrative punishment decision and ordered Qualcomm to stop the illegal act of abusing market dominance in China. It also imposed an RMB 6.088 billion (US$975 million) fine (8% of Qualcomm's sales revenue in China). Qualcomm proposed a series of rectification measures, including: charging royalty fees based on 65% of

		the net sale price of whole mobile phones, not charging royalty fees for expired patents, not requesting Chinese licensees to provide grant-back of patents for free, not tying non-wireless SEPs without proper reasons; not prohibiting Chinese buyers from challenging the license agreements.

As shown in Table 5-1, we can find the turning point of patent competition between the latecomer firms and foreign leading companies, that is, from the acceptance of a royalty fee higher than the benchmark royalty level (Lemley & Shapiro, 2007a) to taking active measures to fight against patent hold up, so as to seek to gain competitiveness in the patent field and reshuffle the profits of the global market. Therefore, based on Huawei's business management strategy over the past two decades and its patent competition with leading companies in developed countries in Europe and the United States, this thesis further explores the reasons and strategies for Huawei to fight against patent hold-up, and its meaning for Chinese companies to seek global market profit and European and American multinational companies to cope with the new situation of patent competition in China's domestic market.

5.1.1 Huawei's anti-holdup motivations

(1) The cultural consensus of Huawei to implement strategies against patent hold-up derives from the continuous updating of IPRs (Xiao, Tylecote & Liu, 2013).

Huawei's business management strategy has undergone three changes in the past 25 years, and at the same time brought about a major shift in Huawei's IP concept. From 1991 to 2000, Huawei took the initial step to expand the Chinese domestic market (with "tokenism" as its IP concept); from 2001 to 2000, it began to engage in the global market (the IP concept is observing the international rules and actively operating its own IP to support its global market development). As shown in Table 5-1, Huawei's first change of IP concept occurred in January 2003 when Cisco filed a patent infringement lawsuit against Huawei; the second change took place when Huawei took the initiative to upgrade its IP and global localization strategies after resolving a number of dispute cases involving its own IP and international IP. From this perspective, it has become Huawei's cultural consensus to take initiative to fight against patent hold-up so as to further realize its IP value, thus safeguarding the sound operation of the company's global localization strategy.

(2) Huawei's grasp of anti-holdup behavior stems from technological advances that have led to a narrowing of the technology gap and even a partial catch-up

When Huawei first entered the industry, there was a big technology gap between it and the leading Western companies. At this point, Huawei could not make a correct assessment of the commercial value of the patented technology of Western leading companies, and lagged farther behind the companies in the West in IP accumulation. Therefore, Huawei had to passively bear high royalty fees from Western leading companies to enter the international market, which are much higher than the benchmark royalty level. Xu Zhijun, then senior vice president of Huawei, said in 2004 that Huawei's CDMA equipment had to pay a royalty fee rate as high as 6.75% at that time. Since then, Huawei has made a strategic decision that the annual R&D investment will be higher than that of the competitors.

Under this strategy, Huawei has made great improvements in its technological capabilities and IP system, making the technology gap with Western leading companies keep narrowing. Surprisingly, Huawei has even taken the lead in certain industrial technologies. According to data from US Patent Freedom, Huawei encountered more than 50 patent negotiations or litigations from NPEs such as IDC from 2009 to 2013. Although Huawei has experienced many disputes in the field of international IP, especially involving so many complicated negotiations or litigations, it is the accumulation of these rich experiences that has enabled Huawei to grow its processing capabilities in the field of international IP affairs. Based on these accumulations, Huawei has always insisted on continuously increasing R&D investment, seeking to create a more favorable patent environment and winning a larger space for global business competition.

(3) The economic motivation for Huawei to fight against patent holdup is due to the continuous reduction of cost advantages.

In the early days, leading companies in Western countries did not fully understand the cost advantages of Chinese companies, including cheap labor, economies of scale, and the cost of China's economic system that has been reduced since the reform and opening up. This is why Chinese ICT companies, including Huawei, could accept a royalty fee higher than the benchmark level in the initial stage of entering the industry.

However, as mentioned in the IP change process of Huawei, Huawei would not have developed from “imitation” to “catch-up” to partial “surpass” in terms of technology without a substantially increasing investment in R&D. In its development process, Huawei's economic globalization has continued to deepen, and the continuous development of various emerging markets has made China's factor costs (including manpower, land, environmental protection.) become prominent. Therefore, the gradually weakening cost advantage, coupled with the operating costs such as financial pressure brought about by global localization, is the financial incentive for Huawei to implement anti-holdup. By launching a new round of royalty fee negotiations with Western leading companies, the existing high rates are reduced so as to balance business profits and ensure the company's sound development.

(4) Huawei’s safeguard to carry out anti-holdup stems from China's emphasis on IPRs and the continuous improvement of related systems.

Since China's reform and opening up, especially since its accession to the WTO, the IP system has undergone two major changes, including the introduction of legislation from the early 1980s, the passive revision of related laws to meet WTO’s requirement, and taking the initiative to improve legislation since 2008 to adapt to the development of economic globalization. One example is that in June 2008, the State Council of China issued the Outline of the National Intellectual Property Strategy to promote the transformation of the IP system from passive revision to active improvement.

It is worth mentioning that in August 2008, the Anti-Monopoly Law of China was issued, and the Patent Law, the Copyright Law and the Trademark Law were successively revised, which became an important symbol of the internationalization of China's IP strategy. The Patent Law clearly stipulates “preventing the abuse of rights by patentees”, "the administrative authority of the patent administration department is mandated to stop infringements", and “adding the PCT provisions”. Another example is the introduction of the Proclamation of the Supreme People's Court of the People's Republic of China in the field of IPR judicial adjudication and administrative law enforcement in China, which has greatly enhanced the judicial decision authority in the field of IP in China. These two examples demonstrate that Huawei and other Chinese ICT companies have strong institutional support for taking actions against patent hold-up.

5.1.2 Huawei’s strategies against patent hold-up

(1) Distinguish the anti-holdup breakthrough

In the case of IDC, IDC's patent licensing behavior and its profit model have long been attacked by the industry, which is an important reason for ICT companies such as Huawei to choose to fight against patent hold-up. The China Handset Alliance used the IDC case as an opportunity to report to the NDRC of China with the target being Qualcomm's infrastructure for 3G and 4G wireless communications, as well as the standard essential patent licensing market for related terminal equipment. These measures are conducive to reversing the disadvantages of companies such as Huawei in the international market, and avoiding patent conflicts with companies that have cooperated with and helped their development (such as IBM, Microsoft.) and from being attacked on all sides.

The moral understanding and support of all parties creates a favorable environment for re-establishing the pattern of profit distribution. What needs to be explained here is that the reason why Huawei does not choose Qualcomm as the object of anti-holdup may be that: first, Huawei does not intend to have a direct conflict with Qualcomm in litigation, because Qualcomm provided technical support and assistance to Huawei when it entered the field in the early days, and Huawei is also looking forward to continuing cooperation with Qualcomm in the future; second, Huawei's chances to succeed in launching antitrust lawsuits against IDC are higher than against Qualcomm, because Qualcomm's industrial status and patent volume are not comparable to those of IDC. If Huawei rashly initiate a lawsuit and lose it, it may miss some regional markets for a long time in the future (Xiao, Tong & Liu, 2015).

(2) Integrate existing remedies for anti-holdup

An important strategy for Huawei and other ICT companies to successfully take anti-holdup actions is to make full use of the judicial remedies of Chinese and US courts, as well as the administrative remedies of relevant antitrust agencies, and to integrate these strategies. The successful use of this strategy has greatly reduced the royalty rates including the standard essential patent royalty rate, and has made IDC to revoke more than 300 investigations and lawsuits against Huawei in the US (see Table 5-1 for Huawei vs. IDC cases).

