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Doctoral Dissertation

Impact of University-Industry Collaboration Policies on
University Patenting in Japan: An Analysis of Japanese
National University Patents

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ABSTRACT

The implementation of university-industry collaboration policies has changed the absence of Japanese university patent activities to an active involvement in patenting, followed by a large increase in the number of patent applications by universities. Besides the achievement of a dramatic increase in number of Japanese university patents, there remains a critical question regarding their quality. This study aims to explore and examine the changes in the nature of university patents resulting from the implementation of university-industry collaboration (UIC) policies. In Japan, as policymakers move steadily in the direction of stimulating patenting activity by universities, no evidence is yet available on the characteristics of university patents and on their relative value. Concerning this importance, the critical questions need to be answered: (1) What are the unique attributes of university patents? (2) How do UIC policies affect university patenting? (3) How do UIC policies affect the knowledge diffusion from universities to industry? (4) What determinants determine university patent value?

Summary of findings in this study include the following: First of all, in terms of the unique attributes of Japanese university patents, Japanese university assignee patents are more basic than UIC patents. However, UIC patents allow inventors to successfully reap the benefits of their own inventions more than university assignee patents and UIC patents are faster in producing offspring. Compared to US university patents, US university patents are more basic than Japanese university patents, but the spillover effect of Japanese university patents is faster. Secondly, regarding the effects of UIC policies, UIC policies significantly affect the increase in both the UIC and university assignee patents. After the implementation of UIC policies, university assignee patents reflected the higher degree of basicness than UIC patents. However, the spillover effect of UIC patents is faster than university assignee patents and UIC patents have a higher degree for inventors to benefit their own inventions.

Thirdly, as for the knowledge diffusion from Japanese universities to industry, Japanese industry cites corporate patents more often than Japanese university patents. However, the gap between them has been continuously reduced since the mid-1990s, which correlated to the period of the first launch of the UIC policies. After the implementation of UIC policies, both the numbers of university patents and citations

received from Japanese industry have increased significantly. Finally, to determine the value of Japanese university patents, the results reveal that the background and the distance in time of technology, and the scope of patent protection have positive impacts and significantly affect the value of patents. US and Japanese university patents share common determinants of value.

These findings have illuminated the Japanese university patenting debates and have important policy implications. Patenting in Japanese universities has grown continuously since the Japanese government began to encourage UICs, and Japan's UIC policies have yielded impressive results in university-industry technology transfer. The comprehensive evidence derived from a growing number of Japanese university patents and citations received from industry can ensure the effective implementation of UIC policies.

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AUTM   Association of University Technology Transfer Managers
ECLA   European Classification
EPO   European Patent Office
IP   intellectual property
IPC   international patent classification
IPRs   intellectual property rights
JPO   Japan Patent Office
MEXT   Ministry of Education, Culture, Sports, Science and Technology
NIS   national innovation system
OECD   Organization for Economic Cooperation and Development
PRO   public research organization
R&D   research and development
SMEs   small and medium enterprises
TLO   technology licensing organization
UIC   university-industry collaboration
USPC   United States Patent Classification
USPTO   United States Patent and Trademark Office
WIPO   World Intellectual Property Organization
ZINB   zero-inflated negative binomial

CHAPTER 1

INTRODUCTION

1.1 Background of the Study

In a knowledge-based economy, innovation and new technological progress are becoming increasingly important. The role of the university has diversified and encompassed a *third mission* of economic development, beyond traditional instructional and research missions. Universities are progressively viewed as proactive contributors to technological development and economic growth (Meyer 2006). Recently, there has been a rise in policy interest on how university technology transfer can be efficiently used for commercialization. The central focus of this issue underlies the collaboration between university and industry in transferring technology for commercial purposes.

In the case of Japan, the additional role of universities in terms of economic contribution derives from the promotion of academia-industry cooperation. This collaboration began to attract attention during the Japanese economic recession in the 1990s (see Fujisue 1998; Tantiyaswasdikul 2013b). In order to solve economic problems, critically considering the establishment of solid economic foundations in the medium to long-term future is important. Japan needs to create new technology-based firms and ensure stable growth of essential industries (Fujisue 1998; Tantiyaswasdikul 2013b). It is vital to effectively collaborate with universities and other institutions that have scientific knowledge in supporting these strategies (Motohashi 2005; Tantiyaswasdikul 2013b).

An important motivation behind this collaborative policy is to make the Japanese national innovation system (NIS) more dynamic and to shift the system from the dominant role of in-house research and development (R&D) conducted at major firms toward one based on a network of active interactions among various innovators, including universities, industries, and government (Motohashi 2005; Tantiyaswasdikul 2013b). In light of the importance of this shift, the Japanese government has administered various policies, including a Program of Economic Structural Reform and the Science and Technology Basic Plan, in which academia-industry collaboration is given priority to revitalize the NIS (Fujisue 1998; Tantiyaswasdikul 2013b). These

strategies aim to promote technology transfer from universities to industry and to re-enforce university-industry cooperation by the implementation of university-industry collaboration (UIC) policies (Motohashi 2005; Tantiyaswasdikul 2012b, 2013b).

Improving UIC is essential for Japan's economic revival, and several researchers have pointed to problems associated with intellectual property (IP) as factors hindering effective collaboration.[1] In addition, Japanese government and business leaders note that one of the greatest barriers to collaboration is the gap between systems of collaboration and IP management in universities and industries.[2] This unsolved system has harmed Japan's technical and economic progress (Kneller 2003). Concerning the transfer of intellectual property rights (IPRs), transfers of exclusive rights are often essential if a company is to take the risk to develop early-stage academic discoveries (Kneller 2003).

Generally, R&D discoveries resulting from universities are not ready for commercial use. These outcomes frequently require more development, even though some may have the potential to be developed into useful products or services (Kneller 2003). The critical problem is most universities are not able to commercialize early-stage discoveries, but the private sector can. However, there must be an effective system of technology transfer and IP management providing incentives for industry to develop and commercialize discoveries originating in universities (Kneller 2003).

The Japanese government has recently considered and implemented various policies to revitalize and encourage UICs. Since the primary goal of technology transfer is to ensure the development of early-stage discoveries by universities for the public benefit (Kneller 2003), a legal framework providing the foundation for effective technology transfer and university-industry R&D cooperation need to be created. Specifically, since the mid-1990s, Japan has implemented several policy measures to promote university–industry technology transfer and commercialization and so facilitate the practical application of research results obtained by public research institutions.

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[1] For detail on the failure of Japanese universities to contribute to overall innovation and R&D, see Yoshihara and Tamai (1999). For obstacles to commercialization of Japanese university inventions regarding public funds, see Kneller (1999).

[2] The gap between systems of collaboration and IP management derived from the informal ties of university-industry cooperation. Kneller (1999) provided a detailed explanation of these informal ties.

Significant laws associated with UIC policies include the Law to Promote the Transfer of Universities Technologies[3] (TLO Law), enacted in 1998; the Law of Special Measures to Revive Industry[4] (the Japanese Bayh-Dole Law), enacted in 1999; the 2000 Law to Strengthen Industrial Technology;[5] and the National University Incorporation Law,[6] enacted in 2004. The legal framework of Japanese technology transfer has greatly changed.[7] The laws and regulations governing ownership and transfer of IPRs were reformed under the UIC policies to make technology transfer occur effectively.[8]

To encourage the formal tie between UIC and technology transfer, the Japanese government has implemented the TLO Law to legitimate and facilitate transparent and contractual transfers of university discoveries to industry (Kneller 2007b). Under the framework of this law, technology-licensing organizations (TLOs) aiming to manage the patents of universities and promote licensing to private sectors have been established. The Japanese government has implemented many policies to support and encourage TLO activities; these include the subsidy and debt guarantee to TLOs. The Japanese government will give a subsidy of 50% and a full debt guarantee to the establishment cost of a TLO by universities and private companies through the Industrial Infrastructure Fund. The government also provides an exemption from fee on patent registration and maintenance and finances the collaboration between universities and small and medium enterprises (SMEs) by the Small-Medium Sized Companies Supporting Corporation Program (Fujisue 1998).

Besides the TLO Law, the Japanese government also enacted the Law of Special Measures to Revive Industry or the Japanese Bayh-Dole Law. The Japanese Bayh-Dole Law is similar to the US Bayh-Dole Act that allows universities to retain their rights in any inventions deriving from public-funded research. This policy has changed the IPR system of Japanese universities and shifted ownership from

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[3] [Daigaku nado Gijutsu Iten Sokushin Hou] (Law No. 52 of 1998).
[4] [Sangyou Katsu-ryoku Saisei Toku-betsu Sochi Hou] (Law No. 31 of 1999).
[5] [Sangyou Gijutsu –ryoko Kyouka Hou] (Law No. 44 of 2000).
[6] [Kokuritsu Daigaku Houjin Hou] (Law No. 112 of 2003).
[7] For recent reforms in university-industry technology transfer in Japan, see Collins and Wakoh (2000); Jiang et al. (2007); Hatakenaka (2010); Kneller (1999, 2003).
[8] For the reformed laws and regulations for technology transfer, see Kneller (2003).

individual inventors to universities. Moreover, to encourage UIC activities, the 2000 Law to Strengthen Industrial Technology has been implemented to establish procedures through which university researchers can obtain permission to consult for, set up, and manage companies. It also accelerates the procedures of the industrial-sponsored commissioned and joint research (Kneller 2007b).

In April 2004, the Japanese government incorporated the national universities as *independent administrative entities*. Before the implementation of the National University Incorporation Law in 2004, Japanese national universities had no independent administrative or financial status. They were branches of the Ministry of Education, Culture, Sports, Science and Technology (MEXT), and thus their laboratories were Japanese government laboratories (Kneller 2003). It was difficult for the private sector to collaborate and support research in Japanese national universities due to the limitations on the IPRs and the restriction on the disbursement and the use of funds of corporate research support (Kneller 2003).

This important change in Japan's research culture has allowed its universities to gain greater control and legal status (Takahashi and Carraz 2009). The roles of universities after incorporation have to be considered as conducting funded or cooperative researches, distributing research results to promote their utilization, and investing in organizations specializing in university technology transfer. Although universities must contribute to technology transfer and commercialization, the universities are independent since they have gained a greater autonomy (Shimoda 2005). They can recruit academic and non-academic staff more easily. Moreover, they can maintain the ownership of their invention, which was seldom the case before the incorporation (Takahashi and Carraz 2009).

The implementation of UIC policies in Japan has been followed by a large increase in the number of patent applications by universities. According to an investigation by MEXT on Japanese national university patents, the number of university patent applications lodged with the Japan Patent Office (JPO) rose sharply, from 979 in 2003 to 2,935 in 2004, then leapt to 4,436 in 2005, and reached 7,448 in 2007 (MEXT 2009). Additionally, based on data from the United States Patent and Trademark Office (USPTO), the number of patents granted to Japanese national universities steadily increased from 31 in 1998 to 92 in 2004, then leapt to 250 in 2005

and reached 410 in 2007.[9]

However, the extent to which this growing number of university patents should be taken as evidence of an increase in the contribution of universities to commercialization depends on the degree to which patents represent commercially useful inventions or have spillover effects on commercial technology development versus the extent to which it represents simply increased filing of patent applications. Regarding the importance of this issue, this study aims to explore and examine the changes in the nature of university patents resulting from the implementation of UIC policies. In Japan, as policymakers move steadily in the direction of stimulating patenting activity of universities, no evidence is yet available on the relative characteristics of university patents or their relative value.

Concerning the effects resulting from the impact of UIC policies, the critical questions need to be answered: (1) What are the unique attributes of university innovations captured by university patents? (2) How do UIC policies affect university-industry technology transfer, especially in university patenting? (3) How do UIC policies affect the trajectories of scientific knowledge diffusion from universities to industry? (4) What determinants determine university patent value? This study addresses these essential questions that are at the heart of the policy debate over the UIC outcomes, which concerns policymakers and scholars in both public and private institutions.

1.2 Problem Statement

Recent work in science and technology policy has focused on the role of the university in economic contribution, in particular in academic patenting (see Caballero and Jaffe 1993; Henderson et al. 1998; Romer 1986, 1990; Sampat 2006). The study on academic patenting results from the Bayh-Dole Act of 1980. The Bayh-Dole Act is one of the most influential pieces of legislation in terms of stimulating the commercialization of university research (Rasmussen 2008; Tantiyaswasdikul 2013b). The significant growth in patenting and licensing by US universities has been widely credited to this legislation.

[9] Based on data obtained from the online records system of USPTO website;
http://www.uspto.gov/patents/process/search/
(Update 20 November 2013).

However, while the act increased the number of university patents, arguments have arisen regarding their quality. The rapid increase in academic patenting has provoked new debates about the quality of these patents (see Henderson et al. 1998; Mowery and Ziedonis 2002; Sampat 2006; Sampat et al. 2003). Although little empirical analysis has focused on assessing the impacts of the Bayh-Dole Act, positive assessments of the effects of the Act, together with other factors, have led governments in many Organization for Economic Cooperation and Development (OECD) countries, including Japan, to consider similar policy initiatives (Mowery and Sampat 2005; Tantiyaswasdikul 2012, 2013b).

In Japan, the study of university patenting is limited owing to the historical lack of such activity. Data from the JPO reveals just 137 university patent disclosures in 1995. In comparison, 5,100 university patent applications were lodged in the US during the same period, based on the data from the Association of University Technology Transfer Managers (AUTM) Licensing Survey, 1991–95 (Arai 1999). This implies numbers of Japanese university patents were most likely underestimated during the 1980s and 1990s. The implementation of UIC policies changes the absence of Japanese university patent activities to active involvement in patenting. The major changes in university patenting derived from the institutional reforms of the technology transfer system and IP management aiming to promote university–industry technology transfer and commercialization resulting from UIC policies.

Motohashi and Muramatsu (2012) examined the effect of the enactment of UIC policies in Japan on university patents there. However, the study focuses only on the UIC patents. The study found that the UIC policies increased the number of UIC patents in the late 1990s while overall patent quality was maintained. Other studies have also found that the UIC policies increased the number of Japanese university patents (Tantiyaswasdikul 2012, 2013b). Besides the dramatic increase in number of Japanese university patents, there remains a critical question on the extent to which this explosion represents the success of the more commercially useful inventions or just represents simply increased filing of patent applications. Based on the lack of evidence in the study of the impact of UIC policies on Japanese university patenting, this research attempts to fill this gap by providing an empirical analysis of Japanese university patents resulting from the implementation of UIC policies.

1.3 Significance of the Study

This study focuses on the impact of UIC policies on Japanese national university patenting by investigating the changes in the nature of university patents resulting from the implementation of UIC policies. This research is the first to systematically construct, quantify, and characterize the unique attributes of Japanese university patents, providing a systematic, comparative analysis of UIC policies and their impact upon university patenting in Japan. Additionally, this research is also the first effort of an investigation on the technological knowledge diffusion from Japanese universities to industry.

The new concern with the relationship of the UICs to university patenting poses questions for policymakers and researchers that have yet to be effectively addressed. This study therefore draws upon empirical research to assess institutional reforms and the intended and unintended impacts they appear to have on university patents. This research provides a useful framework and builds a foundation for the study of academic patenting and UIC policies in Japan.

1.4 Objectives

This study aims to explore and examine the changes in the nature of university patenting resulting from the implementation of UIC policies in Japan. The objective of the study is to provide an investigation into the impact of UIC policies on university-industry technology transfer in patenting both the attributes of patents and value determinants, as well as knowledge diffusion from universities to industry. Additionally, the dissertation intends to systematically construct, quantify, and characterize the unique attributes of university patents under different institutional settings and also provide a comparison analysis with its US counterpart.

The goal is to enable policymakers, scholars, inventors, venture capitalists, and industry experts to understand the policy effects, have a clearer picture of the diffusion of knowledge from Japanese universities to industry, and provide insight into the study of Japanese university patents. The outcomes of this study will not only shed light on the study of UICs but also help inform and formulate better UIC policies to enhance effective university-industry technology transfer to drive and sustain economic growth.

1.5 Data and Methodology

This study focuses on the impact of UIC policies on patenting by Japanese universities. The study provides a quantitative analysis using panel data from the USTPO, which provides detailed data for each patent, covers several decades, and has breakdowns according to all-important information about an invention. The data set consists of all Japanese national university-granted *US Utility Patents* that were applied for from 1980 to 2008.[10] The patents were classified according to assignees and institution type. Specifically, the patents were divided into university assignee patents and university co-assignee patents. The latter group comprises UIC patents that result from joint research collaborations between universities and corporates.

Chapter 3 provides a quantitative analysis of the attributes of university patents. This chapter measures innovation *basicness*, *appropriability*, and *time distance* of Japanese university patents. Additionally, the study also provides a comparative analysis between US and Japanese university patents using *t*-test to compare mean ratings between the attributes of patents.

Chapter 4 presents the impact of UIC policies on the changes in Japanese university patents by dividing the analysis into the periods before and after the implementation of UIC policies. Patent attributes between university assignee and UIC patents were analyzed. Using the similar methodology as that in Chapter 3, an analysis of *t*-test to compare mean rating between the attributes of patents before and after the enactment of UIC policies are presented in this Chapter.

Chapter 5 aims to analyze knowledge diffusion from universities to industry using patent citations. A comparison between two distinct sources of potentially cited patents was analyzed. The first involves Japanese corporations and the second is Japanese universities. The study focuses on a 10% random sample of Japanese industry patents between 1980 and 2008 that might cite Japanese university or corporate patents between 1976[11] and 2008. In this analysis, the citation frequency to

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[10] All data were obtained from the online records system of USPTO website; http://www.uspto.gov/patents/process/search/ (Update 20 November 2013).
[11] The data collection starts from 1976 because the online records system of USPTO website provides the full-text information of patent searching start from patents granted in 1976.
For a more detailed explanation, see USPTO website; http://patft.uspto.gov/netahtml/PTO/search-bool.html.

measure the rate of diffusion was employed. To calculate citation frequency or propensity to cite, I use the equation deriving from Jaffe and Trajtenberg (1996) adapted from the formulation of Caballero and Jaffe (1993) that was created to estimate parameters of the diffusion process.

Chapter 6 provides detailed analyses of the patent value and value determinants. For this purpose, multiple regression analysis through zero-inflated negative binomial (ZINB) regression, where the response variable is the number of forward citations, was employed. This is the most commonly used proxy for the value of patents. For the explanatory variables, I develop four broad value determinants to determine patent value as follows: (1) the technical background of a patent (measured by the number of backward citations); (2) the distance of technology from the application date to present (measured by the year filed of patents); (3) the breadth or scope of patent protection (measured by the number of claims); (4) the technology classification (measured by the number of IPC classes).

Data of patent citations is a key measurement in this research since the important aspects of technology trajectory, coherence, and persistence are embodied in the relationship between the innovation and its technological antecedents and descendants in patent citations. Additionally, patent citations provide an effective means for identifying and tracing these relationships (Trajtenberg et al. 1997). Citations can reveal the attributes of patents, the diffusion of technological knowledge associated within patents, and the patent value. Thus, patent citation is the key indicator of the patent analysis in this study.

1.6 Overview and Chapter Scheme

This study is a systematic, comparative analysis of UIC policies and their impact on university patenting in Japan. The new concern with the relationship of the UICs to university patenting poses questions for policymakers and academics that have yet to be effectively addressed. The debate about the contribution of Japanese universities to industry is of increasing interest. The extent to which the results of collaboration in patenting should be taken as evidence of an increase in the contributions of universities to technology commercialization depends on the extent to

which it represents more commercially useful inventions versus the extent to which it represents simply increased number of patent applications on marginal innovations.

This research explores this issue as a window into the changing role of universities as sources of technology transfer resulting from UICs. This study therefore draws upon empirical research to assess institutional reforms and the intended and unintended impacts they appear to have on university patents. To examine and analyze the impact of UIC policies on Japanese university patents, this analysis provides a wealth of investigation on policies effects. I hope that this study will spur a resurgence of work attempting to better understand the impact of UIC policies in Japan by both theory and empirics. The remainder of this research is organized as follows.