(3) Reasonable appeal against patent hold-up

The "FRAND" (Fair, Reasonable and Non-discriminatory) principle is recognized by international telecommunication organizations such as European Telecommunications

Standards Institute (ETSI) and American Telecommunications Industry Association (TIA). In the three cases of Huawei vs. IDC, Huawei took full advantage of this principle, taking the standard essential patent licensing market as the entry point. Grabbing the point that as the standard essential patent holder, IDC abused its market dominance to undermine the competition order, Huawei appropriately put forward reasonable demands to defend the competitors. Specifically, in the case of Huawei vs. IDC, Huawei disaggregated the claim and respectively filed a request to the US International Trade Commission for a ruling on “standard-essential patent royalty dispute” and stopping IDC’s monopoly torts as a patentee. Huawei's perspective is very precise, which fits the anti-monopoly agency's desire to establish a case benchmark through anti-monopoly specific cases and maintain market order, not only greatly reducing the royalty rate, but also defeating IDC’s infringement in time.

5.1.3 Implications for China’s ICT companies

(1) Accumulate and consolidate patent portfolio while paying attention to improvement of technological capabilities

The development history of Huawei over the past 20 years has fully demonstrated that IPRs are a necessary condition for enterprises to participate in international market competition. The development of “tokenism” or technology imitation alone is not sustainable (Castellaci, Grodal & Mendonca, 2005). Only by attaching great importance to the development of core technologies and their technological capabilities and actively transforming them into their own IP systems can enterprises fundamentally safeguard their position in international market competition (Costa & Mendonça, 2019).

Since China’s reform and opening up, a number of Chinese ICT companies have established their own manufacturing systems by imitating or introducing technology models or business models. Such ICT companies are ruthlessly eliminated by the market due to the lack of core technologies and their own IPRs, making them difficult to counterbalance the weakening cost advantage and the continuous expansion of the technology gap in the new international competition. Therefore, for such a company, the implication of Huawei's case is the belief to firmly develop its own technological capabilities, find ways to accumulate a patent portfolio that is beneficial to the development of the enterprise, and to ensure the balanced development of technological capabilities and IP systems, thereby fundamentally guaranteeing the safety of business operations.

(2) Cultivate technical self-confidence and realize patent value

Different industrial development environments create different opportunities for enterprise development. Different industrial competition requires enterprises to take different responsibilities. While narrowing the technology gap with European and American multinationals and even surpassing them in certain technologies, for the needs of glocalization and the financial pressure brought about by the weakening cost advantage, Huawei depends on its rich IP accumulation and experience in IPR affairs handling and has finally achieved the iconic victory in anti-holdup, which is of great reference value to Chinese ICT companies that have strong technological capabilities and a large amount of IPRs, and are participating in global competition.

Since China’s reform and opening up, China’s current ICT companies have evolved from an imitator at the beginning to becoming leading companies in various industries through market competition (Godinho & Ferreira, 2012). Some companies have even seized the opportunity window of technology and market and become a competitor of Western leading companies. For such companies, the important point of Huawei's case is to aim at the opportunity, adopt coping tactics, and fully integrate their own technological capabilities and IP systems in different jurisdictions of the industry so as to enhance their value. In addition, they should timely conduct negotiations on cross-licensing of standard or non-standard essential patent royalty rates to provide support to further win more market profit margins.

(3) Establish and improve an IP system that is conducive to business strategy

Huawei's development has fully proved the importance of IP strategy serving the enterprise development strategy. Focusing on the characteristics and needs of the enterprise at different development stages, the enterprise should timely transform the IP strategy and integrate it into the overall development strategy of the enterprise so that IPRs fully guarantee the safety of the global operation of the enterprise.

Huawei’s Vice President Song Liuping once mentioned in a speech in June 2015 that Huawei would not independently design IP strategies and that every goal of the company would serve the operation of the company so as to ensure that the company survives and develops (Xiao, Tong & Liu, 2015). This concept has far-reaching implications for Chinese ICT companies that are determined to operate globally but are still in the process of starting or growing.

5.1.4 Implications for Western leading companies

(1) Adapt to situation development and timely adjust the existing patent licensing strategies

Table 5-1 listed the case of actions of “standard essential royalty disputes” and “monopolistic civil disputes” established by the case, which can be used as reference for other courts to deal with relevant cases in the future. Therefore, for Western leading companies, they should follow the “FRAND” (Fair, Reasonable and Non-discriminatory) principle to license patents (including standard essential patent licensing) so as to circumvent antitrust investigations. In addition, they should implement differentiated strategies for different Chinese ICT companies. When negotiating with a company such as Huawei that holds a high-value patent portfolio, the company should adopt different negotiation principles and distinguish standard and non-standard essential patents. In market negotiations, the licensee's patent value should be fully considered if reverse licensing is to be negotiated or contracted. When negotiating with companies with a small number of patents that have low value, the leading companies should also fully consider the other party's claims.

(2) Follow and make full use of the infringement relief rules brought about by changes in China's IP system

As a developing country, China is not only changing its market, but also keeping up with the situation. For Western leading companies, they must always pay attention to the changes of China's IP system, such as the release and improvement of relevant systems such as the Outline of the National Intellectual Property Strategy and new initiatives such as the IP courts established in Beijing, Shanghai and Guangzhou. At the same time, new initiatives also mean new market opportunities.

For non-standard essential patents and standard essential patent infringements that occur in China, based on the “FRAND” (Fair, Reasonable and Non-discriminatory) principle, companies can take litigation or administrative enforcement measures to stop the infringement by flexibly selecting the courts or patent administrative departments where the infringement occurs or where the infringers are located. During the process, the companies should seek reconciliation, mediation or judgment in order to protect and realize their IP value.

(3) Actively cooperate with Chinese companies such as Huawei in emerging fields to seek "relative competitive advantage" in the future

5G, next-generation chips, cloud computing and cloud services are important areas of the future ICT industry. New technologies and business models keep emerging in these fields, indicating high uncertainty of these industries. In order to adapt to the development of emerging fields, it is necessary for Western advanced enterprises to change the existing single patent licensing profit model, adopt a cooperative and open attitude, and cooperate with Chinese companies with rich technical accumulation such as Huawei to seek to win the "relative competitive advantage" in the future.

For example, on June 23, 2015, Qualcomm announced that it invested in SMIC Advanced Technology R&D (Shanghai) Corporation to build China's leading integrated circuit R&D platform and Huawei is one of the joint business firms. The facts show that Western leading companies are already adjusting their existing strategic thinking and making continuous efforts, seeking to obtain or maintain a high future economic status.

5.2 Patent thickets and patent hold-up of digital TV companies

5.2.1 TV technology standard development

On March 22, 1935, Germany began broadcasting the first regular mechanical television program. On April 29, 1931, the Soviet Union began a trial broadcast of television. Two television centers were established in 1938, and television programs were regularly broadcast in Moscow in 1939. In 1932, France established the first state-run television station. By 1939, about 20,000 homes in the United Kingdom owned televisions, and the American RCA's television also debuted at the New York World's Fair, starting the first regular television show, attracting thousands of curious viewers. RCA set the national color TV standard in 1953 and launched RCA color television in 1954 (Xiao & Liu, 2017). The application and development of television technology in Europe and the United States have also spawned their own television systems, transmission and reception standards, laying a foundation for the complexity of television patent technologies and standards in the future.

The development of television was postponed by the Second World War. After the war, the television industry flourished, and television quickly became popular. In 1946, the BBC resumed regular television programming, and the US government lifted the ban on new televisions. For a while, the television industry developed like a wing. In the United States, in just three years from 1949 to 1951, not only television programs have been broadcast nationwide, but the number of televisions has also jumped from 1 million to over 10 million, and hundreds of television stations have been established.

In the early 1950s, black-and-white television gradually became popular in various countries. In 1954, the United States officially launched NTSC (National Television System Committee) compatible color televisions. NTSC uses orthogonal balanced amplitude modulation technology, so it is also called orthogonal balanced amplitude modulation. Most of the Western Hemisphere countries such as the United States and Canada, as well as China's Taiwan, Japan, South Korea, and the Philippines, have adopted this system. In 1956, France proposed SECAM (French abbreviation Séquentiel couleur à mémoire), which means "sequential transmission of color and storage". It is an analog color television system first used in France to systematically modulate an 8MHz wide modulation signal. It was formulated in 1966. For a new color television system. It overcomes the disadvantages of NTSC phase distortion, but uses time separation to transmit two color difference signals. Countries using the SECAM system are mainly concentrated in France, Eastern Europe and the Middle East.

The color television broadcasting standard designated by West Germany in 1962 was Phase Alternating Line (PAL). It adopted the phase inversion quadrature balanced amplitude modulation technique to overcome the disadvantage of color distortion caused by phase sensitivity of NTSC system. Some western European countries, such as West Germany and Britain, Singapore, China and Hong Kong, Australia, New Zealand and other countries and regions adopt this system. According to different parameter details, the PAL system can be further divided into G, I, D and other systems, of which the PAL-D system is the system used in mainland China.

Each of the three-color television systems has its own advantages and disadvantages, and the patented technologies are different. Comparing the results of each other, no one can beat anyone. Therefore, the three-color television systems have coexisted with each other for more than 50 years. Three color TV systems and 13 TV systems are compatible and combined into more than 30 different TV systems. In order to receive and process TV signals of different standards, TV receivers and video recorders of different standards have also been developed. The patented technologies are complicated and different, and each has its own patented technology. According to a survey of more than 200 countries and regions in the world, only 17 of them are used: 8 PAL, 2 NTSC, 7 SECAM. The most used are PAL / B, G, which is used in 60 countries and regions; NTSC / M, which is used in 54 countries and regions; SECAM / K1, which is used in 23 countries and regions. So multi-standard TVs are not full-format, but as long as they can receive PAL / D, K, B, G, I, NTSC / M, SECAM / K, k1, B, G, and standard, they can receive 80% of the world. TV shows from above countries and regions. With different technologies and standards, licensing and transfer of patented technology requires numerous product analyses and comparisons.

NTSC, PAL, and SECAM color TVs are all analog systems. The entire process of generating, transmitting, processing, and recovering the image signals is almost completed under the analog system. Traditional analog TVs are vulnerable to interference, chroma distortion, cross color, line crosstalk, line crawling, large area flicker, and the presence and weak low-resolution disadvantage.

In the 1990s, many industrialized countries successively launched color TV technology updates. In the late 1990s, the British Broadcasting Corporation (BBC) took the lead in establishing the "Columbus" system worldwide. This system enables the BBC's TV program storage, editing, and broadcasting to be fully digitized, that is, non-tape, which greatly improves the BBC's work efficiency and saves production costs. Television agencies are gradually phasing out traditional analog cameras and video tapes, and replacing them with digital cameras and various emerging record carriers. This change has greatly improved the quality of the images. Secondly, transmission technology is diversified. In addition to the traditional wireless microwave transmission, there are transmission methods such as cable TV and satellite TV. These emerging transmission methods effectively reduce the attenuation phenomenon that the signal will inevitably generate during transmission, and ensure better reception quality. Finally, there is the digital transformation of receiving technology. The improvement of sound and picture quality and two-way interaction are the two biggest benefits brought by the widespread digitalization. There are many Japanese color TV companies and the market is developing rapidly. At first, they worked hard to improve display technology and formulated high-definition television standards. However, the United States, European companies and governments have vigorously promoted digitalization, and have successively formulated their own digital television standards, ATSC and DVB. Many patented technologies are embedded in their respective standards to protect their own interests. Later, Japan had to bear the pain to abandon the analog high-definition television standard and turn to the development of the Japanese digital television standard ISDB.

In 2006, the Netherlands stopped terrestrial analog television, becoming the first country in the world to realize digitalization. The United States, Japan, South Korea, Australia and other countries and regions have also closed analog television. 101 countries in Europe, Africa, and Asia plan to start in 2015 Turn off analog television in the year. At present, most of the production and broadcasting systems and satellite, cable, and terrestrial transmission systems in radio and television stations have been digitalized.

Digital television is a revolution in television technology and is regarded by all countries as a “strategic technology” in the new century. Together with the third generation of mobile communications and the new generation of the Internet, it constitutes the three major information infrastructures of the 21st century. China's National Development and Reform Commission has listed digital TV as one of the industries with an annual output value of more than 100 billion yuan.

5.2.2 Digital TV patent thickets and patent hold-up

From the end of the 1970s, China's color TV industry has undergone adjustments in production, market, and technology through the "four steps" of introduction, digestion, absorption, and localization. After more than 30 years of development, it has gradually established a complete set the industrial chain supporting basic components has formed a relatively complete color TV industry system. At present, the color TV industry has become one of the fastest-growing and most internationalized pillar industries in China's electronic information industry. In recent years, China has accounted for about half of the world ’s color TV power.

With the transition from analog TV to digital TV, from the domestic market to the international and domestic markets, domestic backbone TV companies are facing slower growth, overcapacity, increased market competition, patented technical barriers, and increased technical difficulties. The situation of increasing pressure from foreign investment and declining industrial profits has prompted China's color TV industry to enter a new stage of transformation and upgrading. In this process, the patent problem is particularly prominent and has become the most pressing issue affecting the sustainable and healthy development of China's color TV industry. Since the invention of the first television patent, the Nipkov disk, in the 120 years, television technology has continued to develop in various countries around the world. Combined with the improvement of intellectual property systems (especially the patent system), television patent technologies have cumulatively applied for 200,000 patents. Especially in the past 20 years, the rapid development of digital technology and the dispute over digital television standards. Manufacturers and R & D institutions in Europe, America, Japan, and South Korea have laid out a large number of patents in major world markets, forming a "Patent Thickets" when products are complex and multi-technology (Mendonça, 2006). TV patent technology is scattered in the hands of different manufacturers and research institutions, and even individuals; a color TV company must obtain a patent license for the technology involved in the production and sale of televisions, otherwise it will face patent lawsuits; patentees, especially a large number of patents Enterprises with rights, and some of the SEP patents in the standard, dominate patent licensing and litigation.

Since the 1990s, European and American patentees have successively found Chinese color TV companies and required licensing negotiations on the use of television patent technology. In the new century, China has joined the WTO, more and more Chinese mechanical and electrical products have entered the international market, and Chinese companies have encountered increasing patent pressure, especially DVD patent disputes in the first few years of the new century, patent lawsuits, 337 investigations, customs deductions, exhibition sealups, each DVD patent license fee exceeds US $ 20, many DVD manufacturers are forced to sign patent license agreements and pay license fees, and many manufacturers' meager profits are not enough to pay patent fees and are forced to close production or become a foundry of patentee products. In the color TV industry, the patent thickets and the SEPs in the standard have gradually become obstacles that color TV companies cannot overcome in the manufacture and sale of televisions. The color TV patent license fees proposed by European, American, Japanese, and Korean patentees have totaled more than $ 30 per unit; color TV companies are in the thickets, whether based on defensive psychology, or based on increased license negotiation, cross-licensing chips, or other protection of themselves In consideration of benefits, the number of patent applications will continue to increase, forming more patented technologies, resulting in more patents in the color TV industry.

Taking the American digital television standard ATSC as an example, the transmission standard selected the 8-VSD technology developed by Zenith in the United States. The video codec uses mpeg 2. The audio codec uses the Dolby AC3 technology. The Mpeg2 standard forms a patent pool, which is managed by mpegla. The MPEG2 patent pool includes 27 patentees and hundreds of patents in major countries such as the United States, Europe, China, Japan, and South Korea.