Chapter 2 provides a literature review and discussion on patent analysis and the use of patent data in different aspects. Patent analysis has long been considered a rich data source from a few standardized approaches to the study of innovation and technical change. Thus, the topics in this chapter cover the use of patent data, the use of citations, patent citations as indicator of knowledge diffusion, and patent value and value determinants. This chapter will lay down the foundation of patent analysis since it is a key mechanism in this study.

In Chapter 3, the systematic construction, quantification, and characterization of the unique attributes of Japanese university patents were observed. Additionally, a comparison to its US counterpart was employed. This chapter describes and presents main trends in Japanese university patenting over the last 20 years, including an analysis of a variety of measure constructed with citation data, such as forward citation lags, innovation *basicness*, *appropriability*, and *time distance* of patents. These analyses provide us with a clearer picture and deeper understanding of Japanese university patent attributes.

Chapter 4 focuses on the impact of UIC policies on Japanese university patenting by dividing the analysis into the period before and after the implementation of UIC policies. This chapter provides a quantitative analysis of Japanese university patents to examine changes in the nature of university patenting resulting from the implementation of UIC policies in Japan. In this chapter, we can observe a detailed analysis between different institutional settings, which include university assignee and UIC patents. This chapter allows us to observe the differences of patent attributes deriving from the effects of UIC policies.

Chapter 5 discusses a debate centered on the relationship between universities and industry. A critical discussion is based on an argument that there is little evidence that an increase in university patenting has facilitated increased technology transfer or any meaningful growth in the economic contributions of universities. In this chapter, I provide evidence to support the notion that a growing number of university patents do facilitate technology transfer to industry by demonstrating an analysis of knowledge diffusion from universities to industry using patent citations. Additionally, this chapter also covers a comparative analysis between the citation frequency that Japanese industry cited university patents and Japanese industry cited corporate patents.

After the empirical analyses of the impact of UIC policies on Japanese university patents in terms of patent attributes and knowledge diffusion, Chapter 6 provides the patent analysis in detail. This chapter draws attention to the issue of patent value and value determinants by investigating the determinants of patent value in Japanese university patents with different assignees and also makes a comparison to its US counterpart. The study analyzes the measures derived directly from patent data and their relationship to patent value. The result of this analysis improves our understanding of what determines the value of patents.

Chapter 7 provides major findings of the study and conclusion. This chapter summarizes the results of the research presented in this study and discusses their policy implications. The contribution of this research is also provided for scholars in the field. The study concludes by acknowledging some of the more salient research limitations and proposing areas for future study.

CHAPTER 2

PATENT ANALYSIS AND THE USE OF PATENT DATA

2.1 The Use of Patent Data

Patents play an increasingly important role in innovation and economic performance. According to OECD (2004), between 1992 and 2002, the number of patent applications filed in Europe, Japan and the United States increased by more than 40%. The increasing use of patents to protect inventions by businesses and public research organizations (PROs) is closely connected to recent evolutions in innovation processes and economic development (OECD 2004). The lack of good indicators often limits the construction of measures of the economics of technological development (Trajtenberg et al. 1997). However, patents are one possible exception since they have long been considered a rich data source from a few standardized approaches to the study of innovation and technical change providing a unique insight into the processes, the diffusion, and the outcomes of technological knowledge (Goto and Motohashi 2007; Hall et al. 2005)

The *WIPO Intellectual Property Handbook: Policy, Law and Use* (2008, 17) provides the following definition of a patent: "A patent is a document, issued, upon application, by a government office (or a regional office acting for several countries), which describes an invention and creates a legal situation in which the patented invention can normally only be exploited (manufactured, used, sold, imported) with the authorization of the owner of the patent." Patents are temporary monopolies granted for inventions (generally 20 years) that are novel, inventive (non-obvious) and have an industrial application (useful) (OECD 2004). For a patent to be granted, the innovation must be non-trivial, meaning that it would not appear obvious to a skilled practitioner of the relevant technology, and it must be useful, meaning that it has potential commercial value. If a patent is granted, an extensive public document is created (Trajtenberg et al. 1997).

The front page of a patent contains detailed information about the invention, the inventor, the assignee, and the technological antecedents of the invention, all of which can be accessed in computerized form (Trajtenberg et al. 1997). The data contained in patents are highly detailed information on the innovations, providing their

technologies, assignees, and geography (Hall et al. 2005; Tantiyaswasdikul 2013a). Moreover, patent analysis is a unique and highly visible method of the study of technology transfer that allows for a more comprehensive analysis of the importance of the innovations they disclose (Henderson et al. 1998; Tantiyaswasdikul 2012a). Thus, it may be possible to construct patent indicators that can serve as innovation value's proxies (Trajtenberg 1990).

Indicators that are widely used for patent analyses, which we can obtain from patent data, include the following: First, the basic information about inventors and assignees provides the addresses of inventors and assignee in terms of city and country. Scholars use this data to analyze the flow of knowledge in patents regarding geographic boundaries (Bacchiocchi and Montobbio 2009; Jaffe and Trajtenberg 1996). Next is the information about technological antecedents and descendants. This data is represented in the backward and forward citations of patents. The use of patent citations is widely employed to construct a variety of measurements to interpret the importance of the invention covered by a patent (see Goto and Motohashi 2007; Hall et al. 2005; Trajtenberg et al. 1997; Henderson et al. 1998; Tantiyaswasdikul 2013a).

Third is the technology classification.[12] This data was used as one of the determinants to determine patent value (Guellec and van Pottelsberghe de la Potterie 2000; Lerner 1994). The last is the breadth or scope of patent protection. Considering the study of innovation and technical change, policymakers increasingly recognize the breadth of patent protection as an important science and technology policy instrument. The breadth of IP protection has attracted increasing theoretical attention but little empirical evidence (Lerner 1994). The breadth of patent protection covers various topics such as the issue of the optimal length of award and the optimal breadth of patent claims (Lerner 1994).

Patent data have been used extensively in economic research due to the development of patent databases and computerization. According to Hall et al. (2001), there are numerous advantages to the use of patent data. First, each patent contains highly detailed information on an invention and provides the technological area associated with it. Data about the inventors and the assignee are also provided, along with their geographical location. Second, based on database of the USPTO, the stock

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[12] For more detailed explanation of technology classification, see Chapter 3.

of patents is currently in excess of 11 million,[13] and the flow is of over 570,000 patents per year (as of 2011-2012).[14] Moreover, the current numbering and reporting system dates to the 1870s. This indicates that there are over 100 years of consistently reported data. Thus there is a wealth of data potentially available for research (Hall et al. 2001).

Third, the data contained in patents are supplied entirely on a voluntary basis and the incentives to do so are plain and clear, in contrast to other types of economic information. Finally, the most important advantage is patent citations. Citations to previous patents and to scientific literature are included in patent data. These citations provide the possibility to trace multiple linkages between inventions, inventors, assignee, location, etc. Particularly, patent citations allow us to analyze the *importance* of innovations, to capture the enormous heterogeneity in patent value, and to study the technological knowledge flows (Hall et al. 2001).

However, there are certain disadvantages in using patent data since not all inventions meet the patentability criteria set by patent offices. According to Griliches (1990, 1669), "not all inventions are patentable, not all inventions are patented and the inventions that are patented differ greatly in quality, in the magnitude of inventive output associated with them." These facts offer serious limitations to the use of patent data. Additionally, not all the patentable innovations are in fact patented since patenting is a strategic decision and the inventor has to make a tactical decision to patent (Hall et al. 2001).

Patent-based indicators are increasingly being employed to give us new insights into the technological performance of firms, industries, and countries (Tong and Frame 1994). Schmookler (1966) pioneered the use of patent data on a large scale for economic research. Schmookler used patent counts assigned to industries as a measure of innovative activities. In Schmookler's study *Invention and Economic Growth* (1966), he linked patent counts with economic performance across different industries. There have been many studies relevant to his work carried out since his pioneering work, for instance, the work of Griliches (1984) that involved matching patents to firms, and Scherer (1982) worked on a classification of patents into industry of origin and industries of use. The outcomes of both studies were composed of patent

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[13] Based on data obtained from the USPTO website;
http://www.uspto.gov/web/offices/ac/ido/oeip/taf/us_stat.htm (Accessed 19 May 2014).
[14] Based on data obtained from the USPTO website;
http://www.uspto.gov/web/offices/ac/ido/oeip/taf/us_stat.htm (Accessed 19 May 2014).

counts by firms or industries, by year. The result was a detailed technology flow matrix that again could be linked to other external data such as R&D expenditures and productivity growth.

Since the mid-1980s, patent counts have been used to explore technological roots of firms and industries. However, one significant drawback of this method was that they relied exclusively on simple patent counts to indicate the innovation output (Hall et al. 2001). Since innovations vary in their technological and economic value and the distribution of such values is extremely skewed, using simple patent counts is inherently limited in the extent to which they can capture such heterogeneity (Griliches et al. 1986)

To overcome these limitations with the novel finding that citations appear to be correlated with the value of innovations, Trajtenberg et al. (1997) undertook work aimed primarily at demonstrating the potential usefulness of patent citations for a variety of purposes. In *University versus corporate patents: A window on the basicness of invention,* Trajtenberg et al. (1997) pioneered the use of citations as an indicator to reflect spillover effects and significant characteristics of the use of patent citations to measure features of innovations, such as *originality* and *generality* (Caballero and Jaffe 1993; Jaffe et al. 1993).

2.2 The Use of Patent Citations

In the recent years, patent citations have been used increasingly in the study of knowledge flows. Patent citations provide a direct measure of diffusion of inventions. The progress in the study of knowledge flows is partly due to the availability of patent citation data in a readable form provided by the USPTO during the 1990s. Regarding the development of patent databases and computerization, patent citations have become the most informative tool on knowledge flows.

Patent data include citations to previous patents and to the scientific literature. Patent citations work as similarly to references in academic papers. However, patent citations are added with the legal function of identifying technological predecessors or *prior art* of the patented invention (Henderson et al. 1998; Jaffe et al. 1993). Patent citations serve an important legal function, since they delimit the scope of the property rights awarded by the patent. Thus, if patent Y cites patent X, it implies that patent X

represents a piece of previously existing knowledge upon which patent Y builds, and over which Y cannot have a claim. Both the patent applicant and examiner can add patent citations. The applicant has a legal duty to disclose any knowledge of their inventions related to the existing technology. However, the patent examiner, who is supposed to be an expert in the area, has a duty to identify the relevant prior art that the applicant misses or conceals (Henderson et al. 1998; Jaffe et al. 1993; Trajtenberg et al. 1997).

When patents are linked together, the terms used to clarify the relationship are *backward citations* and *forward citations*. A *backward citation* is a patent that was granted earlier that has prior art, which a core patent must cite. A *forward citation* is a newer patent that cites the existing innovation of a core patent. For instance, when patent P (2000) is cited by patent B1 (2001) and patent B2 (2002), patent P is a backward citation of patents B1 and B2. On the other hand, patent P has two forward citations, which are patents B1 and B2. In contrast, when patent P cites patent A1 (1998), patent A2 (1998), and patent A3 (1999), patent P is a forward citation of patents A1, A2, and A3. In addition, patent P has three backward citations: patents A1, A2, and A3. A diagram to describe these relationships is presented in Figure 2.1.
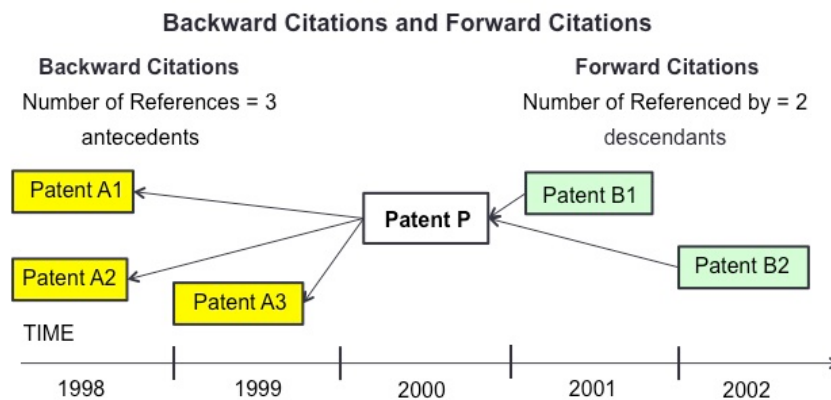
Source: Author, 2014

Figure 2.1: The relationship of backward and forward citations

Patent citations are widely employed to construct a variety of measurements to interpret the importance of the invention covered by a patent (see Goto and Motohashi 2007; Hall et al. 2005; Henderson et al. 1998; Tantiyaswasdikul 2013a; Trajtenberg et al. 1997). Patent citations perform the legal function of delimiting the patent right by

identifying previous patents whose technological scope is explicitly placed outside the bounds of the citing patent (Jaffe and Trajtenberg 1996). Citations can be used for many purposes, including tracing the process of technology development and evaluating the importance of a patent (Goto and Motohashi 2007; Tantiyaswasdikul 2013). Moreover, citation data can provide significant evidence that reveals the links between an innovation and its technological antecedents and descendants clearly (Tantiyaswasdikul 2013a; Trajtenberg et al. 1997).

The number of patent citations has long been presumed to indicate the link between the patents themselves and both the technological and economic value of innovations (Jaffe et al. 1993). Based on the assumption that at least some of such future inventions will cite the original invention, when the future technologies have been invented, at least some must cite earlier inventions in their patents. Thus the number and character of citations received can indicate the technological importance of an invention (Henderson et al. 1998; Trajtenberg 1990). The use of patent citations to construct various measures of patent attributes was presented by Trajtenberg et al. (1997) and Henderson et al. (1998). These scholars used patent citations to measure the *basicness*, *appropriability*, and *time distance* of the invention covered by a patent. This approach clarifies the significance of technological development according to its role in stimulating and facilitating subsequent inventions (Henderson et al., 1998).

To analyze the attributes of patents in Chapters 3 and 4, this study uses the notion of patent citation to develop measures to identify patent attributes as similar those of Trajtenberg et al. (1997). An item of particular importance for this analysis is the citations that receive from newer patents (forward citations) since the important aspects of basicness and of appropriability are embodied in the relationship between the innovation and its technological antecedents and descendants, and that patent citations, made and received, provide an effective means for identifying and tracing these relationships (Trajtenberg et al. 1997).

2.3 Patent Citations as Indicator of Knowledge Diffusion

Acquisition of knowledge is critical for innovation creation and growth of geographic regions (Grossman and Helpman 1991; Singh 2005). Additionally, diffusion of knowledge has important implications for the modeling of technological

change and economic growth (Jaffe and Trajtenberg 1996). To estimate knowledge flow and diffusion, patent citations have been utilized extensively to measure the diffusion of knowledge across a variety of dimensions: geographic space, time, technological fields, organizational boundaries, alliance partnerships, and social networks (see Alcácer and Gittelman 2006; Bacchiocchi and Montobbio 2009; Jaffe and Trajtenberg 1996; Nelson 2009; Peri 2005).

According to Chen and Hicks (2004, 199), "knowledge diffusion can be defined as the adaptations and applications of knowledge documented in scientific publications and patents." From an economic standpoint, the efficient diffusion of knowledge about new technologies is an essential characteristic of growth and development (Robertson and Jacobson 2011). Moreover, diffusion is an essential driver of any system for generating and using technological knowledge (Robertson and Jacobson 2011).

Knowledge diffusion has received significant attention in the economics, management, and public policy literature, especially since the works of Romer (1990) and Grossman and Helpman (1991) discussed models of endogenous economic growth where knowledge was treated as completely diffused within an economy.[15] To estimate knowledge flow and knowledge diffusion, *How can knowledge diffusions be measured?* becomes a critical question for economists and policymakers, although knowledge is an elusive notion, difficult to conceptualize and even harder to measure in a consistent, systematic way (Jaffe and Trajtenberg 2002).

Regarding the difficulty of measuring knowledge flow, unfortunately, "knowledge flows […] are invisible; they leave no paper trail by which they may be measured and tracked" (Krugman 1991, 53). However, Jaffe et al. (1993) argued that knowledge flows do sometimes leave a paper trail in the form of citations to patents that allow us to observe their spillover effects. Since that pioneering work, patent citations have been utilized extensively to measure the diffusion of knowledge.

Knowledge flows were first explored by Caballero and Jaffe (1993). Using models of the process of diffusion for the analysis of citation patterns, they tracked the influence of past inventions across time, space, technological fields and institutions. These models' use of the function of citations allows us to measure the probability of

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[15] For detailed explanation of models of endogenous economic growth, see Grossman and Helpman (1991) and Romer (1990).

citations between patents. Since the pioneering work of Caballero and Jaffe (1993), many studies have been developed using citations as an approximation for knowledge flows.

This study uses the notion of patent citations as indicators of knowledge diffusion to analyze citation frequency and make a comparison between Japanese industry patents citing university patents and Japanese industry patents citing corporate patents in Chapter 5. To calculate citation frequency or propensity to cite, I employ the equation deriving from Jaffe and Trajtenberg (1996), adapted from the formulation of Caballero and Jaffe (1993) that was created to estimate parameters of the diffusion process while controlling for variations over time in the propensity to cite of patents.

2.4 Patent Value and Value Determinants

There has been continued interest in trying to estimate the value of patents since their economic significance is variable (Groliches 1990). However, assessing the value of patents is difficult because the distribution of these values is highly skewed, with a few patents worth a lot and a lot of patents worth nothing (Harhoff et al. 2003). It is known that on average only one to three patents out of 100 yield significant financial returns.[16] This skewed distribution of patent value has been at the origin of slight but increasing attention of economic research that attempts to identify the determinants of patent value (Sapsalis et al. 2006).

The skewness attribute has been discussed by many scholars (see Griliches 1990; Griliches et al. 1986; Pakes 1986; Pakes and Schankerman 1984; Sapsalis et al. 2006; Schankerman and Pakes 1986; Scherer 1965; Scherer and Harhoff 2000). However, an estimation of the dispersion and the skewness in patent value of Schankerman and Pakes (1986) was the first to alert us to its actual magnitude (Griliches 1990). Schankerman and Pakes (1986) investigate changes in the distribution of patent values over time and the correlates of these changes; their study found that the distribution of these values is very dispersed and skewed.

The survey of Griliches (1990) includes the use of patent statistics to illuminate the process of innovation and technical change. The practical implication of his finding is that patent data can be used instead as an indicator of both inventive input and

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[16] For more detailed explanation, see Stevens and Burley (1997).

output. However "the large amount of skewness in this distribution leads to rather pessimistic implications for the use of patent counts as indicators of short-run changes in the output of R&D" (Griliches 1990, 1702). Since the mid-1980s, patent counts have been employed to examine one of the most crucial issues of the times: the technological roots of global economic competition (Tong and Frame 1994). However, when the number of patents was increased dramatically, the indicator of counted patents was no longer appropriate to measure the technological performance. This is because each patent has a different value.

Jacob Schmookler pioneered the use of patent counts to explain the relationship between technology and the country (Schmookler 1966; Tong and Frame 1994). In his *Invention and Economic Growth*, he linked patent counts with economic performance across a wide array of industries. His work showed that in many industries, economic demand pulls technology forward. Since Schmookler's landmark work, many related studies have been carried out (Griliches 1990). Since the pioneering work of Schmookler, many scholars have employed various indicators to determine patent value.

Various indicators have been used as variables to determine patent value in the economic literature on the measurement of the value of patents, such as the number of times the patent is cited (forward citations of patents), or the length of its renewal, or the number of countries where it is taken (patent family size), or the breadth or scope of patent protection (patent claims). Different empirical strategies have been used in the literature to approximate the value of a patent. However, most studies use this available information on patents and apply econometrics functional forms to determine patent value.

Several excellent studies investigate the patent value using the renewal decision to interpret their value. Pakes (1986), Pakes and Schankerman (1984), and Schankerman and Pakes (1986) were the first to develop and estimate models in which the observed renewal decisions are used to estimate the distribution of patent values. Another approach is to estimate a regression function between a set of variables collated with patent value and the response variable that can reflect the value of patent.