In 2003, Zenith sued Changhong and its dealers for infringement of color TV patents in the United States; in 2007, LG of South Korea sued two companies under the Chinese color TV company TCL in the United States, stating that TCL infringed 4 of its digital TV patents;

On August 18, 2009, several patentees in the MPEG2 patent pool filed a lawsuit with the Federal District Court for the Southern District of New York in the United States against Haier (including Haier Trading Company and Haier Group Company) for alleged patent infringement on digital televisions sold in the United States.

During the development of the television industry, European and American color TV companies gradually withdrew from the television manufacturing field and gradually evolved into non-patent enforcement entities. For hundreds of years of television research and development, they invested huge amounts of research and development costs, accumulated huge patent assets, and needed to rely on operating patent assets to obtain return on investment. With the “maximization of value” mining of digital TV patents, it has received unprecedented attention worldwide. Besides the traditional “innovation + patent” or “occupy market + patent license” intellectual property management models, “capital + intelligence” and “patent + operations” business model is booming. A large number of non-patent enforcement entities, NPE, have emerged, and “patent trolls” have been attacked fiercely. In the European and American markets, from DVD products to MP3 to digital TV, patent litigation, customs seizures, and exhibition seizures, this undoubtedly makes “the patent thickets competition” became more intense.

Patent thickets raises the threshold for technological innovation and creates obstacles for innovative companies. In addition, high patent licensing costs lead to increased product costs, which either compress manufacturing company profits or increase consumer purchase prices.

In the context of the patent thickets, a 2007 paper published by Professor Lemley of Stanford Law School and Professor Shapiro of the University of California Haas School of

Business raised the existence of patent hold in patent licensing (Lemley & Shapiro, 2007a). There will be a magnifying effect in the phenomenon of royalty stocking.

On the one hand, for latecomer enterprises, they have difficulties in participating in the patent pool or technical standards, and have no or only few patents for cross-licensing. On the other hand, because many non-practice entities are not engaged in the production, manufacturers cannot claim cross-licensing or counterclaim even with many patents, and many companies have to pay a lot of extra costs to obtain patent licenses.

At the beginning of the 21st century, Chinese color TV companies, in the face of competition from European, American, Japanese, and Korean patentees, abandoned their estrangement and joined together to form a professional IPR coordination committee for the color TV industry to conduct collective bargaining with patentees; On the one hand, domestic color TV companies have pooled their respective patented technologies to form a Chinese color TV patent pool. In the past few years, collective bargaining has achieved certain results, and reasonable licensing conditions have been reached with some European and American patentees. However, in the face of more and more NPEs, much work remains to be done.

In the patent game, the defense methods available to late-developing companies are very limited, such as bringing up the patent invalidation procedure (Louçã & Mendonça, 2002). Therefore, although NPE has promoted patent transactions and even increased the patent awareness of enterprises, it’s unreasonable and even excessive profit model has been criticized, and it has also threatened the industrialization of technological innovation achievements, forming patent holdup.

In the digital television standard, a large number of patented technologies are included and dispersed in the hands of various patentees; MPEG LA has formed the MPEG2 patent pool and ATSC patents, and the DVB-T (transferred Sisvel management in 2008) patent pool; According to the requirements of ISO international standards, the FRAND principle licensing method is implemented. However, the core problem is that the patentee completely controls the patent pool fee policy after the standard is promulgated. No matter MpegLa or Sisvel, these patent pool managers can only conduct business according to the decision of the patentee. This hollow "reasonable" principle has no substantial binding force on patentees, leading to the alienation of the patent pool mechanism, which has gradually evolved into a tool for monopolizing the market, becoming an obstacle to industrial development and social progress, and harming the interests of consumers.

Patent is a legal monopoly. Without the permission of the patentee, no individual or unit can use the patent for business. This is the basis of patent hold-up. To eliminate patent hold-up, it is necessary to use antitrust to restrict the abuse of patent rights. In view of the US digital television and Chinese digital television standards, some patentees have set excessively high prices. Chinese color TV companies have communicated and coordinated with the patentees for many years, but have not made effective progress.

Digital TV standards in the United States, Europe and other countries have been established for more than 20 years, and some patented technologies have also expired. Chinese color TV companies are also making full use of expired patented technologies to reduce licensing costs. However, the development of new color TV technology, especially the development of information technology and intelligent technology, has led to better functions and applications. Europe and the United States have also introduced new generations of digital television standards, and more updated technology applications have brought consumers better experience, but also to the Chinese color TV enterprises more opportunities and threats.

As the new generation of digital TV standards transforms and upgrades to smart TVs, patents will still be a competitive weapon for color TV companies. Chinese color TV companies must increase their patent strength, speed up patent deployment, and take multiple measures to reduce restrictions imposed by the patent thickets and patent hijacking, in order to gradually reduce the cost pressure brought by patent competition in global competition.

Chapter 6: Conclusions

Innovation and development have become the mainstream of today's society. It has become a consensus that patent is a strategic core resource for enterprises and even countries. From the perspective of enterprise development, patent licensing is not only an important way for technology holders to win innovation income, but also an effective way for technology demanders to access to technology. From the perspective of national trade, the international payments of IP fees represented by patents are an important lever for developed countries to balance international trade, but also a "Sword of Damocles" for developing countries.

Since China’s reform and opening up 40 years ago, the development of technological capabilities of latecomer firms has gone through a historical road from technology introduction, technology imitation to imitation innovation, independent innovation, and open innovation. In the meantime, the patent system has also gone through from passive legislation to taking the initiative, to reforming and perfecting the patent system with Chinese characteristics. In this process, it deserves our discussion the high royalty fees that Chinese enterprises have to bear and the renegotiation of patent licensing brought about by the development of their technological capabilities and the weakening cost advantages, especially the strategies taken to reduce royalty fees.

This thesis is comprised of six chapters. The first chapter presents the background, problems and methods of research, as well as the main contents and contributions to the state of art; the second reviews the Chinese and western literature on patent licensing and patent hold-up; the third chapter is based on the injunction factor of the Lemley-Shapiro patent hold-up model and the characteristics of latecomer firms to improve the Lemley-Shapiro model and introduces new variables to construct a corresponding patent hold-up model; the fourth chapter verifies the viewpoints of the thesis through empirical research, key variables, questionnaires (reliability and validity tests), descriptive statistics, and empirical analysis of the factors affecting the royalty fees; the fifth chapter takes Huawei as a case to analyze Huawei's anti-holdup motivations and strategies, and its implications to China's ICT enterprises and Western leading companies.

The main research conclusions are as follows：

(1) Proving technology gap and cost advantage are inducing factors of patent hold-up posed by foreign leading companies to Chinese latecomer firms.

(2) Analyzing the mechanism of patent hold-up and its effects on the patent and licensing behavior of latecomer firms under different participant structures: “one-to-one” and the adverse effects of the bargaining abilities of the latecomer firms with different technological capabilities and cost advantages on foreign leading companies, and on the basis of research came to two propositions: Proposition 1: Patent holdup exists in the negotiation between latecomer firms and leading companies, namely, patent licensing fee higher than the reasonable fee. Proposition 2: The development of technological capabilities of the latecomer firms has narrowed the gap with the leading companies, while the cost increase has weakened the advantage of the latecomer firms, all of which will help to mitigate patent holdup posed by the advanced firms to varying degrees, and proposed five strategies based on propositions.