Lerner (1994) examined the impact of patent scope on the market value of biotechnology firms. To determine the valuation, he developed a proxy for the breadth of patent protection, which is composed of a combination set of the number of

international patent classifications (IPCs) referred to in the patent.[17] He concluded that this variable significantly affects the firm's market value. Putnam (1996) was the first to integrate application data into the analysis of the value of patent. The analytical framework of conditions on application by Pakes and Schankerman (1984) was extended in this analysis. He combined application data and renewal data to estimate the jurisdiction over patent application in each country and pointed out that a result of patents in the different countries is likely to be correlated with the value of the invention and the value of any single national patent right.

The type and number of explanatory variables that have been used as determinants of patent value vary widely across studies. The most frequently used determinants are the number of forward patent citations (when it is not used as a dependent variable), the number of backward patent citations, and the geographical scope for protection (the number of countries in the patent family). Other variables rely on the concepts of opposition procedures, renewal data, application scope (the number of claims) and non-patent citations.

This study examines the determinants of patent value in Chapter 6. For this purpose, multiple regression analysis using forward citations as dependent variable is executed. I develop four broad value determinants to determine patent value as follows: (1) the technical background of a patent (measured by the number of backward citations); (2) the distance of technology from the application date to present (measured by the year the patent was filed); (3) the breadth or scope of patent protection (measured by the number of claims); (4) the technology classification (measured by the number of IPC classes).

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[17] For detailed explanation on IPC classification, see Chapter 4.

CHAPTER 3
ATTRIBUTES OF JAPANESE UNIVERSITY PATENTS

3.1 Introduction

Recently, there has been a rise in policy interest on how university technology transfer can be efficiently used for commercialization. The central focus of this issue underlies the collaboration between university and industry in transferring technology for commercial purposes. Regarding the university-industry linkage, the role of the university has diversified and encompassed a *third mission* of economic development, beyond traditional instructional and research missions (Meyer 2006; Tantiyaswasdikul 2013a). Many countries are undertaking university reforms for greater autonomy and to increase the commercialization of the results of publicly-funded research (Lehrer and Asakawa 2004; Rasmussen 2008; Slaughter and Leslie 1997; Tantiyaswasdikul 2013b; Zhao 2004).

Reforms in national research systems aiming to increase technology transfer and the commercialization of the university research have become a significant policy. The policy changes and the increased expectations that universities should contribute to the commercialization of research have led to several initiatives at the university level. The universities have also reconsidered their policies to create incentives for the researchers to contribute to the commercialization of their research results (Lockett et al. 2003; Rasmussen 2008; Roberts and Malonet 1996; Tantiyaswasdikul 2013b).

In the US the significant role played by universities in commercialization has been recognized, and various policy initiatives have been introduced. The Bayh-Dole Act of 1980 is one of the most influential policy legislations implemented to stimulate the commercialization of university research (Rasmussen 2008; Tantiyaswasdikul 2013b). This act made it significantly easier for US research universities to maintain the IPRs to inventions acquiring from federally funded research (Henderson et al. 1998; Tantiyaswasdikul 2012a, 2013a).

The significant growth in patenting and licensing by US universities has been widely cited as an effect of the Bayh-Dole Act initiative. There are several arguments that the increase in these activities enhanced the social returns to publicly-funded academic research (Mowery and Sampat 2005; Tantiyaswasdikul 2012a, 2013a).

Although little empirical analysis has been directed at assessing its impacts, these assessments and other factors have led governments in many OECD countries, including Japan, to consider policy initiatives that emulate the Bayh-Dole Act (Mowery and Sampat 2005; Tantiyaswasdikul 2012a, 2013b).

Previously, Japanese universities did not engage in the contribution of commercial innovation, in contrast to the US, since the engine of Japanese innovation is played by industrial sector. As shown in Figure 3.1, industry R&D investment accounted for between 70% and 80% of the total national R&D expenditures in Japan over the last 20 years, while its share was between 50% and 70% in the US during the same time. The role of universities in national innovation has been considered limited. Major innovations were achieved by industry. Figure 3.2 shows the US universities spending more than twice as much on R&D as their Japanese counterparts over the last 20 years and shows the gap widening.
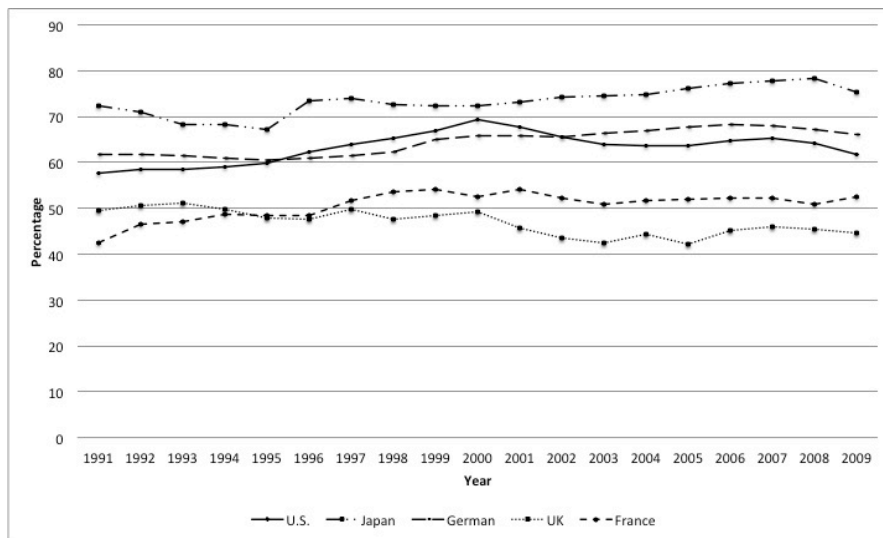
Source: OECD, Main science and technology indicators 1997; 2002; 2006; 2012
Based on data obtained from OECD website; http:// http://www.oecd.org/sti/msti.html
(Accessed 17 November 2013).

Figure 3.1: Percentage of gross domestic expenditure on R&D financed by industry between 1991 and 2009

Figure 3.2: Higher education expenditure on R&D between 1991 and 2009

Until the recognition of UIC in encouraging economic growth, the Japanese government had implemented several policy measures to promote university-industry technology transfer and commercialization for the practical use of research results achieved by public research institutions, including the Law on Special Measures for Industrial Revitalization and Innovation or the Japanese Bayh-Dole Act.

Besides the Japanese Bayh-Dole Act, there are other significant laws to support the efficiency of university-industry linkage in transferring technology, which include the Law for Promoting University-Industry Technology Transfer (TLO Law) enacted in 1998; the 2000 Law to Strengthen Industrial Technology; and the enactment of the National University Incorporation Law in 2004.

These legislations have resulted in the continuous increase in the number of Japanese university patent grants since 1998 (Tantiyaswasdikul 2012a). Based on the USPTO, a continuous growth in the number of patents granted for Japanese national universities has been witnessed, in particular in the period after the university incorporation law in 2004, from 31 in 1998 to 92 in 2004 to 250 in 2005 and 410 in 2007.

However, the extent to which this achievement should be taken as evidence of an increase in the contribution of universities to commercialization depends not just on

patent numbers but on the degree to which patents represent commercially useful inventions or have spillover effects on industry. Regarding the importance of this issue, this study aims to explore and examine the attributes of Japanese university patents by making a comparison to US university patents. Considering the attributes of university patents, this study compares US and Japanese university patents in terms of innovation basicness, appropriability, and time distance, which can reflect the characteristic of spillover effects of university patents.

This study discusses the differences in the attributes of US and Japanese university patents. Comparison with the US is important, because many of the new reforms aim specifically to emulate the technology transfer system in the US, which many Japanese believe to be a major contributor to the dynamism of American's high technology industries (Collins and Wakoh 2000). The objective is to systematically construct, quantify, and characterize the unique attributes of US and Japanese university patents and make a comparative analysis between them.

The remainder of this chapter is organized as follows: Section 3.2 summarizes literature reviews on US university patenting and Section 3.3 then reviews the literature on Japanese university patenting. Section 3.4 provides the measures of patent attributes. Section 3.5 provides the patent classifications. Section 3.6 presents the data collection and data set, while Section 3.7 presents the empirical analysis and findings. The last section offers a conclusion.

3.2 US University Patenting

In the 1980s, the US government considered the importance of universities in driving economic growth and innovation-based strategies in the 1950s and 1960s. Due to the US facing the slowdown of productivity growth and being challenged by Japanese and German firms in international markets, the US government turned to universities to improve the competitiveness of US industry (Sakakibara 2007). An important channel of university-industry linkage in the US, which is much less prominent in Japan and most Western European economies, is the creation of new companies. There were hundreds of start-up companies arising from university innovations, which contributed to the development of the biotechnology, microelectronics, and computer industries (Sakakibara 2007).

Since universities are in principle dedicated to expand their contribution to research's results in driving economic growth, universities have been under increasing pressure to translate the results of their work into industrially appropriable technology (Handerson et al. 1998). Due to the fact that ownership and management of IP are central to how university discoveries are transferred to industry, the change in the system of university IP ownership is the critical issue. In the early 1980s, the importance of universities in commercialization was recognized and various policy initiatives were introduced in the US. The significant policy that was implemented is the Bayh-Dole Act (Sakakibara 2007). The Bayh-Dole Act, or the Patent and Trademark Law Amendments Act, is US legislation dealing with IP management arising from federal government-funded research. The act made it significantly easier for American research universities to maintain IPRs to inventions derived from federally funded research (Henderson et al. 1998; Tantiyaswasdikul 2012a, 2013a).

US universities played a significant role in transferring technology to commercialization in the passage of the Act. The number of university patent applications and grants has increased, and their annual growth rate is more than twice that of commercial patents (Sakakibara 2007). However, while the act increased the number of university patents, arguments have arisen regarding their quality. Recently, there has been a rise in discussion on academic patenting resulted from the Bayh-Dole Act of 1980. The first attempt to quantify key aspects of university patents is the study of Trajtenberg et al. (1997), which provided a comparative analysis of basicness and appropriability of US university and corporate patents in 1975 and 1980.

In this analysis, basicness refers to fundamental features of innovations such as originality or closeness to science and appropriability refers to the attributes of inventions that allow their inventors to benefit. The results indicated that based on the prior notion that universities perform more basic research than corporations, the measures of basicness in university patents are significantly higher than in corporate patents. Additionally, the degree of appropriability in corporate patents is significantly higher than in university patents, which indicates the higher ability of inventors to reap benefits from their own inventions.

By taking a similar approach to Trajtenberg et al. (1997), Henderson et al. (1998) characterized the US university patenting from 1965 to 1988 and made comparison to a 1% random sample of patents registered during the same period.

Henderson et al. (1998) explored this issue by investigating the changes in the importance and generality of patents. This study found a decrease in the relative importance and generality of university patents, together with a simultaneous increase in their number. This decline in patent quality reflects the rapid increase in patents obtained by universities, most of which lacked patent experience.

On the other hand, Sampat et al. (2003) re-examined the same sample as Henderson et al. (1998), but with the inclusion of citation data through 1999, and found no decline in patent importance. This indicates a truncation problem in the citation data, since university patents tend to have a longer citation lag than corporate patents. Additionally, Mowery and Ziedonis (2002) further analyzed the estimates of Henderson et al. regarding the number of patents and experiences of universities and found that patent quality declined only for universities that had applied for patents before the enactment of the Bayh–Dole Act but held fewer than 10 patents, and for universities that applied for patents only after the enactment of the Bayh–Dole Act. Overall patent quality did not decline for universities that had applied for patents before the Bayh–Dole Act and held 10 or more patents. The analysis of overall US university patenting suggests that the patents issued to institutions that entered into patenting and licensing after the effective date of the Bayh-Dole act are indeed less important and less general than the patents issued before and after 1980 to US universities with longer experience in patenting (Mowery and Ziedonis 2002).

There has been a continuous increase in the number of US university patents, as presented in Figure 3.3. The significant growth during the 1980s and 1990s in patenting and licensing by US universities has been widely cited as an effect of the Bayh-Dole Act initiative. However, the study of Mowery et al. (2001) pointed out that the Bayh-Dole Act itself has had little impact on the university patenting. The university patent portfolios shifted to some extent previously to and independently of Bayh-Dole Act, and these changes are significant factors behind the increase in patenting and licensing. Mowery et al. (2001) reveal that the evidence derived from three leading US universities represents the similarity in their patent and licensing portfolios although two of them were active in patenting and licensing before the enactment of Bayh-Dole Act and one of them became active only after its passage.
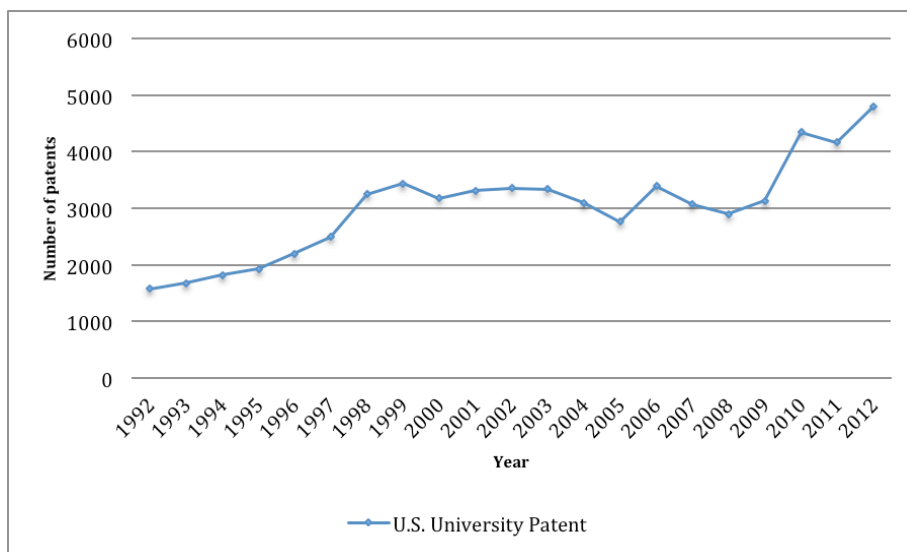
Figure 3.3: US college and university patent grants 1992-2012

The Bayh-Dole Act is one of the most influential pieces of legislation in terms of stimulating the commercialization of university research (Rasmussen 2008; Tantiyaswasdikul 2013b). The significant growth in patenting and licensing by US universities has been widely credited to this legislation. Several arguments exist that the increase in these activities enhanced the social returns of publicly funded academic research (Mowery and Sampat 2005; Tantiyaswasdikul 2012a, 2013a). Although little empirical analysis has focused on assessing the impacts of the Bayh-Dole Act, positive assessments of the effects of the Act, together with other factors, have led governments in many OECD countries, including Japan, to consider similar policy initiatives (Mowery and Sampat 2005; Tantiyaswasdikul 2012a, 2013a).

3.3 Japanese University Patenting

In the early 1980s, while the importance of universities in commercialization was recognized and various policy initiatives were introduced in the US, in Japan this was a period of strong economic growth. Japan conveyed the different way universities contribute to commercial innovation. The engine of innovation in Japan was driven by the private sector, and university-industry technology transfer in that period was

informal (Sakakibara 2007).

The informal ties of university-industry linkage in Japan resulted from many restrictions set by the national universities in cooperating with industry in the past.[18] These difficulties effected the IP management in universities and industries. Informal transfer of university technologies occurs in many ways, including professor's consultancy for companies, corporate researchers working in university laboratories and communicate research results back to their companies, or graduates find employment in industrial sectors (Kneller 1999; Tantiyaswasdikul 2013b). These informal channels of technology transfer are hardly captured in official statistics.

Many university discoveries are transferred to the private sector informally and unaccounted for in any normal statistics (Kneller 1999; Tantiyaswasdikul 2013b). Sometimes the transfer of IPRs occurs with a short document that serves as an assignment not an official or contract agreement. These unofficial documents lead to the problem that some productive faculty members do not know how many of their discoveries have been patented by companies (Kneller 1999; Tantiyaswasdikul 2013b).

The study of Kneller (1999) based on the Japan Patent Office (JPO) showed that Japanese companies neither develop, nor license approximately two-thirds of the technologies for which they actually obtain patents, usually because the companies are not interested in that technologies and they want to block other companies from using them.[19] According to Kneller (2007b, 47) "*Sleeping university inventions* unused by companies was a key concern of the government agencies that promoted the 1998-2004 reforms. Government advisory committees that recommended adopting a US-style system reasoned that ownership would give universities incentives to manage their own inventions so as to maximize their commercial and societal value."

The Japanese government considered and administered various policies, including a Program of Economic Structural Reform and the Science and Technology Basic Plan, in which academia-industry collaboration was given an important position to revitalize the national innovation system (Fujisue 1998). These strategies were implemented toward a network-based approach of UIC, and the Japanese Science and

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[18] Kneller (2007b) provided a detailed explanation of the restrictions set by the national universities regarding UIC.
[19] For detail on frequent reasons for companies not developing university inventions, see Kneller (2007b).

Technology Basic plan strongly advocated the promotion and enhancement of active interactions among innovation actors (Motohashi 2005; Tantiyaswasdikul 2012a, 2013b).

In 1998 the Law to Promote the Transfer of University Technologies (TLO Law) was enacted, with an emphasis on university patenting. The TLO Law legitimized and facilitated transparent, contractual transfers of university discoveries to industry, even though it did not change the basic ownership system. It provided a fig leaf to allow contractual licensing of inventions to industry, even though a rigorous analysis of funding sources might have revealed that inventions arose under project specific government funding. It also provided for subsidies of about US$ 180,000 annually for five years for approved TLOs. Starting from five TLOs approved in 1998, the number of approved TLOs increased to thirty-nine by the end of 2005 (Kneller 2007b).

The Japanese government has implemented many policies to support and encourage TLO activities; these include the subsidy and debt guarantee to TLOs. The Japanese government will give a subsidy of 50% and a full debt guarantee to the establishment cost of a TLO by universities and private companies through the *Industrial Infrastructure Fund*; exemption from fees is offered on patent registration and maintenance; collaboration between universities and small-medium sized companies is financed by the Small-Medium Sized Companies Supporting Corporation program (Fujisue 1998).

Besides the TLO Law, Japanese government also enacted the Law of Special Measures to Revive Industry or the Japanese Bayh-Dole Law. The Japanese Bayh-Dole Law is similar to the US Bayh-Dole Act that allows universities to retain their rights to any inventions deriving from public-funded research. The Japan Bayh-Dole Law has the same effect as US Bayh-Dole Act, *except that it did not apply to national universities until they obtained legal status as semiautonomous administrative entitles in 2004* (Kneller 2007b). This policy has changed the IPR system of Japanese universities and shifted ownership from individual inventors to universities.

To encourage UIC activities, the 2000 Law to Strengthen Industrial Technology was also implemented to establish procedures through which university researchers can obtain permission to consult for, set up, and manage companies. It also accelerates the procedures of the industrial-sponsored commissioned and joint research

(Kneller 2007b; Tantiyaswasdikul 2013b). The Law to Strengthen Industrial Technology allowed national university researchers to engage in paid outside work on behalf of private firms (Kneller 2007b).

In April 2004, the Japanese government incorporated the national universities as *independent administrative entities*. This important change in Japan's research culture has allowed its universities to gain higher control (Takahashi and Carraz 2009; Tantiyaswasdikul 2013b). The roles of universities after incorporation have to be considered as conducting funded or cooperative researches, distributing research results to promote their utilization, and investing in organizations specializing in university technology transfer; however, the universities are autonomous and independent since they have gained a greater autonomy (Shimoda 2005; Tantiyaswasdikul 2013b). They can more easily recruit academic and non-academic staff and they can retain the ownership of their invention, which was seldom the case before the Incorporation (Takahashi and Carraz 2009; Tantiyaswasdikul 2013b).

With the last of these reforms, the legal framework of Japan's technology transfer system came to closely resemble that of the US. Many standard indices of technology transfer activity compare favorably to US indices. Average patent applications per TLO were higher than historical US averages. Average numbers of licenses were also higher. However, average royalties are probably lower than historical US levels (Kneller 2007b).

The collaboration between Japanese universities and industry has been based on individual networks and informal transfer of knowledge. There are limited studies on the Japanese universities' research on patenting. It was not until the period of UIC in Japan that Japanese government considered the importance of collaboration and implemented various policy initiatives to encourage the university-industry technology transfer in a formal way.