(3) Verifying the reasons for and problems caused by patent hold-up of latecomer firms under the above-mentioned conditions based on questionnaire. Empirical analysis results show that: ①Ten years ago, the technology gap had a significant positive correlation with the actual royalty rate. ②In the past three years, the technology gap has a significant negative correlation with the actual royalty rate and in further regression analysis finding that the main factor leading to this result is a significant negative correlation between the R&D capability gap and the actual royalty rate, indicating that the leading foreign companies exert more patent hold-up pressure to the latecomer firms when they the technology gap between them narrows to a certain degree. ③In both time periods, there is a significant positive correlation between the actual royalty rate and the cost advantage of the latecomer firms.④Based on further analysis of the dynamic impact of the technology gap on the actual royalty rate, the thesis finds that the change in the R&D capability gap is significantly negatively correlated with the actual royalty rate over the recent three year.

(4) Based on above analysis and the case study about the Huawei patent licensing case and digital TV companies case, proposing the coping strategies for Chinese latecomer firms under different patent hold-up condition from the Huawei patent licensing case: Distinguish the anti-holdup breakthrough, integrate existing remedies for anti-holdup and reasonable appeal against patent hold-up. Summing up three implications for China ICT companies: ① Accumulate and consolidate patent portfolio while paying attention to improvement of

technological capabilities. ②Cultivate technical self-confidence and realize patent value. ③Establish and improve a IP system that is conducive to business strateg

The main contributions of the thesis are:

(1) based on the existing literature and the actual situation in China, the thesis discusses and analyzes the influencing factors and characteristics of patent hold-up posed by foreign leading enterprises to Chinese latecomer firms. From the perspective of the latecomer firms, the thesis adopts two important factors of cost advantage and the technology gap to construct the conceptual model and mathematical model of patent hold-up, making the patent licensing theory closer to the actual situation of the latecomer firms to a certain extent. This not only helps to explain the patent competition that Chinese enterprises have encountered in the local and international competition over the past 40 years since China's reform and opening up, but is also instructive for national companies to participate in global competition;

(2) open the "black box" of patent licensing participant structure and competitiveness, and deeply and systematically investigate the formation mechanism of patent hold-up posed by foreign leading enterprises on latecomer firms under different conditions and its impact on the licensing behavior of latecomer firms. The thesis opens the black box of the patentee and licensee, discusses the causes of patent hold-up, and proposes corresponding strategies for latecomer firms based on the impact of the dynamic change of the cost advantage and technology gap on patent hold-up. These studies can expand the theoretical system of patent holdup to a certain extent, and help to enrich the innovation theory from the perspective of latecomer firms;

(3) further validate and deepen the above theoretical research conclusions through empirical and case studies. For example, the technology gap and cost advantage of the latecomer firms are analyzed at two time points: ten years ago and the recent three years. One of the important conclusions of the empirical studies is that compared with "10 years ago", in the recent three years, as the cost advantage of the latecomer firms weakens and their technology gap with leading companies narrows, the degree of patent hold-up they suffer have not mitigated, revealing that as "inside innovators", are facing more technological competition from Chinese latecomer firms that are getting closer to advanced and cutting-edge technologies. However, foreign leading companies will not easily give up their existing technology and market advantages. Therefore, if latecomer firms want to

obtain lower royalty rates under such circumstance, they must adopt a corresponding strategy to reopen negotiations with foreign leading companies.

There are still many shortcomings in the thesis: first, the factors affecting patent holdup do not only include external ones, but also internal factors of the enterprise; second, the thesis does not explain the phenomenon of high royalty fees between leading companies and latecomer firms. These all need further investigation.

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Appendix 1 Questionnaire design

1.1 Technology gap questionnaire

(1) Regarding the extent to which the value of patented technology affects the reasonable royalty fees, please rate the following statement:

value of the patented technology	Degree of impact on the reasonable royalty fees 1 = very low; 2 = lower; 3 = medium; 4 = higher; 5 = very high				
Compared with the existing technology, the patent can help to improve	1	2	3	4	5
The extent to which patents are superior to other alternative technologies	1	2	3	4	5
The difficulty of patent circumvention	1	2	3	4	5
Speed of technological updating in the industrial field of patents	1	2	3	4	5
The degree to which patent commercialization relies on other complementary technologies	1	2	3	4	5
Imitation difficulty of infringing products	1	2	3	4	5

(2) Regarding the extent to which the commercial value of patents affects the reasonable royalty fees, please rate the following statement:

the commercial value of patents	Degree of impact on the reasonable royalty fees 1 = very low; 2 = lower; 3 = medium; 4 = higher; 5 = very high				
Additional sales revenue from the use of patents	1	2	3	4	5
Use patents to reduce costs or increase profits	1	2	3	4	5
Time required for commercialization of patents	1	2	3	4	5

Qualifications or equipment investment required for the use of patents	1	2	3	4	5
Market growth rate of patented products	1	2	3	4	5
Life cycle of patented products	1	2	3	4	5

(3) Regarding the extent to which the legal value of patents affects the reasonable royalty fees, please rate the following statement:

the legal value of patents	Degree of impact on the reasonable royalty fees 1 = very low; 2 = lower; 3 = medium; 4 = higher; 5 = very high				
Patent protection scope	1	2	3	4	5
Market areas covered by patents	1	2	3	4	5
The term of the patent	1	2	3	4	5
Type of patent license (solo, exclusive, non-exclusive, or cross)	1	2	3	4	5
Geographic region where the license is applicable	1	2	3	4	5
Patent license duration	1	2	3	4	5
Number of patents (single patent or patent portfolio)	1	2	3	4	5
The possibility that the patent is declared wholly or partly invalid	1	2	3	4	5
Intelligibility of the infringing imitation products	1	2	3	4	5

(4) Regarding the extent to which the strategic value of patents affects the reasonable royalty fees, please rate the following statement:

the strategic value of patents	Degree of impact on the reasonable royalty fees 1 = very low; 2 = lower; 3 = medium; 4

	= higher; 5 = very high				
Help ensure the position of the company in the existing market	1	2	3	4	5
Help companies win new markets	1	2	3	4	5
Help strengthen the company's technology R&D capabilities	1	2	3	4	5
Help ensure the safety of business operations	1	2	3	4	5
Help limit the development of competitors	1	2	3	4	5
Help to enhance the brand image of the licensed company	1	2	3	4	5

(5) Regarding your company's R&D capability and its development, please rate the following statements:

R&D capability and its development	level of compliance 1=very small; 2=relatively small; 3=intermediate; 4=relatively large; 5=very large				
Over the recent three years, the percentage of R&D investment to sales revenue of your company compared with foreign leading companies	1	2	3	4	5
Over the recent three years, the number of new products developed by your company per year compared with foreign leading companies	1	2	3	4	5
Over the recent three years, the number of invention patent applications of your company compared with foreign leading companies	1	2	3	4	5
Ten years ago or when your company was established, the R&D capability gap with the foreign leading companies	1	2	3	4	5

The percentage of R&D investment to sales revenue of your company compared with local similar companies	1	2	3	4	5
The number of new products developed by your company per year compared with local similar companies	1	2	3	4	5
The number of invention patent applications of your company compared with local similar companies	1	2	3	4	5

(6) Regarding your company's manufacturing capability and its development, please rate the following statements:

manufacturing capability and its development	level of compliance 1=very small; 2=relatively small; 3=intermediate; 4=relatively large; 5=very large				
Over the recent three years, the production equipment replacement efficiency of your company compared with foreign leading companies	1	2	3	4	5
Over the recent three years, the production process efficiency of your company compared with foreign leading companies	1	2	3	4	5
Over the recent three years, the repair rate of your company compared with foreign leading companies	1	2	3	4	5
Over the recent three years, energy consumption per unit product of your company compared with foreign leading companies	1	2	3	4	5
Ten years ago, or when your company was established, the manufacturing capability gap with foreign leading companies	1	2	3	4	5
The production equipment replacement efficiency of your company compared with local similar companies	1	2	3	4	5
The production process efficiency of your company compared with local similar companies	1	2	3	4	5
The repair rate of your company compared with local similar companies	1	2	3	4	5