In Japan, study of university patenting is limited owing to the historical lack of such activity. Data from the JPO reveals just 137 university patent disclosures in 1995. In comparison, 5,100 university patent applications were lodged in the US during the same period, based on the data from the AUTM Licensing Survey, 1991–95 (Arai 1999). In the past, several obstacles made it difficult for university professors to patent their work. For instance, publication was prioritized over patents. Other obstacles were

the complex and time-consuming process of preparing for and successfully lodging a patent application and patent maintenance fees (Arai 1999).

Since 1998, Japanese universities have expanded their academic inventions resulting in a continuous increase in the number of patent grants (Tantiyaswasdikul 2012a). Based on the USPTO, a continuous growth in the number of patents granted for Japanese national universities has been witnessed, in particular in the period after the university incorporation law in 2004. Figure 3.4 shows the trend in patenting at Japanese national universities by USPTO. There was a significant increase in the number of university patents from 15 patents in 1997 to 31 patents in 1998. Moreover, after the university incorporation law of 2004 the number of granted patents among Japanese national universities rose dramatically, from 92 patents in 2004 to 250 patents in 2005, and reached 410 patents in 2007.
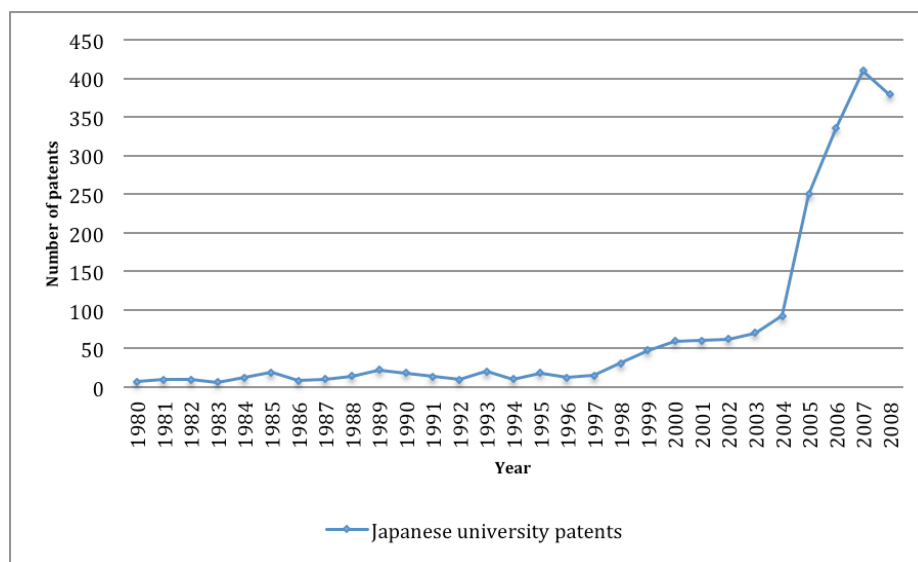
Source: Based on data obtained from the online records system of USPTO website;
http://www.uspto.gov/patents/process/search/
(Updated November 2013).

Figure 3.4: Japanese university patent grants 1980-2008

Before the incorporation of the national universities, most patents belonged to private companies conducting joint research with the university or belonged to individual inventors, but after their incorporation there has been a huge increase in so-called institutional patents belonging to the university, along with a relative decrease in patents belonging to private companies. Incorporation has not changed the amount of

IP created by universities, but rather who is claiming ownership over that IP. The number of patents has traditionally been underestimated, since a large number of previous patents belong to individuals or companies due to the informal bond between professors and corporations.

Regarding the results of joint research projects between universities and industry, many university discoveries are transferred to the private sector informally and hence unaccounted for in the statistics (Kneller 1999). Sometimes the transfer of IPRs occurs via a short document rather than an official IPR transfer or contract agreement. These unofficial documents create a problem whereby some productive faculty members do not know how many of their discoveries have been patented by companies (Kneller 1999). This difficulty means numbers of university patents were most likely underestimated during the 1980s and 1990s. However, UIC has increased rapidly since the late 1990s (Okamuro and Nishimura 2013). This growth is reflected not only in the rising number of joint research projects but also that of UIC patents (Motohashi and Muramatsu 2012; Tantiyaswasdikul 2013b).

The study of Motohashi and Muramatsu (2012) is the first attempt to examine the effect of the enactment of UIC policies in Japan on university patents there. The study found that the UIC policies increased the number of UIC patents in the late 1990s while overall patent quality was maintained. Other studies have also found that the UIC policies increased the number of Japanese university patents (Tantiyaswasdiku, 2012a, 2012b, 2013b). Since 1998, Japanese universities have expanded their academic inventions owing to the continuous increase in the number of patent grants (Tantiyaswasdikul 2012a). Based on data from the USPTO, continuous growth in the number of patents granted for Japanese national universities occurred particularly after the National University Incorporation Law in 2004, rising from just 31 in 1998 to 92 in 2004, before leaping to 250 in 2005 and then reaching 410 in 2007. This evidence indicates that UIC policies have been successful.

Besides the achievement of a dramatic increase in the number of Japanese university patents, there remains a critical question as to whether this explosion represents the success of the more commercially useful inventions or simply represents increased filing of patent applications on marginal inventions. To clarify the issue, this study provides a comparative analysis of the attributes of university patents between US and Japan. Since there are few studies investigating Japanese university patents

and there is no study that examines the attributes of Japanese university patents, this study is the first attempt to clarify the attributes of Japanese university patents by allowing a comparison to US university patents.

3.4 Measures of Attributes of Patents

The use of patent citations is widely employed to construct a variety of measurements to interpret the importance of the invention covered by a patent (Goto and Motohashi 2007: Hall et al. 2000; Henderson et al. 1998; Tantiyaswasdikul 2013a; Trajtenberg et al. 1997). Patent citations perform the legal function of delimiting the patent right by identifying previous patents whose technological scope is explicitly placed outside the bounds of the citing patent (Jaffe and Trajtenberg 1996). Citations can be used for many purposes, including tracing the process of technology development and evaluating the importance of a patent (Goto and Motohashi 2007; Tantiyaswasdikul 2013a). Moreover, citation data can provide significant evidence that clearly reveals the links between an innovation and its technological antecedents and descendants (Tantiyaswasdikul 2013a; Trajtenberg et al. 1997).

The number of patent citations has long been presumed to indicate the link between the patents themselves and both the technological and economic value of innovations (Jaffe et al. 1993). When the future technologies have been invented, at least some must cite earlier inventions in their patents. Thus the number and character of citations received can indicate the technological importance of an invention (Henderson et al. 1998; Trajtenberg 1990). The use of patent citations to construct various measures of patent attributes was presented by Trajtenberg et al. (1997) and Henderson et al. (1998). These scholars used patent citations to measure the *basicness*, *appropriability*, and *time distance* of the invention covered by a patent. This approach clarifies the significance of technological development according to its role in stimulating and facilitating subsequent inventions (Henderson et al. 1998).

The measures of basicness and appropriability rely exclusively on information contained in patents. First of all, the difference between basic scientific research and applied scientific research in the context of basicness and appropriability of innovation must be discussed. Based on the study of Nelson (1959), the areas of basic and applied scientific research are hard to separate and the spectrums of these two activities are

less clearly defined. However, the goal and direction of an applied research project seems to capture practical problem solving, while a basic research project is more associated with the new possibilities and changes. Basic research is likely to result in significant breakthroughs in scientific knowledge, while applied research has limitation in solving a specific practical problem (Nelson 1959).

According to Trajtenberg et al. (1997, 20), basicness refers to "fundamental features of innovations such as originality, closeness to science, breadth, etc. that impinge on incentives to engage in R&D and on choice of research projects." To indicate basicness, scholars used forward citations of patents to measure their *importance*. The *importance* is the first and probably the key aspect of the relationship between a patent and its descendants (Trajtenberg et al. 1997). This measure is designed to capture the technological impact of an invention as reflected in the number and importance of its descendants, and hence corresponds to the most intuitively appealing notion of basic innovations. In the words of Kuznets (1962, 26),

> some inventions, representing as they do a breakthrough in a major field, have a wide technical potential in the sense that they provide a base for numerous subsequent technical change…the first steam engine, which initiated a whole series of major technical changes and applications…is vastly different from the invention of the safety match or the pocket lighter. This wide range is for our purposes the major characteristic relevant to the problem of measurement.

The *importance*, denoted as *IMPORTF* captures citations of follow-up innovations to an originating patent on which they built. Thinking of citations to a patent as coming from follow-up advances that at least in part build upon or stem from the originating patent, in this sense, *IMPORTF* reflects both the number of subsequent citations and the importance of the core innovation, each of which are key characteristics of basic innovation.

Appropriability describes the attributes of inventions that allow their inventors to benefit (Trajtenberg et al. 1997). Based on general economic arguments, which argue that basic innovations usually derive from basic research, more basic

innovations should be more difficult to appropriate.[20] The indicator of forward self-citations was used to measure appropriability. Self-citation is the citation made by the same assignee. In the study of Caballero and Jaffe (1993), the measurement of rates of self-citation can indicate the degree of appropriation of potential spillovers from a given invention by the organization that owns it.[21] Thus forward citations with the same assignee as the original patent are denoted as *PSELFF*.

The time distance of an innovation has been presented to relate to its basicness and appropriability (Trajtenberg et al. 1997). Forward looking time distance, denoted as *TIMEF*, is defined as the average forward citation time lag. Arguably, more basic innovations will take more time to produce offspring, as they encounter more difficulties in R&D relative to their degree of basicness.

Using the validated measurement models proposed by Trajtenberg et al. (1997), I construct the following metrics of basicness, appropriability, and time distance to analyze the attributes of Japanese national university patents. The first measure is *IMPORTF*. This measure is designed to capture the technology impact of an invention as reflected in the number and importance of its descendants (Trajtenberg et al. 1997). I use the citation-based measure *IMPORTF* and define it as

$$IMPORTF_i = NCITING_i + \lambda \sum_{j=1}^{nciting_i} NCITING_{i+1,j}$$

where *NCITING* is the number of patents citing the core patent (number of forward citations). Thus *IMPORTF* is the aggregate number of citing patents, including second-generation citations. Index i corresponds to the patent under consideration and $i+1$ corresponds to citing patents. Here $0 < \lambda < 1$ is an arbitrary discount factor meant to down-weight the second generation descendants of a patent relative to the first generation citing patents. According to Trajtenberg et al. (1997), discounting is introduced to alleviate the thorny problem of attribution: suppose that patent X is cited just by patent Y, but patent Y is cited by many patents. Without

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[20] Arrow (1962) and Nelson (1959) provide a detailed and critical explanation of the problem of appropriability for firms undertaking basic research.
[21] Caballero and Jaffe (1993) provides evidence that shows the relationship between self-citations and market value.

discounting, *IMPORTF* for patent X will be larger than for patent Y, but intuition says that patent Y is the one that had the largest direct impact. Like Trajtenberg et al. (1997), I set λ to 0.5.[22]

IMPORTF presumably captures important determinants of the social returns to innovations: those with many descendants, or with descendants that span a wide range of technical fields, are likely to have high social returns. For example, Trajtenberg (1990) found that the social value of innovations in computed tomography scanners is highly correlated with a citations-weighted count of patents in that field. On the other hand, high marks of *IMPORTF* do not necessarily imply high private returns, the key intervening variable being, of course, appropriability. Thus, innovations with high *IMPORTF* may yield low returns if other firms do the follow-up innovations.[23]

The second citation-based measure is *PSELFF*. *PSELFF* measure relates to the ownership structure of the innovation's descendants since *PSELFF* is defined simply as the ratio of citing patents issued to the same assignee as that of the originating patent. The rationale for this measure is that these subsequent patents are likely to reflect follow-up developments of the original invention, and that these developments are the conduit that leads to the appropriation of returns. Thus, the higher the proportion of these later developments that take place in-house the larger would be the fraction of the benefits captured by the original inventor (Trajtenberg et al. 1997). When forward self-citations can indicate the degree of appropriation of potential spillovers from an innovation associated with the core patent, I use the number of forward self-citations to determine *PSELFF*, which I define as

$$PSELFF_i = \frac{NCITING_{z,i}}{NCITING_i}$$

where *NCITING* is the number of patents citing the core patent (number of forward citations). Index *i* corresponds to the patent under consideration and *z* corresponds to self-citation patents.

The last citation-based measure is *TIMEF*. This measure is designed to capture the distance in time between the innovation and its offspring. The presumption is that

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[22] For more detailed explanation of the value of λ, see Trajtenberg et al. (1997).
[23] For more detailed explanation of innovations and social returns, see Nelson (1959).

remoteness in time may be related to the aspect of basicness and to the conditions of appropriability (Trajtenberg et al. 1997). If the technical difficulties encountered in the R&D process were commensurate with the degree of basicness, in that case more basic innovations would take longer to generate offspring. I define *TIMEF* as

$$TIMEF_i = \sum_{j=1}^{nciting_i} \frac{LAG_j}{NCITING_i}$$

where *LAG* is the number of years between the application date of a citing patent and that of the core patent. Thus *TIMEF* is the average forward lag of citing patents.

3.5 Technology Classification

Technology classification allows patent documents to be easily retrieved and identified. This use of classifications helps to expedite prior art searches, and helps avoid possible ambiguity that may be present in other keyword search fields (Harris et al. 2010). Patent classifications can be classified into two major categories: an application-oriented system that represents a particular industrial sector of an invention and a function-oriented approach, which focuses on the type of an invention that can be classified into cross industry (Adams 2001; Tantiyaswasdikul 2012a). The International Patent Classification (IPC) uses an application-oriented approach, which has been influenced by the German classification and the US/British function-oriented approach, contrary to the US national classification that uses principally a function-oriented classification (Adams 2001; Tantiyaswasdikul 2012a).

Each of these major classification systems was developed with a different underlying philosophy, and this philosophical difference is reflected in the classification system design (Harris et al. 2010). The World Intellectual Property Office (WIPO) established the IPC by dividing technology into eight sections, which claims approximately 70,000 separate classifications down to the subgroup level.[24] IPC is the most widely used patent classification system. The United States Patent

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[24] Based on data obtained from WIPO website;
http://www.wipo.int/classifications/ipc/en/general/preface.html
(Accessed 24 February 2014).

Classification (USPC) system was established by the USPTO, and classifies patents into at least one of approximately 470 classes and 163,000 subclasses.[25] The USPTO uses the USPC primarily, but US-issued patents reference the IPC system as well (Harris et al. 2010).

To depict the technology field of each patent, this study uses the IPC classification as the representative of the technology area of an invention, since the IPC scheme reflects the economic importance of new inventions, as opposed to the technical focus of the US scheme (Lerner 1994). Additionally, IPC classifications tend to be based largely on constituent materials or components, or underlying scientific processes, rather than on industrial use (Kneller 2007a).

The 1971 Strasbourg Agreement established the IPC under WIPO, which divides technology into eight discrete sections. The primary objective of this Agreement was to overcome the difficulties caused by using diverse national patent classification systems (Harris et al. 2010). A patent is assigned to one or more of the 71,000 IPC codes that indicate the related technical field or fields the patent covers. These codes are arranged in a hierarchical, tree-like structure with five distinct components.[26] According to Harris et al. (2010), for example, US Patent 7,667,005 is assigned one IPC code – C07K 16/28. This is illustrated in Figures 3.5 and 3.6.
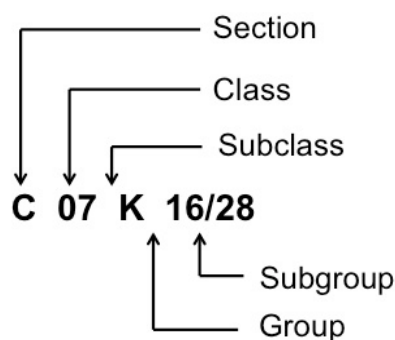
Source: Author, 2014

Figure 3.5: An example illustrating the components of an IPC classification

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[25] Based on data obtained from USPTO website;
http://www.uspto.gov/patents/resources/classification/index.jsp
(Accessed 24 February 2014).
[26] Based on data obtained from WIPO website;
http://www.wipo.int/classifications/ipc/en/general/preface.html
(Accessed 24 February 2014).

C   Chemistry and Metallurgy

C 07   Organic chemistry

C 07K   Peptides

C 07K 16/28   Against receptors, cell surface antigens

               or cell surface determinants

Source: Author, 2014

Figure 3.6: A hierarchical representation of the IPC classification provided for C07K 16/28

The highest hierarchical level contains the eight sections of the IPC corresponding to very broad technical fields, labeled A through H. Classes are further subdivided into more than 600 subclasses (Harris et al. 2010). Based on the database of the WIPO, the technology classification of IPC is classified in Table 3.1, which is composed of eight sections with approximately 70,000 subdivisions, including section A: Human necessity; section B: Performing operations, Transporting; section C: Chemistry, Metallurgy; section D: Textiles, Paper; section E: Fixed constructions; section F: Mechanical engineering, Lighting, Heating, Weapons, Blasting; section G: Physics, and section H: Electricity.

Table 3.1: Technological classifications of IPC

Title	Corresponding IPC
Section A: Human necessities	
Agriculture	A 01
Food stuffs; Tobacco	A 21-A 24
Personal or domestic articles	A 41-A 47
Health; Life-saving; Amusement	A 61-A 63
Subject matter not otherwise provided for in this section	A 99
Section B: Performing operation; Transporting	
Separating; Mixing	B 01-B 09
Shaping	B 21-B 32
Printing	B 41-B 44
Transporting	B 60-B 68
Micro-structural technology; Nano-technology	B 81-B 82
Subject matter not otherwise provided for in this section	B 99
Section C: Chemistry; Metallurgy	
Chemistry	C 01-C 14
Metallurgy	C 21-C 30
Subject matter not otherwise provided for in this section	C 99
Section D: Textiles; Paper	
Textile or flexible materials not otherwise provide for	D 01-D 07
Paper	D 21
Subject matter not otherwise provided for in this section	D 99
Section E: Fixed constructions	
Building	E 01-E 06
Earth or rock drilling; Mining	E 21
Subject matter not otherwise provided for in this section	E 99
Section F: Mechanical engineering; Lighting; Heating; Weapons; Blasting	
Engines or pumps	F 01-F 04
Engineering in general	F 15-F 17
Lighting; Heating	F 21-F 28
Weapons; Blasting	F 41-F 42
Subject matter not otherwise provided for in this section	F 99
Section G: Physics	
Instruments	G 01-G 12
Nucleonics	G 21
Subject matter not otherwise provided for in this section	G 99
Section H: Electricity	
Basic electric elements	H 01
Generation, conversion, or distribution of electric power	H 02
Basic electric circuitry	H 03
Electronic communication technique	H 04
Electronic technique not otherwise provided for	H 05
Subject matter not otherwise provided for in this section	H 99

Source: Based on data obtained from the online records system of WIPO website: World Intellectual Property Organization (WIPO). International Patent Classification (IPC) Official Publication. http://web2.wipo.int/ipcpub/#refresh=page. (Accessed 24 February 2014).

In practice, there are few inventions that can be classified into one particular technology; most of the innovations include hybrid elements (Adams 2001; Tantiyaswasdikul 2012a, 2012b). To extend this approach, for example, although the air cleaner and water purifier containing the honeycomb structure appears under IPC Section B (Performing operations; Transporting), and has a sub-class B01D and B01J for evaporating and chemical or physical process, the related technology that this invention uses is classified as IPC Section F (Mechanical engineering; Lighting; Heating; Weapons; Blasting), with a sub-class F01N for gas-flow silencers or exhaust apparatus.