Energy consumption per unit product of your company compared with local similar companies	1	2	3	4	5

(7) Regarding your company’s marketing capability and its development, please rate the following statements:

marketing capability and its development	level of compliance 1=very small; 2=relatively small; 3=intermediate; 4=relatively large; 5=very large				
In the recent 3 years, the level of competition between similar products of your company and foreign leading companies in the market	1	2	3	4	5
In the recent 3 years, the competitiveness of similar products of your company compared with foreign leading companies	1	2	3	4	5
In the recent 3 years, the share of similar products of your company in the domestic market compared with foreign leading companies	1	2	3	4	5
In the recent 3 years, the share of similar products of your company in the international market compared with foreign leading companies	1	2	3	4	5
Ten years ago, or when your company was established, the marketing capability gap with foreign leading companies	1	2	3	4	5
The competitiveness of your company's products compared with local similar companies	1	2	3	4	5
Your company's dependence on brand and quality for market expansion	1	2	3	4	5
Your company's dependence on cost for market expansion	1	2	3	4	5

1.2 Cost advantage questionnaire

(8) Regarding your company’s labor cost and its development, please rate the following statements:

Labor cost and its development	level of compliance 1=very small; 2=relatively small; 3=intermediate; 4=relatively large; 5=very large				
In the recent 3 years, the ratio of employee's compensation to the cost of your company compared to foreign leading companies	1	2	3	4	5
In the recent 3 years, the ratio of social insurance spending to the cost of your company compared to foreign leading companies	1	2	3	4	5
In the recent 3 years, the ratio of education and training to the cost of your company compared to foreign leading companies	1	2	3	4	5
Ten years ago, or when your company was established, the labor cost advantage of your company compared to foreign leading companies	1	2	3	4	5
The number of people available to your company compared to ten years ago or when your company was established,	1	2	3	4	5
The level of education of the people available to your company compared to ten years ago or when your company was established,	1	2	3	4	5

(9) Regarding your company's material resource cost and its development, please rate the following statements:

material resource cost and its development	level of compliance 1=very low; 2=relatively low; 3=intermediate; 4=relatively high; 5=very high				
In the recent 3 years, the cost of raw materials of your company compared to foreign leading companies	1	2	3	4	5
In the recent 3 years, the land cost of your company compared to foreign leading companies	1	2	3	4	5
In the recent 3 years, the energy consumption cost of your	1	2	3	4	5

company compared to foreign leading companies					
In the recent 3 years, the environmental cost (such as pollution control and waste disposal costs) of your company compared to foreign leading companies	1	2	3	4	5
Ten years ago, or when your company was established, the material resource cost advantage of your company compared to foreign leading companies	1	2	3	4	5

1.3 Patent hold-up degree questionnaire

(10) Regarding the actual royalty rates charged by the foreign leading companies (or other organization, individuals, the same below) [actual royalty fee (rate)/reasonable royalty fee (rate)], please rate the following statements：

Actual royalty rates	level of compliance 1=very low; 2=relatively low; 3=intermediate; 4=relatively high; 5=very high				
Overall, the actual royalty rates your company accept from foreign leading companies	1	2	3	4	5
Ten years ago, or when your company was established, the actual royalty rates your company accepted from foreign leading companies compared with the rates between foreign companies	1	2	3	4	5
Ten years ago, or when your company was established, the actual royalty rates your company accepted from foreign leading companies compared with the rates they charged other Chinese companies	1	2	3	4	5
The actual royalty rates your company accepts now from foreign leading companies compared to the rates ten years ago or when your company was established,	1	2	3	4	5
In the recent 3 years, the actual royalty rates your company accepts from foreign leading companies compared with the rates between foreign companies	1	2	3	4	5
In the recent 3 years, the actual royalty rates your company accepts from foreign leading companies compared with the	1	2	3	4	5

rates they charge other Chinese companies					
The actual royalty rates your company accepts from foreign leading companies compared with the rates between Chinese companies	1	2	3	4	5

1.4 Other indicator questionnaire

(11) Regarding China's patent protection system and its development, please rate the following statements:

patent protection system and its development	level of compliance 1=very low; 2=relatively low; 3=intermediate; 4=relatively high; 5=very high				
The impact of “temporary injunction” on the strength of patent protection	1	2	3	4	5
The impact of “permanent injunction” on the strength of patent protection	1	2	3	4	5
The impact of “pretrial evidence preservation” on the strength of patent protection	1	2	3	4	5
The impact of “disclosure of evidence” on the strength of patent protection	1	2	3	4	5
The impact of “reversion of burden of proof” on the strength of patent protection	1	2	3	4	5
The impact of punitive damages on the strength of patent protection	1	2	3	4	5
The impact of the statutory maximum damages on the strength of patent protection	1	2	3	4	5
The impact of the actual damages judged by the court on the strength of patent protection	1	2	3	4	5

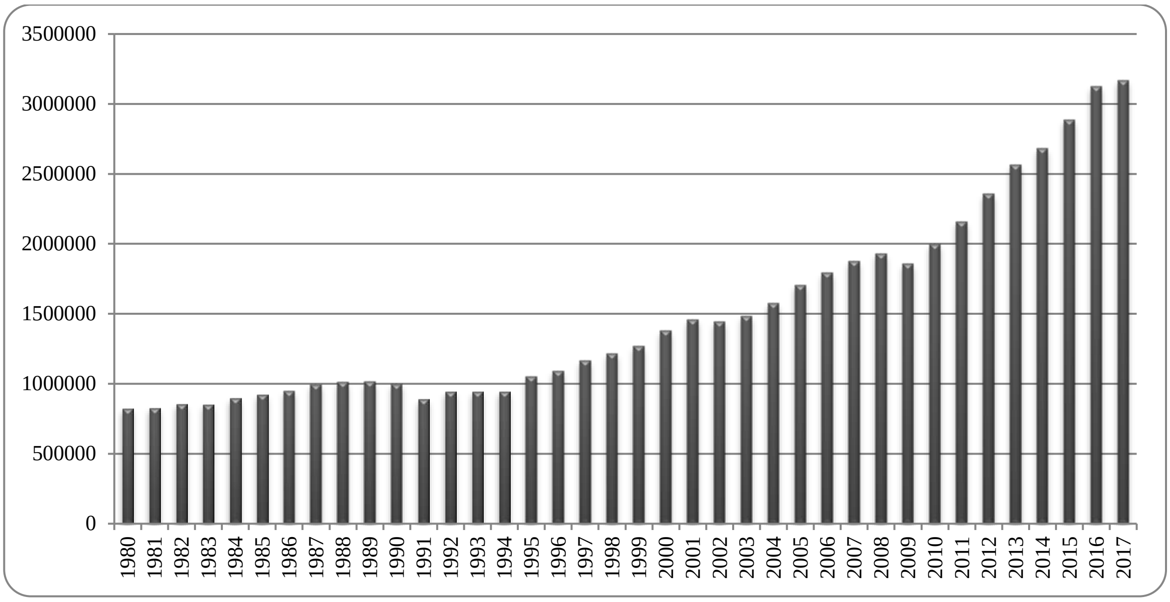
(12) Basic information of your company

(1)Your company was founded in	Your company accepts patent licenses from foreign leading