The technology classifications based on the IPC codes of US and Japanese university patents are presented in Figures 3.7 and 3.8. The majority of US university patents are associated with IPC class C, IPC class A, and IPC class G, respectively. On the other hand, Japanese university patents are associated with the technological fields of IPC class C, IPC class H, and IPC class G, respectively.
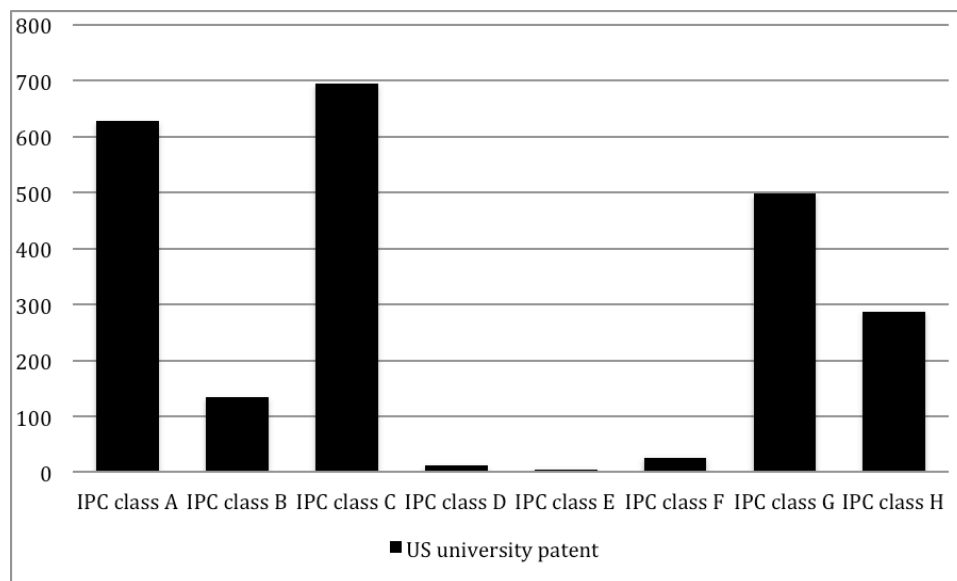
Source: Based on data obtained from the online records system of USPTO website;
http://www.uspto.gov/patents/process/search/
(Updated November 2013).

Figure 3.7: IPC classifications of US university patents
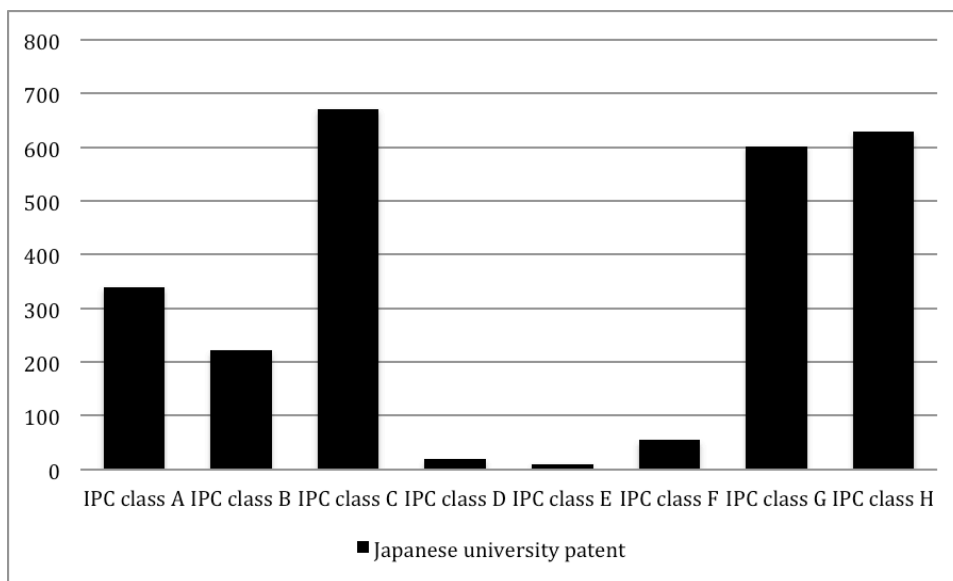
Figure 3.8: IPC classifications of Japanese university patents

3.6 Data Collection and Data Set

This study focuses on a comparison of attributes of university patents between US and Japan, using panel data from the USPTO. The Japan UIC policy initiatives that have been implemented since 1998 and the number of Japanese university patents owned by universities is limited by institutional and regulatory disincentives; the data in this analysis covers the period after the enactment of UIC policies from 1998 to 2008. For Japan, the data set consists of all Japanese national university granted *US Utility Patents* that were applied from 1998 to 2008.[27] For the US, the data set composes of a 5% random sample of the US university patents granted at USPTO between 1998 and 2008.[28]

This study analyzes and compares US and Japanese university patents in basicness, appropriability, and time distance. Table 3.2 presents the descriptive statistics of these variables. The count numbers of US university patents is 1,755 and

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[27] All data were obtained from the online records system of USPTO website;
http://www.uspto.gov/patents/process/search/
(Update 20 November 2013).
[28] All data were obtained from the online records system of USPTO website;
http://www.uspto.gov/patents/process/search/
(Update 20 November 2013).

the count numbers of Japanese university patents is 1,779, respectively. However, only patents with forward citations are used to measure *PSELFF* and *TIMEF*. Thus, 730 of 1,755 US university patents and 540 of 1,779 Japanese university patents are included in the analysis of the attributes of *PSELFF* and *TIMEF*.

Table 3.2: Descriptive statistics of basicness, appropriability, and time distance of Japanese and US university patents between 1998 and 2008

	Count number	Mean	Std. Dev.	Maximum	Minimum
IMPORTF					
US university patents	1755	3.53	10.97	151	0
Japanese university patents	1779	2.08	12.01	339	0
PSELFF					
US university patents	730	0.18	0.34	1	0
Japanese university patents	540	0.17	0.34	1	0
TIMEF					
US university patents	730	5.18	2.65	14	0
Japanese university patents	540	3.69	2.52	11	0

IMPORTF is extremely skewed for both countries of patents, in particular in Japanese university patents as presented in Figure 3.9 and 3.10. For US university patents, the maximum value of *IMPORTF* is 151, the minimum is 0, and the mean is 3.53, with a standard deviation of 10.97. For Japanese university patents, the maximum is 339, the minimum is 0, and the mean is 2.08, with a standard deviation of 12.01. If *IMPORTF* accurately reflects the technological *value* of patents, then most patents have little value and only a few have a large impact.

PSELFF and *TIMEF* are comparatively normally distributed for US and Japanese university patents. For *PSELFF*, the statistics between US and Japan are not much different; the mean of US university patents is 0.18 and the mean of Japanese university patents is 0.17, with similar standard deviations of 0.34. For *TIMEF*, the maximum value of US university patents is 14, the minimum is 0, and the mean is 5.18, with a standard deviation of 2.65. For Japanese university patents, the maximum is 11, the minimum is 0, and the mean is 3.69, with a standard deviation of 2.52.
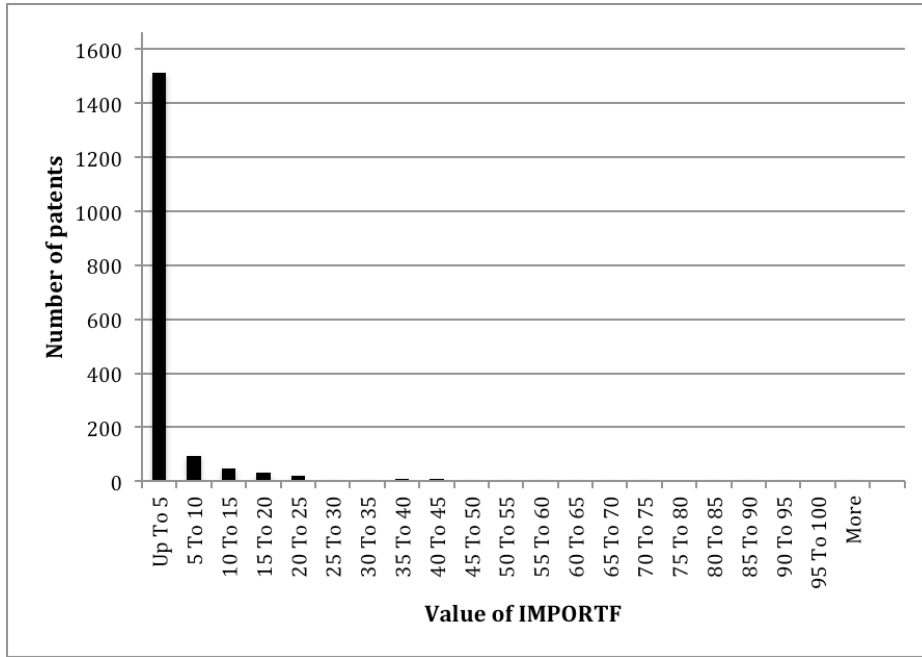
Source: Calculation of *IMPORTF* based on data obtained from the online records system of USPTO website; http://www.uspto.gov/patents/process/search/ (Updated November 2013).

Figure 3.9: Frequency distribution of *IMPORTF* of US university patents between 1998 and 2008
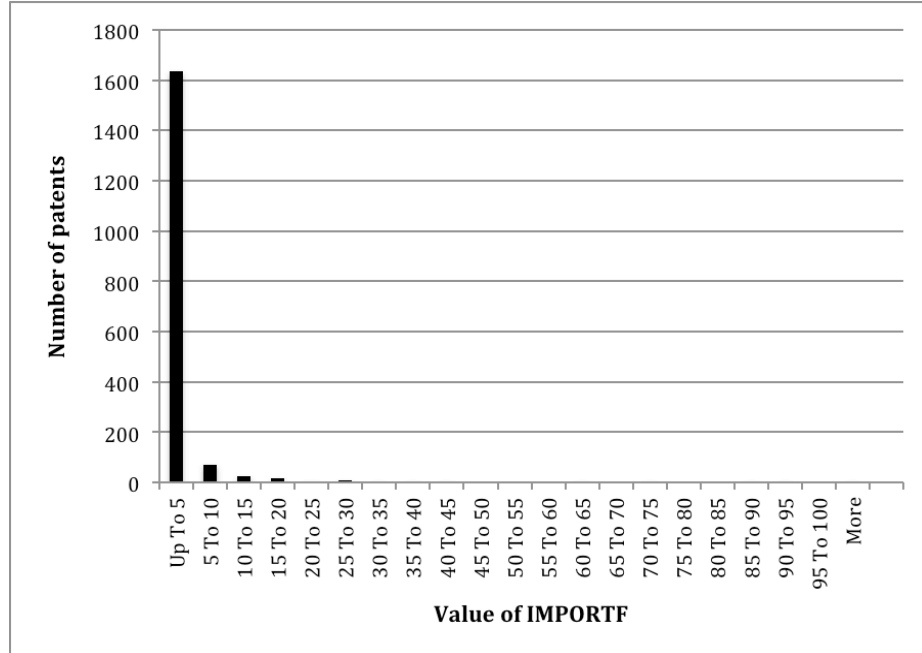
Source: Calculation of *IMPORTF* based on data obtained from the online records system of USPTO website; http://www.uspto.gov/patents/process/search/ (Updated November 2013).

Figure 3.10: Frequency distribution of *IMPORTF* of Japanese university patents between 1998 and 2008

3.7 Empirical Analysis and Findings

Table 3.3 compares mean ratings between US and Japanese university patents across three measures. In order to avoid relatively large standard deviations as presented in Table 3.2, all the figures are converted to the logarithmic form. Since the data contain zero values and taking the log of zero is undefined, each number is added by 1 before taking the log. Considering the result of the two-sample t-test, the evidence shows statistically significant differences in the measure of *IMPORTF* and *TIMEF*. US university patents have higher values of *IMPORTF* and *TIMEF* in terms of basicness than Japanese university patents, while there is no significant difference in the measure of *PSELFF*.

Table 3.3: Comparison of mean ratings: Japanese and US university patents between 1998 and 2008 (Two-sample t-test)

	US university patents			Japanese university patents			Mean difference	t ratio	df	p
	Obs	Mean	Std. Dev.	Obs	Mean	Std. Dev.				
IMPORTF	1,755	0.29	0.44	1,779	0.19	0.35	0.10***	7.4198	3337.4	0.0000
PSELFF	730	0.06	0.10	540	0.05	0.10	0.01	0.9395	1168.00	0.3477
TIMEF	730	0.74	0.24	540	0.61	0.24	0.13***	8.9655	1167.78	0.0000

Note: *** represent statistical significance at the 1% level.

The underlying presumption regarding basicness and appropriability is that universities perform more basic research than corporations (Trajtenberg et al. 1997), and thus that research results from universities will have more basicness in terms of higher degrees of both *IMPORTF* and *TIMEF*. However, more basic innovations are more difficult to appropriate. Therefore, inventors are better able to benefit from industry research outcomes than university research outcomes, meaning corporate patents have higher *PSELFF*. Regarding patents resulting from the UIC, the UIC patents tend to have lower degrees of basicness compared to university assignee patents. Additionally, since UIC patents intend to promote the transfer of university technology to industry for commercialization, UIC patents are expected to exhibit higher *PSELFF* than university assignee patents.

The results from Table 3.3 reveal that US university patents are associated with more basic research, as represented in the higher degree of *IMPORTF* and *TIMEF* than Japanese university patents with significant differences. The explanation for these outcomes is that Japanese university patents are composed of both university assignee and UIC patents and the number of UIC patents account for almost 50% of the total number of Japanese university patents. The large number of UIC patents in Japan derives from the joint research projects between universities and industry resulting from UIC policies. On the other hand, the majority of the US university patents is university assignee patents, which the UIC patents account for only 2.5%. However, the results show no significant difference with the indicator of *PSELFF*.

The lower degree of *TIMEF* of Japanese university patents compared to US university patents also can be explained regarding the technology classification of patents. Japanese university patents take less time to produce offspring compared to US university patents because majority of Japanese university patents are associated with the technological fields of chemistry (IPC class C), electricity or electronics (IPC class H), and physics (IPC class G), respectively. On the other hand, the majority of US university patents are associated with chemistry (IPC class C), human necessities including drugs and medical (IPC class A), and physics (IPC class G), respectively. A critical explanation is that patents in electronics (IPC Class H) are much more highly cited during the first few years after granting, while patents in drugs and medical (IPC class A) start with the low rate of citation frequency and grow over time at a slow pace (Jaffe and Trajtenberg 1996).

In Jaffe and Trajtenberg's (1996) *Flows of knowledge from universities and federal laboratories: Modeling the flow of patent citations over time and across institutional and geographic boundaries*, the researchers revealed that patents in electronics (IPC class H) get on average twice as many citations as those in all other fields. However, the large initial citation advantage of this field fades rather quickly. Patents in electronics are much more highly cited during the first few years after granting; however, due to their faster obsolescence, in later years they are actually less cited than those in all other fields.[29]

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[29] For a detailed explanation of knowledge diffusion across technological fields, see Jaffe and Trajtenberg (1996).

On the other hand, patents in drugs and medical (IPC class A) start with a low rate of citation frequency, but due to the low obsolescence rate this actually grows over time (at a slow pace). The conjecture here is that due to the long lead times in pharmaceutical research, follow-up developments are slow in coming. Thus, whereas in electronics a given innovation has very little impact 10-20 years later because the field is evolving so fast, in pharmaceuticals a new drug may still prompt follow-up innovations much later, after its medical and commercial viability have been well established (Jaffe and Trajtenberg 1996).

3.8 Conclusion

This paper investigates and compares the attributes between US and Japanese university patents. The US has given universities stronger patent rights on their inventions than has Japan since 1980, with the enactment of the Bayh-Dole Act. Japan has emulated the Bayh-Dole Act since 1999 with the implementation of various UIC policies to encourage university-industry technology transfer. Since UIC policies in Japan encourage the collaboration of R&D activities between universities and firms, the results of collaboration in patenting include both the university assignee patents and university co-assignee (UIC patents).

Comparing the institutional type of the assignee of patents, UIC patents in Japan account for almost 50% of the total number of Japanese university patents, while US university patents have co-assignee patents between university and firm of only 2.5% of the total number of US university patents. In terms of technology classification, the majority of US university patents are associated with the technological fields of chemistry, human necessities, and physics while the majority of Japanese university patents are associated with the technological fields of chemistry, electronics, and physics, respectively.

Both of the differences in type of assignee and technological field between US and Japanese university patents affect the attributes of these patents. Japanese university patents are associated with a lower degree of basicness than US university patents, as reflected in the measure of *IMPORTF* and *TIMEF*, since Japan has a much greater ratio of UIC patents to the total number of university patents. Additionally, the lower degree of *TIMEF* of Japanese university patents compared to US university

patents also can be explained by the difference in technological fields. Japanese university patents are associated with a higher number of electronics (IPC class H) than US university patents, while US university patents are associated with a higher number of human necessities (IPC class A) than Japanese university patents. A critical explanation is that patents in electronics are much more highly cited during the first few years after being granted, while patents in drugs and medical start with the low rate of citation frequency and grow over time with a slow pace (Jaffe and Trajtenberg 1996).

Patenting in Japanese universities has grown continuously since the Japanese government began to encourage UICs, and Japan's UIC policies have yielded impressive results in terms of collaboration and technology transfer between universities and industries. However, there are a few studies investigating on Japanese university patents. Moreover, there is no study examining the attributes of Japanese university patents. Thus, this study is the first attempt to clarify the attributes of Japanese university patents by allowing a comparison to US university patents. However, the limitations of this analysis are apparent. In assessing the attributes of Japanese university patents, the time lag to accumulate the number of patents to analyze their attributes is short and not enough to provide concrete evidence. Nevertheless, I believe that the results of this analysis underscore the importance of complementing analyses of aggregate data on Japanese university patents.

CHAPTER 4

IMPACT OF UNIVERSITY-INDUSTRY COLLABORATION POLICIES ON JAPANESE UNIVERSITY PATENTS

4.1 Introduction

The Japanese government has recently considered and implemented various policies to revitalize and encourage university–industry collaborations (UICs). Specifically, since the late 1990s, Japan has implemented several policy measures to promote university–industry technology transfer and commercialization and so facilitate the practical application of research results obtained by public research institutions. Significant laws associated with UIC policies include the Law for Promoting University–Industry Technology Transfer (TLO Law) enacted in 1998; the Law on Special Measures for Industrial Revitalization and Innovation (the Japanese Bayh-Dole Act) enacted in 1999; the 2000 Law to Strengthen Industrial Technology; and the National University Incorporation Law enacted in 2004.

The implementation of UIC policies in Japan has been followed by a large increase in the number of patent applications by universities. According to an investigation by MEXT on Japanese national university patents, the number of university patent applications lodged with the JPO rose sharply from 979 in 2003, to 2,935 in 2004, then leapt to 4,436 in 2005, and reached 7,448 in 2007 (MEXT 2009). Additionally, based on data from the USPTO, the number of patents granted to Japanese national universities steadily increased from 31 in 1998, to 92 in 2004, then leapt to 250 in 2005 and reached 410 in 2007, respectively.[30] The evidence thus indicates that the UIC policies were quite successful.

However, the extent to which this achievement should be taken as an evidence of an increase in the contribution of universities to commercialization depends not just on patent numbers but on the degree to which patents represent commercially useful inventions or had spillover effects on industry. Regarding the importance of this issue, this study aims to explore and examine the changes in the nature of university

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[30] Based on data obtained from the online records system of USPTO website; http://www.uspto.gov/patents/process/search/ (Update 20 November 2013).

patenting resulting from the implementation of UIC policies in Japan. By considering the attributes of university patents, this study compares university assignee and UIC patents in terms of innovation basicness, appropriability, and time distance that can reflect the characteristic of spillover effects of university patents.

This study discusses the impact of UIC policies and the attributes of Japanese university patents. The objective is to systematically construct, quantify, and characterize the unique attributes of Japanese university patents under different types of assignees through quantitative analyses of university patents before and after UIC policy implementation. The remainder of this chapter is organized as follows: Section 4.2 summarizes UIC policies in Japan and Section 4.3 then reviews the literature on university patenting. Section 4.4 discusses measures of patent attributes. Section 4.5 presents the data collection and data set, while Section 4.6 presents the empirical analysis and findings. The last section gives a conclusion.

4.2 University-Industry Collaboration Policies in Japan

UICs have been recently become a policy focus in Japan, with the objective being to facilitate such interactions (Takahashi and Carraz 2009). However, relationships between universities and industry have a long history in Japan, dating back to the pre-war period (Motohashi and Muramatsu 2012; Tantiyaswasdikul 2012a, 2013b). During the pre-war period, university professors were active in business startups and technology transfers (Etzkowitz et al. 2000; Motohashi and Muramatsu 2012; Tantiyaswasdikul 2012a, 2013b). During the 1920s and 1930s strong and effective linkages existed between large firms and universities, particularly in Engineering, focused on industrially oriented research and development (Sakakibara 2007). In the 1940s, during the Second World War, university and industrial research was geared toward military purposes (Motohashi and Muramatsu 2012; Tantiyaswasdikul 2012a, 2013b).