(year)	companies from______(year).
(2)Nature of your company: □State-owned and holding □Private □Foreign investment and holding □ Others	
(3)Your company's industry：□Electronic information and communication □Internet □Computer software □Semiconductor □Biology & Medicine □ Energy □ Chemicals □ Machinery □Cars □Home Appliances □ Metal □Food & Beverages □Textiles & Clothing □Building Materials □Wood Furniture □Rubber & Plastics □Cultural Media □ Others, please specify:_____________	
(4)Please list your company's main product categories (<4 categories):___________________________	
(5)The focus of your company's innovation is: □product innovation □process innovation □business model innovation □ Others________	
(6)Overseas distribution of your company's products or services (multiple choices): □North America □Western Europe and Northern Europe □Japan and South Korea □Eastern Europe and Russia □Africa □Southeast Asia □Latin America □ Others_______	
(7)The type of foreign entity that allows your company to use its patents: □Company □University □Individual □Others_______	
(8)The residence of foreign entities that allows your company to use its patents (multiple choices):□US □Germany □Japan □South Korea □France □Switzerland □Netherlands □UK □Sweden □Italy □Others__	
(9)Is there a direct competition between the foreign patent holder who permits your company to use its patent and your company: □Yes □No	
(10)The patent granted by a foreign patentee to your company is: □Single patents □multiple patents	

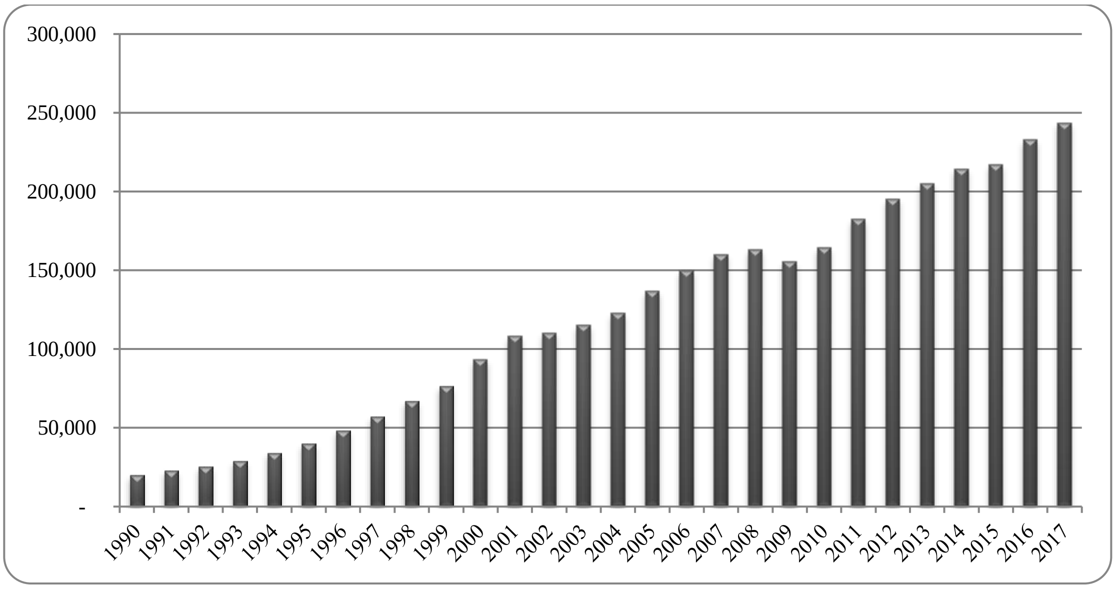
Appendix 2 Figures

Appendix 2.1: Amount of patent applications worldwide, 1980-2017



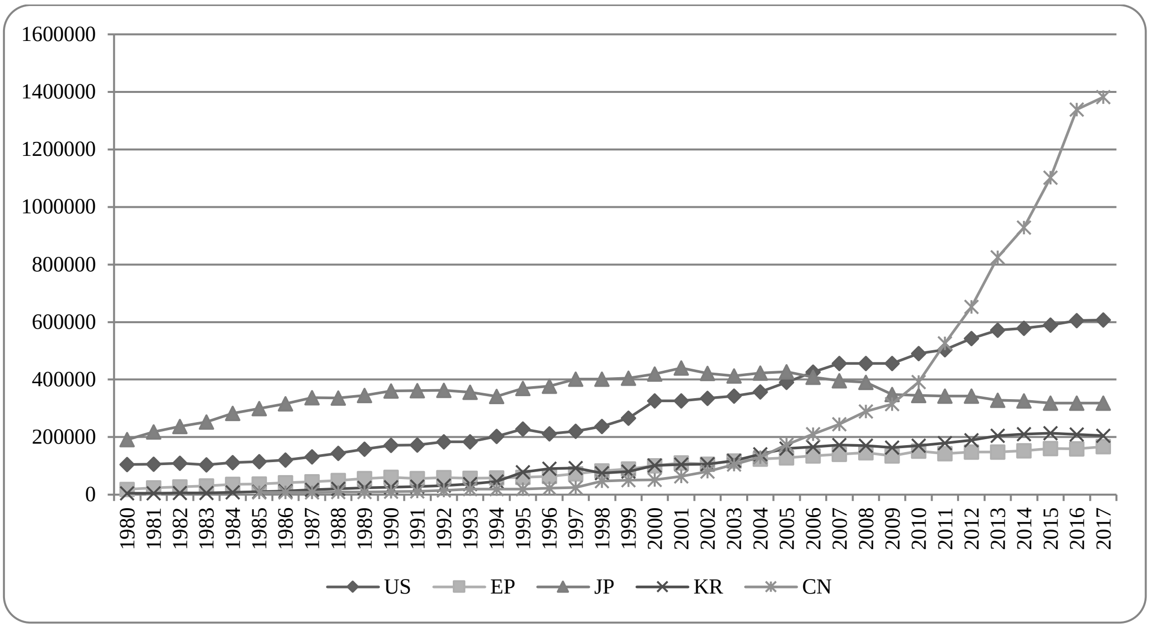
Source: WIPO (2019) (inventions only)

Appendix 2.2: The amount of PCT applications, 1990-2017



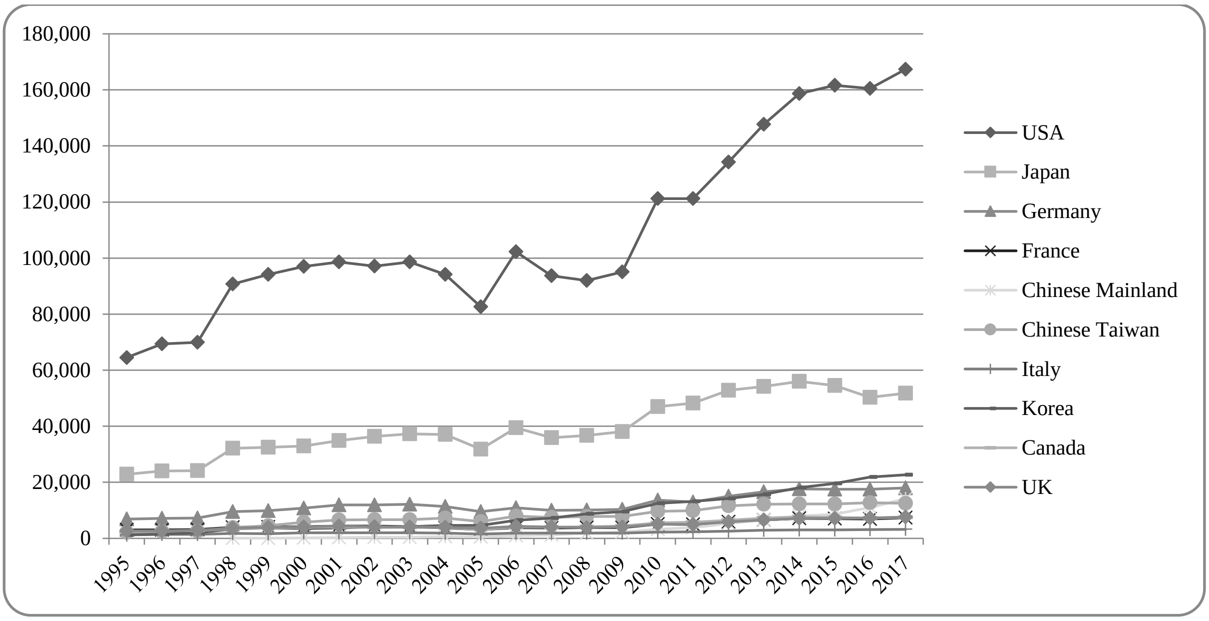
Source: WIPO (2019)