UIC activity in Japan declined in the post-war period. However, such collaborations were encouraged again in 1957 when the Ministry of Education decided to promote scientific and technological education at universities. Budgets for university scientific and engineering departments were greatly increased to overcome material and institutional insufficiencies, and the Ministry also recognized the

necessity of UICs (Sakakibara 2007). In 1961 the Act on Research and Development Partnerships focused on Mining and Manufacturing Technology was enacted as a pioneering policy to support collaborative research among universities, industry, and the government (Motohashi and Muramatsu 2011; Tantiyaswasdikul 2012a, 2013b). In 1967, the system to accept engineers from industries as visitors in graduate programs and laboratories began and industrial leaders acknowledged the urgent need for closer cooperation with universities (Sakakibara 2007).

However, the shift toward closer ties between universities and industry was blocked in the late 1960s by student protests against UICs[31] (Motohashi and Muramatsu 2012; Sakakibara 2007; Tantiyaswasdikul 2012a, 2013b). In response, formal ties between academia and industry were ended, and university–industry relations shifted to an informal mode, where activity was focused at the level of individual faculties (see Etzkowitz et al. 2000; Motohashi and Muramatsu 2012; Pechter and Kakinuma 1999; Tantiyaswasdikul 2012a, 2013b).

The first major post-World War II initiative to promote university–industry interaction occurred in 1983. This program promoted joint research between universities and industries (Motohashi and Muramatsu 2012; Tantiyaswasdikul 2012a, 2013b). Professors were the focus, and companies provided them with researchers and funding to pursue specific research projects (Hane 1999; Sakakibara 2007). The joint research system thus became the starting point of the growth in official research collaborations during the 1980s.

The additional role of universities in economic contribution derives from the promotion of academia-industry cooperation. This collaboration attracted attention during the Japanese economic recession in the 1990s (Fujisue 1998; Tantiyaswasdikul 2013b). In order to solve the economic problem, critically considering the establishment of solid economic foundations is important and it is vital to effectively collaborate with universities and other institutions that have scientific knowledge in supporting these strategies (Motohashi 2005; Tantiyaswasdikul 2013b).

An important motivation behind this collaborative policy is to shift the system from the dominant roles of in-house R&D conducted at major firms toward one based

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[31] The student protests against the close relationship between universities and private firms related to the extension of the US–Japan Security Treaty in relation the Korean and Vietnam Wars and were motivated by concern that UICs could be geared to military purposes, a concern that still exists.

on a network of active interactions among various innovators (Motohashi 2005; Tantiyaswasdikul 2013b). Regarding this importance, the Japanese government has considered and implemented various policies, including a Program of Economic Structural Reform and the Science and Technology Basic Plan, in which UIC is given an important position (Fujisue 1998; Tantiyaswasdikul 2013b). These strategies have been implemented toward a network-based approach to UIC.

In the early 1990s, Japan introduced a UIC system that adopted US achievements in university–industry technology transfer to drive economic growth (Motohashi and Muramatsu 2012; Tantiyaswasdikul 2012a, 2013b). Regarding the importance of this system, the following laws were enacted between 1998 and 2004 to change the Japanese legal framework related to UIC, IP management, and university–industry technology transfer: (1) The 1998 Law for Promoting University–Industry Technology Transfer (TLO Law), (2) The 1999 Law on Special Measures for Industrial Revitalization and Innovation (The Japanese Bayh-Dole Law), (3) The 2000 Law to Strengthen Industrial Technology, (4) The 2004 National University Incorporation Law.

To encourage formal linkage of UIC and technology transfer, the Japanese government has promoted the establishment of TLOs (Fujisue 1998; Takahashi and Carraz 2009). Various policies have been implemented to support and encourage TLO activities, including subsidies and debt guarantees for TLOs; exemption from patent registration and maintenance fees; and the financing of collaboration between universities and SMEs via the Program to Support Cooperation with Small-Medium Sized Companies (Fujisue 1998).

Besides the TLO Law, the Japanese government also enacted the Law on Special Measures for Industrial Revitalization and Innovation, also called the Japanese Bayh-Dole Act. This law resembles the US Bayh-Dole Act, which allows universities to retain their rights in relation to inventions derived from public-funded research. This policy has changed the IPR system of Japanese universities and shifted ownership from individual inventors to universities. To encourage UIC activities, the 2000 Law to Strengthen Industrial Technology has also been implemented to establish procedures for university researchers to obtain permission to consult for, establish, and manage companies. The same law also accelerates the procedures involved in pursuing industrial-sponsored commissioned and joint research (Kneller 2007c).

In 2004, the Japanese government incorporated the national universities as *independent administrative entities*. This important change in Japan's research culture allowed national universities increased control over their affairs and an independent legal status (Takahashi and Carraz 2009). Before the enactment of the National University Incorporation Law, Japanese national universities were not only funded and controlled by MEXT, but legally were attached to MEXT. Additionally, any IPRs associated with an invention by a national university faculty member were in principle held by the inventor and were granted to the university only in exceptional circumstances. Such exceptions included inventions associated with applied research supported by special government research funds, or particular large-scale government research facilities installed for special research purposes (Shimoda 2005).

Recently, systemic reforms to strengthen the collaboration between universities and industries have advanced substantially. The policy initiative aiming to encourage university technology transfer to make contributions to the Japanese economy and society has a positive impact on the increased number of joint research projects and university patents. According to an investigation by the MEXT (2009) on Japanese national university patents, the number of university patent applications lodged with the JPO rose sharply from 979 in 2003 to 2,935 in 2004, then leapt to 4,436 in 2005, and reached 7,448 in 2007. Additionally, based on data from the USPTO, the number of patents granted to Japanese national universities steadily increased from 31 in 1998 to 92 in 2004, then leapt to 250 in 2005 and reached 410 in 2007.[32]

4.3 Academic Patenting

Recent work on academic patenting results from the Bayh-Dole Act of 1980. The Bayh-Dole Act, or the Patent and Trademark Law Amendments Act, is US legislation dealing with IP management arising from federal government-funded research. The act made it significantly easier for American research universities to maintain IPRs to inventions derived from federally funded research (Henderson et al. 1998; Tantiyaswasdikul 2012a, 2013b). This change appears to have strongly

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[32] Based on data obtained from the online records system of USPTO website;
http://www.uspto.gov/patents/process/search/
(Update 20 November 2013).

influenced the way in which university research is transferred to the industrial sector. The number of university patent applications and grants has increased, and their annual growth rate is more than twice that of commercial patents (Sakakibara 2007).

However, while the act increased the number of university patents, arguments have arisen regarding their quality. The first attempt to quantify key aspects of university patents is the study of Trajtenberg et al. (1997). The study provided a comparison analysis of basicness and appropriability of US university and corporate patents in 1975 and 1980. In this analysis, basicness refers to fundamental features of innovations and appropriability refers to the attributes of inventions that allow their inventors to benefit. The results indicated that based on the prior notion that universities perform more basic research than corporations, the measures of basicness in university patents are significantly higher than corporate patents. Additionally, the degree of appropriability in corporate patents is significantly higher than university patents, which indicates the higher ability of inventors to reap benefits from their own inventions.

By taking a similar approach to Trajtenberg et al. (1997), Henderson et al. (1998) characterized US university patenting from 1965 to 1988 and made comparison to a 1% random sample of patents registered during the same period. Henderson et al. (1998) explored this issue by investigating the changes in the importance and generality of patents. This study found a decrease in the relative importance and generality of university patents, together with a simultaneous increase in their number. This decline in patent quality reflects the rapid increase in patents obtained by universities, most of which lacked patent experience.

On the other hand, Sampat et al. (2003) re-examined the same sample as Henderson et al. (1998), but with the inclusion of citation data through 1999, and found no decline in patent importance. This indicates a truncation problem in the citation data, since university patents tend to have a longer citation lag than corporate patents. Additionally, Mowery and Ziedonis (2002) further analyzed the estimates of Henderson et al. regarding the number of patents and experiences of universities, and found that patent quality declined only for universities that had applied for patents before the enactment of the Bayh–Dole Act but held fewer than 10 patents, and for universities that applied for patents only after the enactment of the Bayh–Dole Act. Overall patent quality did not decline for universities that had applied for patents

before the Bayh–Dole Act and held 10 or more patents.

The Bayh-Dole Act is one of the most influential pieces of legislation in terms of stimulating the commercialization of university research (Rasmussen 2008; Tantiyaswasdikul 2013b). The significant growth in patenting and licensing by US universities has been widely credited to this legislation. Several arguments exist that the increase in these activities enhanced the social returns of publicly funded academic research (Mowery and Sampat 2005; Tantiyaswasdikul 2012a, 2013b). Although little empirical analysis has focused on assessing the impacts of the Bayh-Dole Act, positive assessments of the effects of the Act, together with other factors, have led governments in many OECD countries, including Japan, to consider similar policy initiatives (Mowery and Sampat 2005; Tantiyaswasdikul 2012a, 2013b).

Since the end of the 1990s, several OECD governments have adopted policies inspired by the Bayh-Dole Act. Geuna and Rossi (2011) recently identified a trend in Europe to shift the IP management model from inventor ownership to institutional ownership.[33] These changes have affected the growth of university patents among European countries, but Geuna and Nesta (2006) found the effects remain heterogeneous across countries and disciplines. Compared with the US and Canada, which have a systematic survey conduction made by the Association of University Technology Managers (AUTM), there are very little reliable data on patenting and licensing by public research organizations (PROs) for OECD countries.

The evolution of IP culture in Canadian universities resembles that in the US since the passage of the Bayh-Dole Act (Trosow et al. 2012). Over the last two decades, Canadian universities have moved toward the establishment of special IP-related offices to facilitate technological innovation and commercialization of university research (Trosow et al. 2012). Tantiyaswasdikul (2013a) analyzed and measured the outcomes of university technology transfer between different types of IP ownership policy using numbers of invention disclosures, licenses, spin-off companies, and patents as specific indicators. The evidence suggests that IPRs policy affects quantitative results of patent commercialization. Considering the similar ratings of new invention disclosures and patent value, Canadian universities with a policy of

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[33] Italy was the only country that went in the opposite direction by adopting an inventor ownership policy in 2001. Currently, Italy and Sweden are the only European nations to implement an inventor ownership model for IP management.

institutional IP ownership tend to produce more new licenses and patents, while those with a policy of inventor IP ownership generate more spin-off companies.

In Japan, study of university patenting is limited owing to the historical lack of such activity. Data from the JPO reveal just 137 university patent disclosures in 1995. In comparison, 5,100 university patent applications were lodged in the US during the same period, based on the data from the AUTM licensing Survey, 1991–95 (Arai 1999). In the past, several obstructions made it difficult for university professors to patent their work. For instance, publication was prioritized over patents. Other obstacles were the complex and time-consuming process of preparing for and successfully lodging a patent application and patent maintenance fees (Arai 1999).

Regarding the results of joint research projects between universities and industry, many university discoveries are transferred to the private sector informally and hence unaccounted for in the statistics (Kneller 1999c). Sometimes the transfer of IPRs occurs via a short document other than an official IPR transfer or contract agreement. These unofficial documents create a problem whereby some productive faculty members do not know how many of their discoveries have been patented by companies (Kneller 1999c). This difficulty meant numbers of university patents were most likely underestimated during the 1980s and 1990s. However, UIC has increased rapidly since the late 1990s (Okamuro and Nishimura 2013). This growth is reflected not only in the rising number of joint research projects but also that of UIC patents (Motohashi and Muramatsu 2012; Tantiyaswasdikul 2013b).

The study by Motohashi and Muramatsu (2012) is the first attempt to examine the effect of the enactment of UIC policies in Japan on university patents there. The study found that the UIC policies increased the number of UIC patents in the late 1990s while overall patent quality was maintained. Other studies have also found that the UIC policies increased the number of Japanese university patents (Tantiyaswasdikul 2012a, 2013b). Since 1998, Japanese universities have expanded their academic inventions owing to the continuous increase in the number of patent grants (Tantiyaswasdikul 2012a). Based on data from the USPTO, continuous growth in the number of patents granted for Japanese national universities occurred particularly after the National University Incorporation Law in 2004, rising from just 31 in 1998 to 92 in 2004, before leaping to 250 in 2005 and then reaching 410 in 2007. This evidence indicates that UIC policies have been successful.

Besides a dramatic increase in the number of Japanese university patents, there remains a critical question concerning the extent to which this explosion represents the success of the more commercially useful inventions or simply increased filing of patent applications. To clarify this issue, this study provides an investigation into the changes in the nature of university patenting resulting from the implementation of UIC policies in Japan. By taking a similar approach as Trajtenberg et al. (1997) to identify the attributes of Japanese university patents, this analysis is the first attempt to systematically construct, quantify, and characterize the unique attributes of Japanese university patents under different types of assignees.

4.4 Measures of Attributes of Patents

The number of patent citations has long been presumed to indicate the link between the patents themselves and both the technological and economic value of innovations (Jaffe et al. 1993). Based on the assumption that at least some of such future inventions will cite the original invention, when the future technologies have been invented, at least some must cite earlier inventions in their patents. Thus the number and character of citations received can indicate the technological importance of an invention (Henderson et al. 1998; Trajtenberg 1990). The use of patent citations to construct various measures of patent attributes was presented by Trajtenberg et al. (1997) and Henderson et al. (1998). These scholars used patent citations to measure the *basicness*, *appropriability*, and *time distance* of the invention covered by a patent. This approach clarifies the significance of technological development according to its role in stimulating and facilitating subsequent inventions (Henderson et al. 1998).

First of all, the differences between basic scientific research and applied scientific research in the context of basicness and appropriability of innovation must be discussed. Based on the study by Nelson (1959), the areas of basic and applied scientific research are hard to separate and the spectrums of these two activities are less clearly defined. However, the goal and direction of an applied research project seem to capture the practical problem solving, while a basic research project is more associated with the new possibilities and changes. Basic research is likely to result in significant breakthroughs in scientific knowledge, while applied research has limitations in solving a specific practical problem (Nelson 1959).

In the words of Trajtenberg et al. (1997, 20), basicness refers to "fundamental features of innovations such as originality, closeness to science, breadth, etc. that impinge on incentives to engage in R&D and on choice of research projects." To indicate basicness, scholars used forward citations of patents to measure their *importance*, denoted as *IMPORTF*. *IMPORTF* captures citations of follow-up innovations to an originating patent on which they built. In this sense, *IMPORTF* reflects both the number of subsequent citations and the importance of the core innovation, each of which are key characteristics of basic innovation.

Appropriability describes the attributes of inventions that allow their inventors to benefit (Trajtenberg et al. 1997). Based on general economic arguments, which argue that basic innovations usually derive from basic research, more basic innovations should be more difficult to appropriate.[34] The indicator of forward self-citations was used to measure appropriability. Self-citation is the citation made by the same assignee. In the study by Caballero and Jaffe (1993), the measurement of rates of self-citation can indicate the degree of appropriation of potential spillovers from a given invention by the organization that owns it.[35] Thus, forward citations with the same assignee as the original patent, denoted *PSELFF*, are used.

One of the interesting issues in this context is whose patents are cited, and in particular, to what extent they cite previous inventions patented by the same assignee (we refer to these as self-citations), rather than patents of other, unrelated assignees. This has important implications, inter alia, for the study of spillovers: presumably citations to patents that belong to the same assignee represent transfers of knowledge that are mostly internalized, whereas citations to patents of *others* are closer to the pure notion of (diffused) spillovers (Hall et al. 2001)

The time distance of an innovation has been presented to relate to its basicness and appropriability (Trajtenberg et al. 1997). Forward looking time distance, denoted as *TIMEF*, is defined as the average forward citation time lag. Arguably, more basic innovations will take more time to produce offspring as they encounter more difficulties in R&D relative to their degree of basicness.

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[34] Arrow (1962) and Nelson (1959) provide a detailed and critical explanation of the problem of appropriability for firms undertaking basic research.
[35] Caballero and Jaffe (1993) provide evidence that shows the relationship between self-citations and market value.

Using the validated measurement models proposed by Trajtenberg et al. (1997), I construct the following metrics of basicness, appropriability, and time distance to analyze the attributes of Japanese national university patents. The first measure is *IMPORTF*. This measure is designed to capture the technology impact of an invention as reflected in the number and importance of its descendants (Trajtenberg et al. 1997). I use the citation-based measure *IMPORTF* and define it as

$$IMPORTF_i = NCITING_i + \lambda \sum_{j=1}^{nciting_i} NCITING_{i+1,j}$$

where *NCITING* is the number of patents citing the core patent (number of forward citations). *IMPORTF* is the aggregate number of citing patents, including second-generation citations. Index *i* corresponds to the patent under consideration and *i+1* corresponds to citing patents. Here $0< \lambda < 1$ is an arbitrary discount factor meant to down-weight the second generation descendants of a patent relative to the first generation citing patents. Like Trajtenberg et al. (1997), I set λ to 0.5.

The second citation-based measure is *PSELFF*. This measure is designed to capture the appropriability of patents. When forward self-citations can indicate the degree of appropriation of potential spillovers from an innovation associated with the core patent, I use the number of forward self-citations to determine *PSELFF*, which I define as

$$PSELFF_i = \frac{NCITING_{z,i}}{NCITING_i}$$

where *NCITING* is the number of patents citing the core patent (number of forward citations). Index *i* corresponds to the patent under consideration and *z* corresponds to self-citation patents.

The last citation-based measure is *TIMEF*. This measure is designed to capture the distance in time between the innovation and its offspring. The presumption is that remoteness in time may be related to aspects of basicness and to the conditions of appropriability (Trajtenberg et al. 1997). More basic innovations would take longer to generate offspring. I define *TIMEF* as

$$TIMEF_i = \sum_{j=1}^{nciting_i} \frac{LAG_j}{NCITING_i}$$

where *LAG* is the number of years between the application date of a citing patent and that of the core patent. Thus *TIMEF* is the average forward lag of citing patents.

4.5 Data Collection and Data Set

This study focuses on the impact of UIC policies on patenting by Japanese universities using panel data from the USPTO. Therefore I first illustrate the trend in Japanese university-granted *US Utility Patents* that were applied from 1980 to 2008. Figure 4.1 shows the trend in patenting at Japanese national universities by the USPTO. During the 1980s and 1990s, the number of university patents was small owing to a lack of patenting activity by university professors. Additionally, informal collaboration with industry led to companies filing many patent applications that involved work done by universities. The number of university patents significantly increased after the implementation of UIC policies, from 15 in 1997 to 31 in 1998. Moreover, after the National University Incorporation Law of 2004, the number of patents granted to Japanese national universities rose dramatically, from 92 in 2004, to 250 in 2005, and reached 410 in 2007. To analyze the attributes of Japanese university patents, considering the number of patents after 1997 is critical since there was a significant change in the number of Japanese university patents after the UIC policies implementation.
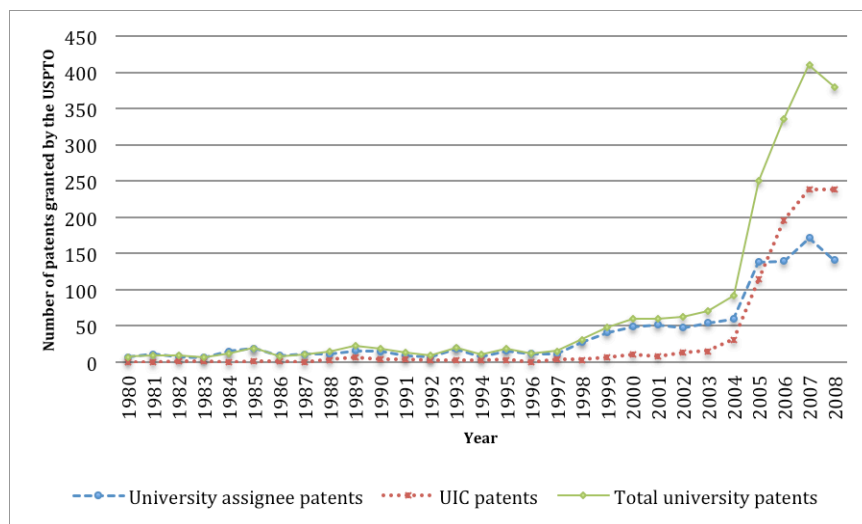
Source: Based on data obtained from the online records system of USPTO website;
http://www.uspto.gov/patents/process/search/
(Updated 20 November 2013).

Figure 4.1: Trends in Japanese national university patents

The data set consists of all Japanese national university-granted *US Utility Patents* that were applied from 1980 to 2008.[36] The patents were classified according to assignees and institution type. Specifically, the patents were divided into university assignee patents and university co-assignee patents. The latter group comprises UIC patents that result from joint research collaborations between universities and corporations. This study analyzes and compares university assignee and UIC patents in terms of basicness, appropriability, and time distance. Table 4.1 presents the descriptive statistics of these variables in the patent data set. The total number of patents is 2,012. However, only patents with forward citations are used to measure *PSELFF* and *TIMEF*. Thus, 744 of 2,012 patents are included in the analysis of the attributes of *PSELFF* and *TIMEF*.

Table 4.1: Descriptive statistics of basicness, appropriability, and time distance of Japanese university patents

	Count number	*Mean*	*Std. Dev.*	*Maximum*	*Minimum*
IMPORTF					
Japanese university patents	2,012	9.24	47.44	896	0
PSELFF					
Japanese university patents	744	0.13	0.30	1	0
TIMEF					
Japanese university patents	744	5.12	3.89	24.33	0

The distribution of *IMPORTF* is extremely skewed as presented in Figure 4.2, with the mean of 9.24 and a standard deviation of 47.44. However, this skewness is consistent with previous findings (Trajtenberg et al. 1997) that most patents turn out to be of very little significance in terms of the first and second generations of forward citations. The distribution of *PSELFF* is much more normally distributed, with the mean of 0.13 and a standard deviation of 0.30. *TIMEF* is normally distributed, with the mean of 5.12 and a standard deviation of 3.89. Both of the *PSELFF* and *TIMEF* are also consistent with previous findings (Trajtenberg et al. 1997).

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[36] All data were obtained from the online records system of USPTO website; http://www.uspto.gov/patents/process/search/ (Update 20 November 2013).
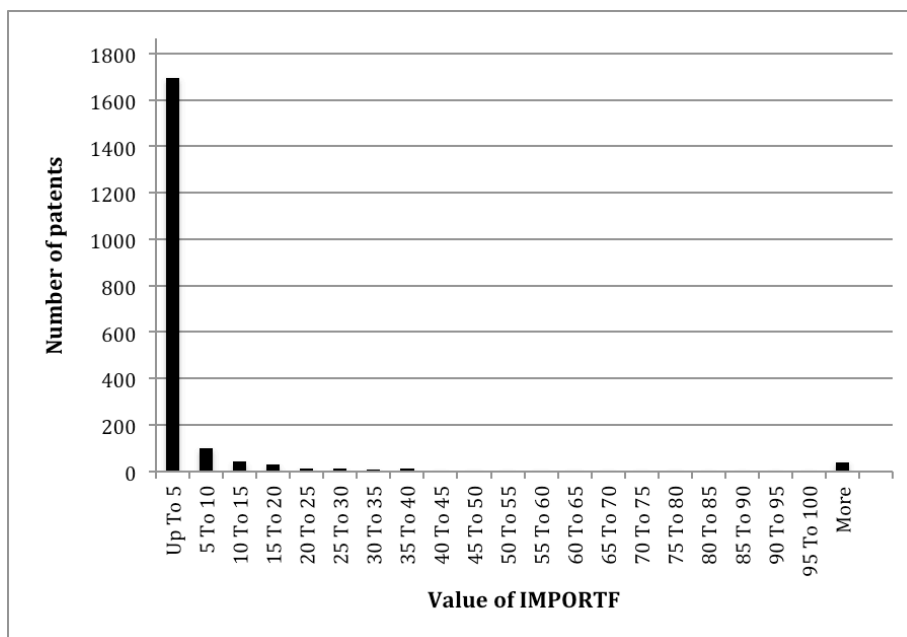
Source: Calculation of *IMPORTF* based on data obtained from the online records system of USPTO website; http://www.uspto.gov/patents/process/search/ (Updated November 2013).

Figure 4.2: Frequency distribution of *IMPORTF* of Japanese university patents between 1980 and 2008

4.6 Empirical Analysis and Findings

The underlying presumption regarding basicness and appropriability is that universities perform more basic research than corporations (Trajtenberg et al. 1997), and thus that research results from universities will have more basicness in terms of both *IMPORTF* and *TIMEF*. However, more basic innovations are more difficult to appropriate. Therefore inventors are better able to benefit from the industry research outcomes than university research outcomes, meaning corporate patents have higher *PSELFF*. Since UIC patents result from research collaboration between universities and corporations, intended to promote the transfer of university technology to industry for commercialization, UIC patents are expected to exhibit higher *PSELFF* than university assignee patents.

The entire sample totals 2,012 Japanese national university patents, of which 744 have forward citations. Classifying these numbers into university assignee and UIC patents reveals 1,120 university assignee patents, among which 458 have forward citations, and 892 UIC patents, among which 286 have forward citations. Table 4.2

presents the sample means of the proposed measures for university assignee and UIC patents, and the two-sample *t*-test is performed to assess the significance of the differences between them. In order to avoid relatively large standard deviations as presented in Table 4.1, all the figures are converted to the logarithmic form. Since the data contain zero values and taking the log of zero is undefined, each number is added by 1 before taking the log.

Table 4.2 Comparison of mean ratings: University assignee patents and UIC patents (two-sample *t*-test)

	University assignee patents			UIC patents			Mean difference	*t* ratio	*df*	*p*
	Obs	Mean	Std. Dev.	Obs	Mean	Std. Dev.				
IMPORTF	1,120	0.40	0.61	892	0.20	0.42	0.20***	8.3578	1964.74	0.0000
PSELFF	458	0.02	0.07	286	0.07	0.12	- 0.05***	-6.8414	408.084	0.0000
TIMEF	458	0.78	0.27	286	0.58	0.26	0.20***	9.9530	630.208	0.0000

Note: *** represent statistical significance at the 1% level.

The results for *IMPORTF* and *TIMEF* strongly support the notion that university assignee patents are associated with more basic innovation than UIC patents. University assignee patents receive significantly more first- and second-generation citations and take significantly longer in producing offspring. Specifically, UIC patents take less time to obtain than predecessor patents and more quickly yield offspring. This could be interpreted to indicate that UIC patents are more applied and less basic than university assignee patents. Regarding appropriability, the measure of *PSELFF* is clearly much larger for UIC than university assignee patents, suggesting it may indicate the extent to which inventors successfully reap the benefits of their own inventions.

However, the comparison of patent attributes between Japanese university assignee and UIC patents in Table 4.2 is not the main result and it was totally influenced by the increased number of patents resulting from the UIC policies that have been implemented since 1998. Regarding the significant change in the number of Japanese university patents after the UIC policies implementation, a detailed analysis of the attributes of patents is needed. The next analysis thus compares university assignee and UIC patents in terms of their basicness, appropriability, and time distance

before and after the implementation of UIC policies. Regarding the impact of UIC policies on the increase in the number of university patents, I classify this analysis into the periods before and after the enactment of UIC policies, including from 1980 to 1997 and 1998 to 2008. Table 4.3 shows descriptive statistics of the measures between the two periods.

Table 4.3: Descriptive statistics of basicness, appropriability, and time distance of Japanese university patents

	Count number	Mean	Std. Dev.	Maximum	Minimum
IMPORTF					
1980 - 1997	233	64.073	122.512	896	0
1998 - 2008	1,779	2.053	11.869	339	0
PSELFF					
1980 - 1997	201	0.041	0.158	1	0
1998 - 2008	543	0.165	0.334	1	0
TIMEF					
1980 - 1997	201	8.950	4.738	24.33	0
1998 - 2008	543	3.701	2.234	11	0

Both before and after the enactment of UIC policies the *IMPORTF* of university patents were skewed; especially after the policy was implemented the *IMPORTF* was extremely right skewed. On the other hand, before 1998 *PSELFF* of university patents were highly right skewed, while subsequently their distributions become much more normal. Meanwhile, the *TIMEF* is more normally distributed both before and after this period.

Table 4.4 compares mean ratings between university assignee and UIC patents across three measures in different time frames. In order to avoid relatively large standard deviations as presented in Table 4.3, all the figures are converted to the logarithmic form. Since the data contain zero values and taking the log of zero is undefined, each number is added by 1 before taking the log. Considering the result of the two-sample *t*-test for the significance of the differences between them, the evidence shows statistically significant differences in the measure of *IMPORTF* both before and after the enactment of UIC policies. Before the implementation UIC policies, UIC patents revealed higher degree of *IMPORTF* than university assignee patents, but after the implementation university assignee patents presented the higher value of *IMPORTF* than UIC patents.

Table 4.4: Comparison of mean ratings: University assignee patents and UIC patents (two-sample *t* test)

	University assignee patents			UIC patents			Mean difference	*t* ratio	*df*	*p*
	Obs	Mean	Std. Dev.	Obs	Mean	Std. Dev.				
1980 - 1997										
IMPORTF	205	1.20	0.75	28	1.64	0.75	- 0.44**	-2.9084	34.7955	0.0063
PSELFF	173	0.01	0.05	28	0.02	0.06	- 0.01	-0.9272	32.8168	0.3606
TIMEF	173	0.94	0.27	28	0.94	0.20	0.00	-0.1405	44.3192	0.8889
1998 - 2008										
IMPORTF	915	0.23	0.39	864	0.16	0.29	0.07***	4.4045	1685.44	0.0000
PSELFF	285	0.03	0.08	258	0.08	0.12	- 0.05***	-5.8976	431.499	0.0000
TIMEF	285	0.68	0.23	258	0.54	0.23	0.14***	7.0024	535.405	0.0000

Note: ***, ** represent statistical significance at the 1% and 5% levels, respectively.

Regarding the measures of appropriability and distance, after the UIC policies have been implemented, the measures of *PSELFF* and *TIMEF* reveal statistically significant differences. University assignee patents presented the higher value of basicness than UIC patents with the indicator of *TIMEF* and UIC patents reflected the higher degree of appropriability than university assignee patents with the indicator of *PSELFF*.

Regarding the notion that university assignee patents are associated with more basic innovation than UIC patents, the value of *IMPORTF* of university assignee patents should then be higher than UIC patents. However, before 1998 UIC patents presented a different result, with a greater significant value of *IMPORTF* than those of University assignee patents. There was a probability that UIC patents in that period obtained higher degrees of *IMPORTF* than University assignee patents since there was a small number of UIC patents between 1980 and 1997 but they had a large impact to *IMPORTF* value.

UIC patents in that period derived from joint research projects between universities and firms, which was the beginning of the growth in official research collaborations during the 1980s. There was a possibility that joint research projects in that period did not have a commercialization purpose, therefore the outcome of research was associated with more basic innovation rather than applied innovation. For the research results that the corporation expected to have a commercialization purpose,

the company might collaborate with university professors in an informal way since there were not any UIC policies to support the IPRs in that period. Thus it was more convenient for the corporation to manage the research results. The other indicators that can indicate the basicness of UIC patents in the period before the implementation of UIC policies are the measure of *PSELFF* and *TIMEF*. There are no statistically significant differences between university assignee and UIC patents in between these two measures.

In the period after 1998, university assignee patents had statistically significant higher values of *IMPORTF* than UIC patents. This result confirms the underlying presumption regarding basicness of university assignee patents. Regarding time distance, after the UIC policies were enacted, the distance measure is strong and conclusive since the time distance differs significantly between the two groups; that is, the follow-up innovations of university assignee patents appear to take longer than those of UIC patents. The time lag to produce offspring of university assignee patents was longer than for UIC patents, reflecting the characteristic of basicness.

Regarding appropriability, after the implementation of UIC policies, UIC patents have a higher *PSELFF* than university assignee patents, with statistical significance indicating a greater ability to reap benefits from inventions. There is a possibility that UICs are successful in transferring technology for commercialization due to the high degree of self-citations of UIC patents.

4.7 Conclusion

This study attempted to quantify the attributes of Japanese university patents that result from the implementation of the UIC policies. The various aspects of basicness, appropriability, and time distance of innovation of patents have been analyzed using patent citation data. This analysis used the entire sample of Japanese national university patents to systematically quantify and analyze their important attributes. I characterized and compared the important dimensions of innovations associated with different institutional settings. After constructing a set of validated measures, I found evidence of different attributes between university assignee and UIC patents.

Relying on previous studies that showed the results of university research to be more basic than those of UIC research, I found evidence that the measures of importance (*IMPORTF*) appear to capture aspects of the basicness of innovations underlying university assignee patents. The fraction of citations from patents awarded to the same inventor was found to be much higher for UIC patents than university assignee patents, supporting the notion that *PSELFF* accurately reflects appropriability. The measure of time distance (*TIMEF*) also clearly appears to be related to basicness, and temporal distance fits conjectures about the situation where university assignee patents appear to take longer to generate descendants than do UIC patents.

Comparing the situations before and after the implementation of UIC policies, before 1998 UIC patents had greater significant value of *IMPORTF* than university assignee patents. However, this is because of the small number of UIC patents in that period, but they had a large impact to *IMPORTF* value. After 1998, university assignee patents presented the higher values of *IMPORTF* than UIC patents. This result confirms the underlying presumption regarding basicness of university assignee patents. In addition, university assignee patents also reflect the characteristic of basicness with significantly longer times in producing offspring. However, after the implementation of UIC policies, UIC patents exhibit stronger appropriability than university assignee patents, suggesting that the associated inventors can better benefit from their inventions. Additionally, the results indicate that UIC policies significantly impact the increase in university patents, including both UIC and university assignee patents.

There are two possibilities to specify the growth in Japanese university patenting. Firstly, UIC policies provide incentives for Japanese universities to expand their performance in pursuing the development of patent inventions as well as their patent portfolios. Secondly, UIC policies reduce the obstacles that the inventors face in patenting their inventions and support them by encouraging universities to establish TLOs to assist patenting activities and to commercialize the inventions. However, Japan's UIC policies have only been implemented for a decade and a half, and effective patenting activity to support university–industry technology transfer remains a challenge for all those involved in innovation.

Since 1998, important reforms have been implemented to UIC in Japan. Significantly, Japanese universities have become autonomous corporations able to assert ownership over their inventions. Based on the above analysis, we can argue that Japan's new UIC policies have made it easier for research results at Japanese national universities to be patented. Patenting in Japanese universities has grown continuously since the Japanese government began to encourage UIC, and Japan's UIC policies have yielded impressive results in terms of collaboration and technology transfer between universities and industries.

CHAPTER 5

KNOWLEDGE DIFFUSION FROM JAPANESE UNIVERSITIES TO INDUSTRY USING PATENT CITATIONS

5.1 Introduction

In the knowledge-based economy, innovation and new technological development is becoming increasingly important. Research universities have adopted an economic mission and become knowledge entrepreneurs (Fisher and Atkinson-Grosjean 2002). The role of the university has diversified and encompassed a *third mission* of economic development beyond traditional instructional and research missions. Universities are increasingly viewed as proactive contributors to technological development and economic growth (Meyer 2006).

Reforms in national research systems aiming to increase technology transfer and the commercialization of the university research have become a significant policy. The Bayh-Dole Act of 1980 in the US is one of the most influential policy legislations to stimulate the commercialization of the research results produced within universities (Rasmussen 2008). The policy changes and increased expectations that universities should contribute to the commercialization of research have led to several initiatives at the university level. The universities have also reconsidered their policies to create incentives for the researchers to contribute to the commercialization of their research results (Lockett et al. 2003; Rasmussen 2008; Roberts and Malonet 1996).

The extent to which this knowledge within universities can be efficiently transferred to the industrial sectors is of increasing policy interest, especially in OECD countries including Japan. The Japanese government has considered and administered various policies including a Program of Economic Structural Reform and the Science and Technology Basic Plan, in which academia-industry collaboration is given an important position to revitalize the national innovation system (Fujisue 1998). These strategies have been implemented toward a network-based approach of UIC, and the Japanese Science and Technology Basic plan has strongly advocated the promotion and enhancement of active interactions among innovation actors, including government-university-industry cooperation (Motohashi 2005; Tantiyaswasdikul 2012a).

Acquisition of knowledge is critical for innovation creation and growth of geographic regions (Grossman and Helpman 1991; Singh 2005). Additionally, diffusion of knowledge has important implications for the modeling of technological change and economic growth (Jaffe and Trajtenberg 1996). Knowledge diffusion has received significant attention in the economics, management, and public policy literature, especially since the works of Romer (1990) and Grossman and Helpman (1991) discussed models of how endogenous economic growth with knowledge was treated as completely diffused within an economy.[37] To estimate knowledge flow and diffusion, patent citations have been utilized extensively to measure the diffusion of knowledge across a variety of dimensions: geographic space, time, technological fields, organizational boundaries, alliance partnerships, and social networks (see Alcácer and Gittelman 2006; Bacchiocchi and Montobbio 2009; Jaffe and Trajtenberg 1996; Nelson 2009; Peri 2005).

Patent analysis has long been considered a rich data source from a few standardized approaches for the study of innovation and technical change (Goto and Motohashi 2007; Hall et al. 2000, 2001; Tantiyaswasdikul 2013). University patents are increasingly considered a possible source of commercial technology. Recently, the analyses of university patents gained great interest and discussion from academics and policymakers, in particular in the issue of an increase in number of patents and a decline in their quality (Bacchiocchi and Montobbio 2009; Henderson et al. 1998; Jaffe and Trajtenberg 1996; Mowery et al. 2005; Sampat et al. 2003).

While this evidence remains in some respect controversial, the underlying policy issue is whether a policy initiative aimed at promoting patenting in universities is really creating incentives to generate and disclose important and general inventions to the public use (Bacchiocchi and Montobbio 2009). Sampat (2006) argues that there is little evidence that an increase in the role of the university in commercialization has facilitated increased technology transfer or any meaningful growth in the economic contributions of universities. Moreover the recognition that there is a large number of research contributions from universities that never result in patents and presumably have impacts that cannot be traced via the patent citation-based research is widely discussed (Jaffe and Trajtenberg 1996).

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[37] For a detailed explanation of models of endogenous economic growth, see Romer (1990) and Grossman and Helpman (1991).

As policymakers move steadily in the direction of stimulating patenting activity of universities, no evidence is yet available on the general characteristics of university patents or their relative value. This study focuses on a model to describe knowledge diffusion from universities to industries by the process of generating subsequent citations to patents. In this study, the institutional comparisons between two distinct sources of potentially cited patents, Japanese corporations and Japanese universities, in knowledge diffusion to industries have been analyzed. I examine separately the diffusion of knowledge between these two institutions and Japanese industry in between 1980 and 2008 using a panel data of the USTPO.

The main objective of this study is to analyze knowledge diffusion from universities to industry using patent citation. It finds that in the case of Japanese industry, Japanese corporate patents are cited more often compared to Japanese university patents. However, the gap between them has been continuously lessened since 1998, which correlated to the period of the first launch of the UIC policies in Japan. The remainder of this chapter is organized as follows: Section 5.2 describes technology transfer and knowledge diffusion from universities to industry in Japan. Section 5.3 outlines the model specification used to estimate the citation frequency of industry patents to corporate patents and university patents. The summary of data is presented in section 5.4. Section 5.5 presents empirical analysis and findings. The last section is the conclusion.

5.2 Technology Transfer and Knowledge Diffusion from Universities to Industry

During the past three decades, the issue of technology transfer has received high attention from various academic researchers and policymakers. The definitions of technology transfer are varied, according to the discipline and purpose of the research (Bozeman 2000). However, works on technology transfer mainly focus on technology as an entity, and not on any particular applied science (Bozeman 2000; Stock and Tatikonda 2000). Technology transfer is the process by which technological research results are transferred into useful processes, products, or programs. Technology transfer is a movement of know-how, technical knowledge, or technology from one organizational boundary of the source to another (Stock and Tatikonda 2000).