Appendix 2.3: Patent applications by the world's five largest patent offices (IP5), 1980-2017



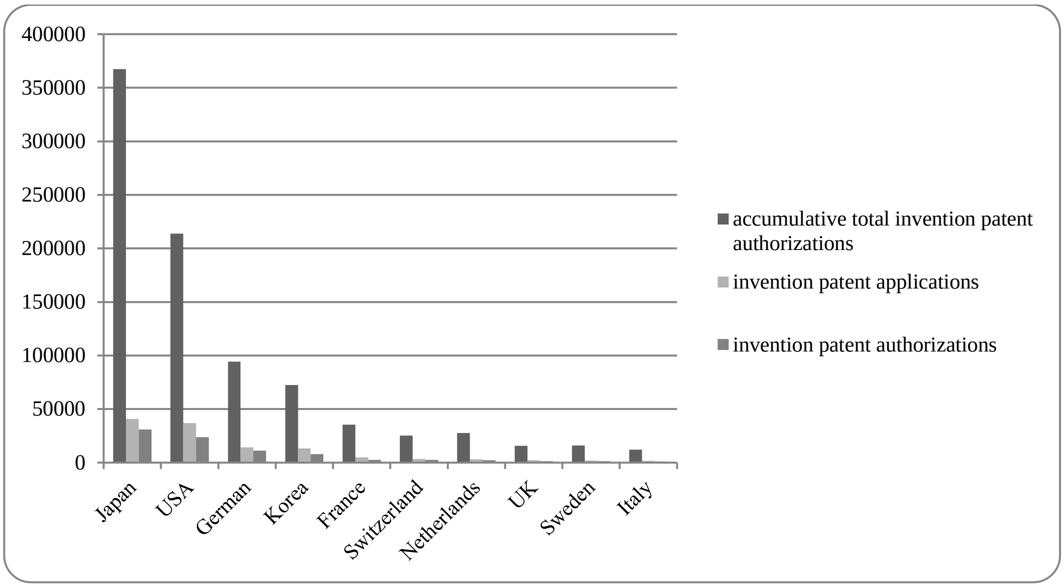
Source: WIPO (2019) (inventions only)

Appendix 2.4: PCT applications filed by the top 10 origins, 1990-2017



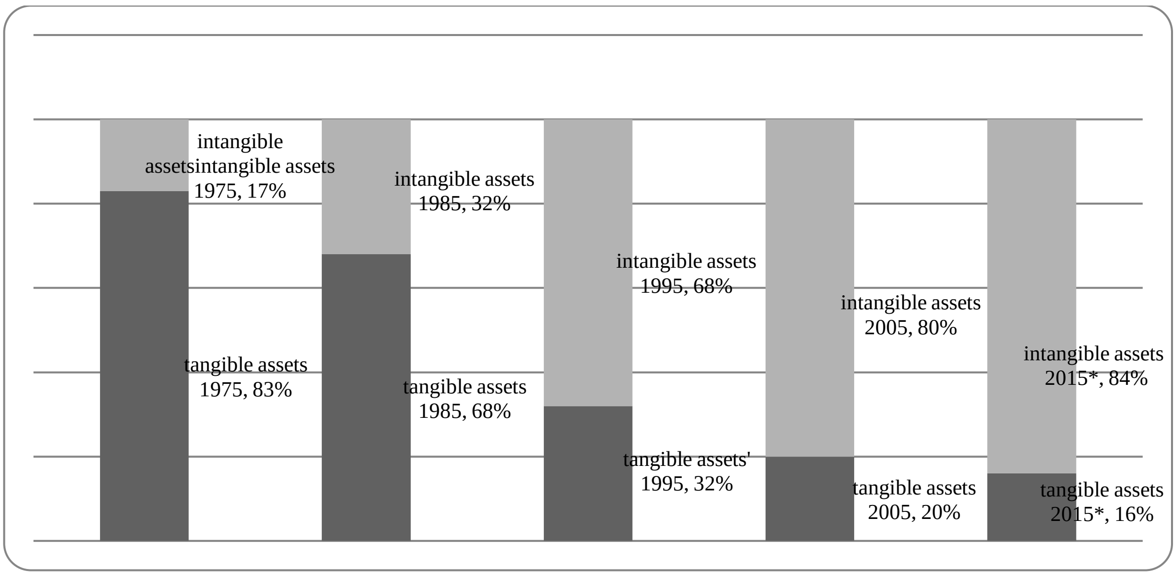
Sources: United States Patent and Trademark Office (2019) (including invention patent, design patent and plant patent)

Appendix 2.5: Patent applications and authorizations in CNIPA, 1985-2017



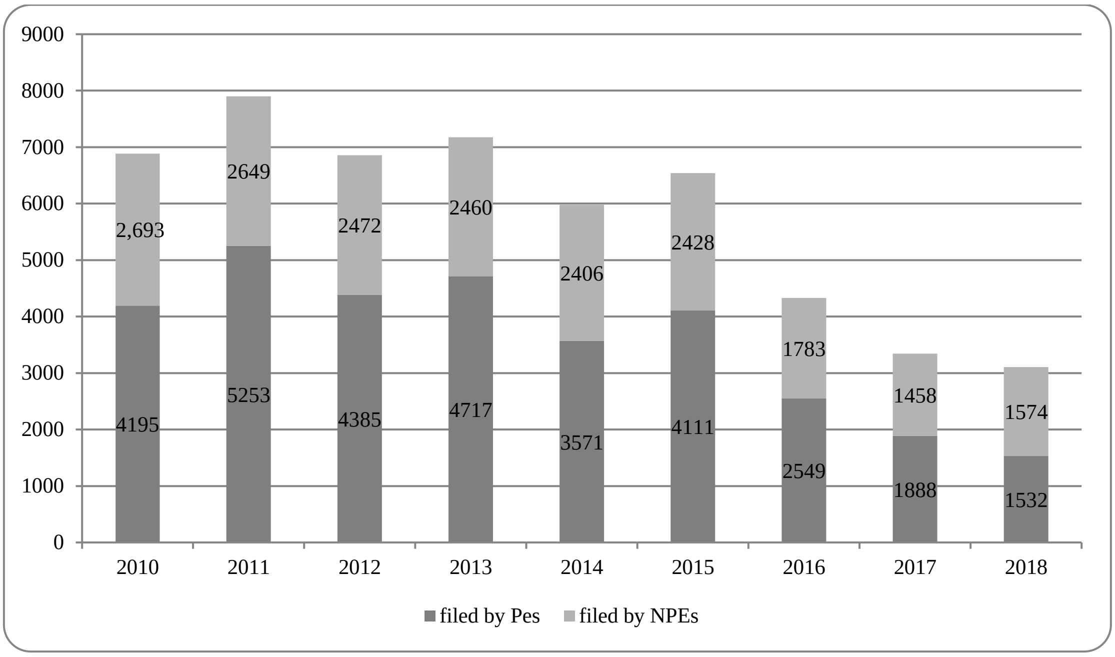
Source: CNIPA (2018)

Appendix 2.6: Change in asset structures of 500 listed companies in the S&P 500 Index (%)



Source: Ocean Tomo (2015) (2015* is the statistical result of January 1, 2015)

Appendix 2.7 The structure of United States patent litigation cases, 2010-2018 (Total Defendants Added in Cases)



Source: RPX Corporation (2018)

Appendix 2.8 The patent litigation structure encountered by Huawei and ZTE in the United States, 2000-2018