In the study of innovation and technical change, the term *technology transfer* refers to the process whereby an invention or an intellectual property from academic or public research is licensed through use rights to a for-profit entity and eventually commercialized (Freidman and Silberman 2003). The transfer of technology is the diffusion of research knowledge through three major forms of mechanisms including conferences and scientific publications, the training of a skilled labor force, and the commercialization of knowledge (Landry et al. 2006). Notable mechanisms of commercialization can be considered through consulting activities, research contracts with industry, patenting, and spin-off company formations (Landry et al. 2006).

Before the 1980s, the majority of research focused on a cross-national technology transfer, especially the transfer of technology from industrialized nations to less developed countries. In the early 1980s, the research agenda shifted to domestic technology transfer, particularly in works by US scholars (Bozeman 2000). The domestic technology transfer includes the transfer of technology among private sectors and from public to private sectors, the latter of which is becoming increasingly important. Expansion of federal laboratory roles and university roles in technology transfer and cooperative research, as well as other technology-based economic development programs has shifted the university's role to facilitating the third mission of economic contribution (Bozeman 2000).

The focus on technology transfer to commercialization, in particular in university research outcomes in patenting, emerged in the 1980s when there were major changes in federal law in the US, including the passage of the Bayh-Dole Act of 1980 (Tantiyaswasdikul 2012a). The Bayh-Dole Act or the Patent and Trademark Law Amendments act is the US legislation dealing with IP management arising from federal government-funded research. An assessment of the effects of this act shows that it made it significantly easier for American research universities to maintain the IPRs to inventions acquired from federally-funded research (Henderson et al. 1998; Tantiyaswasdikul 2012a). The change appears to have had a powerful effect on the way in which university research is transferred to the industrial sector, and TLOs have been established to support the many universities that are actively pursuing technology transfer activities (Henderson et al. 1998; Tantiyaswasdikul 2012a).

The significant growth in patenting and licensing by US universities has been widely cited as an effect of the Bayh-Dole Act initiative. There are several arguments

that the increase of these activities enhanced the social returns to publicly funded academic research (Mowery and Sampat 2005; Tantiyaswasdikul 2012a). Although there has been little empirical analysis directed at assessing its impacts, these assessments and other factors have led governments in many OECD countries including Japan to consider policy initiatives that emulate the Bayh-Dole Act (Mowery and Sampat 2005; Tantiyaswasdikul 2012a).

In Japan, university-industry technology transfer was informal and active at the level of individual faculties such as scholarship funding to professors and student employment sponsored by companies (see Motohashi and Muramatsu 2012; Pechter and Kakinuma 1999; Tantiyaswasdikul 2012b, 2013b). The first major post-World War II initiative to promote university industry interaction was in 1983. This program was implemented to facilitate the joint research between universities and industries (Motohashi and Muramatsu 2012; Tantiyaswasdikul 2012b, 2013b).

In this program, professors were the central entity, and companies provided these professors with researchers and funding to pursue specific research projects (Hane 1999; Sakakibara 2007). The system of joint research marked the starting point of official joint research activities and, until the beginning of the 1990s, Japan introduced a UIC system modeled on the basis of the United States' achievement in university industry technology transfer in driving economic growth (Motohashi and Muramatsu 2012; Tantiyaswasdikul 2012b, 2013b).

Due to its importance, the *Science and Technology Basic Law* was enacted in 1995, followed by many UIC policies in the first Science and Technology Basic plan (FY 1996-2000) that encouraged the promotion of technology transfer from universities to industries, the Second Science and Technology Basic plan (FY 2001-2005) that reinforced UIC and IP management, and the Third Science and Technology Basic plan (FY 2006-2010) that reorganized the major tools for innovation.

Japan adopted a similar policy in the late 1990s to encourage university participation in technology transfer. The following laws enacted between 1998 and 2004 have changed the Japanese legal technology transfer framework:[38] (1) The 1998 Law to Promote the Transfer of University Technologies (TLO Law), (2) The 1999 Law of Special Measures to Revive Industry (The Japanese Bayh-Dole Law), (3) The

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[38] For more detailed explanation of UIC policies in Japan, see Tantiyaswasdikul (2013b).

2000 Law to Strengthen Industrial Technology, (4) The 2004 University Incorporation Law.

Recently, systemic reforms to strengthen the collaboration between universities and industries have advanced substantially. The policy initiative aiming to encourage university technology transfer to make contributions to the Japanese economy and society has a positive impact on the increased number of joint research projects and university patents. According to an investigation by the MEXT (2009) on Japanese national university patents, the number of university patent applications lodged with the JPO rose sharply from 979 in 2003 to 2,935 in 2004, then leapt to 4,436 in 2005 and reached 7,448 in 2007. Additionally, based on data from the USPTO, the number of patents granted to Japanese national universities steadily increased from 31 in 1998 to 92 in 2004, then leapt to 250 in 2005 and reached 410 in 2007, respectively as presented in Figure 5.1.[39] The evidence thus indicates that the UIC policies were quite successful.
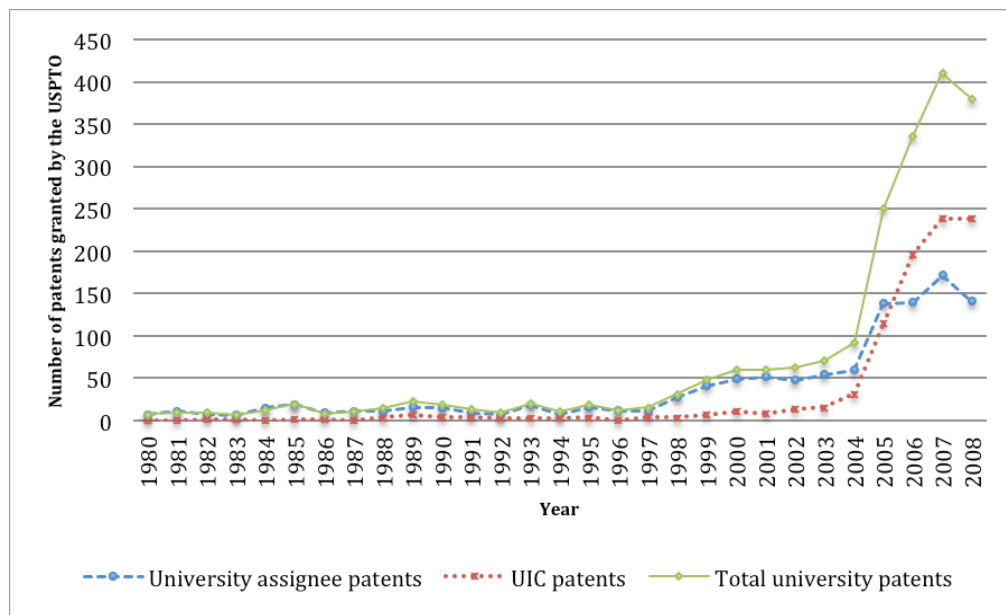
Source: Based on data obtained from the online records system of USPTO website;

http://www.uspto.gov/patents/process/search/

(Updated 20 November 2013).

Figure 5.1: Trends in Japanese national university patents

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[39] Based on data obtained from the online records system of USPTO website;
http://www.uspto.gov/patents/process/search/
(Update 20 November 2013).

Besides the achievement of a dramatic increase in number of Japanese university patents, there remains a critical question as to the extent to which this explosion represents the success of the more commercially useful inventions or simply increased filing of patent applications. To clarify the issue, this study provides an analysis of knowledge diffusion from universities to industry using patent citations to identify the contribution of Japanese university R&D outcomes in terms of patenting to Japanese industry.

5.3 Model Specification

I analyze knowledge diffusion from Japanese universities to industry by making a comparison of knowledge diffusion from Japanese corporations to industry. In this analysis, I use the citation frequency to measure the rate of diffusion. To calculate citation frequency or propensity to cite, I employ the equation derived from Jaffe and Trajtenberg (1996), adapted from the formulation of Caballero and Jaffe (1993) that was created to estimate parameters of the diffusion process while controlling for variations over time in the *propensity to cite* of patents.[40] The equation describes the likelihood that any particular patent K granted in year T would cite some particular patent k granted in year t and this process is assumed to be determined by the combination of an exponential process of knowledge diffusion and obsolescence as the Equation 1

$$p(k,K) = \alpha(k,K)\exp[-\beta_1(k,K)(T-t)] \times [1 - \exp(-\beta_2(T-t)]$$

(1)

where p (k,K) is the likelihood that any particular patent k, granted at time t, is cited by some particular patent K, granted at time T. The parameter β_1 determines the rate of obsolescence and the parameter β_2 determines the rate of diffusion. And both processes are the exponential function depending upon the citation lag (T-t). I refer to the likelihood determined by Equation 1 as the *citation frequency*. The coefficient α is a multiplicative factor, as the constant term in a simple regression model. The estimate

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[40] For a detailed explanation of the equation, see Jaffe and Trajtenberg (1996).

of a particular α (k,K), indicates the extend to which a patent k is more or less likely to be cited, with respect to a base characteristic patent, by a patent K.
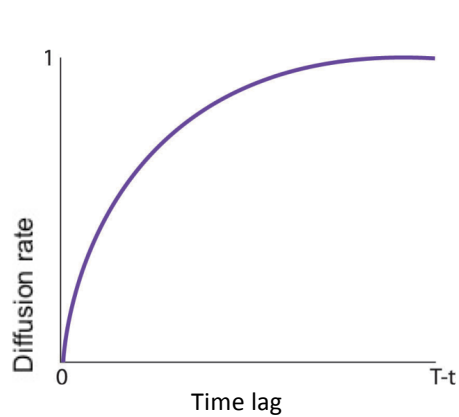
Source: Author, 2014

Figure 5.2: Diffusion distribution
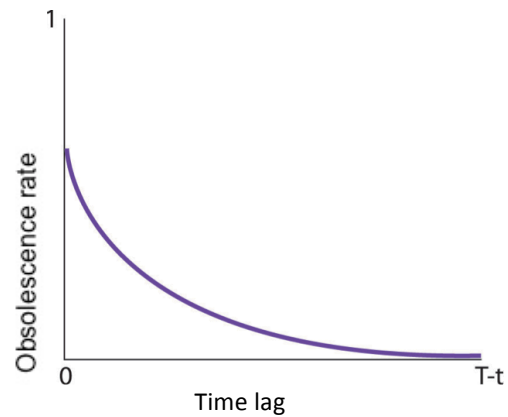
Source: Author, 2014

Figure5.3: Obsolescence distribution

The distribution of diffusion and obsolescence can be drawn as the graphs in Figure 5.2 and Figure 5.3. These exponential functions represent growth rate which indicate that after a patent was grant, it can be fall into diffusion category when it was cited by other patents and in the same time it can be described in obsolescence distribution when its invention start to decay and has not been cited by any following patents. In the study of Jaffe and Trajtenberg (1996), the nature of citations was revealed in a pattern of gradual diffusion and ultimate obsolescence, with maximum citation frequency occurring after about 5 years.

The constants term α and the structural parameter β_1 depend upon k and K, i.e. upon particular features of both cited and citing patents. From the empirical point of view, modeling single pairs of patents (citing and cited) might deal with very small expected values from one side and to enormously increase the computational burden from the other side. Therefore I aggregate patents in homogeneous groups and model the number of citations to a particular group of cited patents by a particular group of citing patents.

In this paper, I consider the followings as attributes of the cited patent k that might affect its citation frequency: index t indicates the filed year of the granted potentially cited patent; index i indicates the institutional type of the assignee of the potentially cited patent (Japanese corporate and Japanese university). As attributes of

the potentially citing patent K that might affect the citation likelihood, the index T corresponds to the filed year of the granted potentially citing patent and focus on location of Japanese industry. A treatable formulation of the model to calculate propensity to cite or citation frequency is presented in Equation 2[41]

$$P_{itT} = \frac{C_{itT}}{(n_{it})(n_T)} \tag{2}$$

where P_{itT} is citation frequency of a particular group of citing patents in time T made to a particular group of potentially cited patents in time t. The amount of citations to a specific group of cited patents in time t by a specific group of citing patents in time T is C_{itT}. n_{it} and n_T represent the total amount of potentially cited and citing patents for each of the particular (it) and (T) groups, respectively.

For example, measuring the citation frequency with which Japanese industry patents in 1980 cite Japanese university patents between 1976 and 1980 using Equation 2 can be explained as: P indicates the propensity to cite or citation frequency with which Japanese industry will cite any particular group of patents; i indicates the institutional type (an example is to measure propensity to cite university patents); t indicates the time lag (an example is the time lag of 1976-1980); T indicates the measurement of citation frequency that Japanese industry patents made (an example would be to measure citation frequency of Japanese industry in 1980 to any particular group of patents).

C_{itT} is the number of citations in which Japanese industry patents in 1980 cite university patents between 1976 and 1980; i indicates the institutional type, which would be, for example, measured propensity to cite university patents; t indicates the time in period of 1976-1980; and T indicates the year of 1980. n_{it} is the number of potentially cited patents; i indicates the institutional type, which is an example of measured propensity to cite university patents; t indicates the time in period of 1976-1980. n_T is the number of potentially citing patents, which is the number of Japanese industry patents in 1980; and T indicates the year of 1980.

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[41] For detail of the citation function, see Jaffe and Trajtenberg (1996).

5.4 Data Collection and Data Set

I measure knowledge diffusion using patent citation data and employ a model of the flow of patent citations over time and across institutions to calculate the probability of knowledge flow from universities to industry. The analysis in this paper is based on the citations made to two distinct sets of *potentially cited* patents (Japanese corporate patents and Japanese university patents). The data set consists of Japanese patents granted *US Utility Patents* that were applied from 1976 to 2008.[42] The first set is a sample of Japanese university patents (2,075 potentially cited patents). The second set is the Japanese corporate patents (854,228 potentially cited patents). I have identified a 1-in-10 random sample of granted Japanese industry patents (82,992 citing patents) filed between 1980 and 2008 that cite any of the patents in these two sets (856,303 potentially cited patents).

Table 5.1 shows the statistics for citation frequency variables. The data consist of one observation for each feasible combination of value of *i, t* and *T*. For the cited patents the year provided data range from 1976 to 2008 and two institutional types. For citing patents, this analysis has 29 years between 1980 and 2008 of Japanese industry patents.

Table 5.1: Descriptive statistics of patents

	Count number (Years)	Mean	Std. Dev.	Maximum	Minimum
Number of citations (C_{itT})					
University patents	29	20.24	23.68	108	3
Corporate patents	29	32,666.86	18,658.92	59,897	6784
Potentially cited patents (n_{it})					
University patents	29	420.93	496.68	2,075	46
Corporate patents	29	349,820.55	256,871.02	854,228	33,489
Potentially citing patents (n_T)	29	2,861.79	1,283.01	4,618	959
Citation frequency (P_{itT}) (10^{-5})					
University patents	29	2.25	1.58	6.80	0.90
Corporate patents	29	5.74	4.99	21.12	1.51

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[42] The data collection starts from 1976 because the online records system of USPTO website provides the full-text information of patent searching start from patents granted in 1976. For a more detailed explanation, see USPTO website; http://patft.uspto.gov/netahtml/PTO/search-bool.html.

5.5 Empirical Analysis and Findings

The comparative result of citation frequency between Japanese industry patents and university patents and corporate patents is presented in Figure 5.4. The trend reveals that corporate patents are more cited by industrial sectors than the university patents. This result corresponds with the analysis of Bacchiocchi and Montobbio (2009). They used European Patent Office (EPO) patent data of four large European countries, the US, and Japan in the period 1978-1998 to calculate knowledge diffusion between public and private sectors. The scholars found that in most of the cases, including Japan, knowledge incorporated in corporate patents is more highly cited by industrial sectors than knowledge embedded in university and PRO patents.[43]
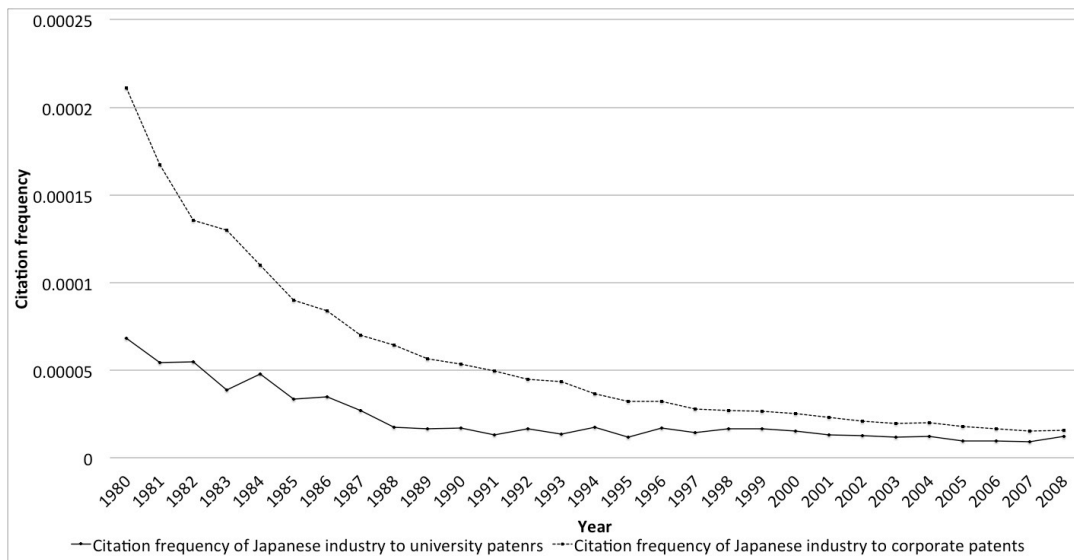
Source: Based on data obtained from the online records system of USPTO website;
http://www.uspto.gov/patents/process/search/
(Updated 28 February 2014).

Figure 5.4: A comparison of citation frequency trends between Japanese industry to university patents and corporate patents from 1980 to 2008

The trends in Figure 5.4 derived from the Equation 2, which is an equation to calculate the propensity to cite or citation frequency (P_{itT}). It must be emphasized that Figure 5.4 does not show the tendency of citation frequency from 1980 to 2008; it demonstrates a comparison of citation frequency that Japanese university patents and

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[43] For the detailed results of knowledge diffusion between public and private sectors among European countries, US, and Japan, see Bacchiocchi and Montobbio (2009).

corporate patents received from industry at one time.

Figure 5.4 presents a comparison of citation frequency trends between Japanese industry to university patents (P_{utT}) and corporate patents (P_{ctT}) from 1980 to 2008, when u represents university patents; c represents corporate patents; t represents the filed year of the granted potentially cited patent (university or corporate patents); and T represents the filed year of the granted potentially citing patent (Japanese industry patents from 1980 to 2008). However, to describe this graph, we cannot conclude that there are gradual declines in citation frequency from both of the two institutions between 1980 and 2008, as stated above. The important reason is that citation collections need time to accumulate means we cannot compare the number of citations received by patents among different years; instead, we have to compare them between different types of institutions but within the same year.

Since Figure 5.4 cannot describe all of the aspects related to the comparison between citation frequencies that Japanese industry made to corporate and university patents, I created the other graphs for more precise observation, to reveal the factors behind these trends. Regarding Equation 2, which describes the citation frequency, a ratio of citation frequency with which Japanese industry-cited university patents to citation frequency with which Japanese industry-cited corporate patents is taken. Thus, the relative citation frequency made by Japanese industry cited university patents to Japanese industry cited corporate patents are as in Equation 3.

$$Relative\ citation\ frequency = \frac{P_{utT}}{P_{ctT}} \qquad (3)$$

Figure 5.5 shows the results deriving from Equation 3, which is the ratio of citations received by the university to citations received by corporate patents, or the relative citation frequency of Japanese industry-cited university patents to Japanese industry-cited corporate patents. We can observe that from 1980 to the beginning of the 1990s, the trend was more stable than the rest of the period. The upward trend has started since the 1990s causing a reduced gap of citation frequency between Japanese industry and university patents and corporate patents in Figure 5.4. The upward trend in this figure reveals the more comprehensive understanding of why the gap between citation frequency received between university and corporate patents in Figure 5.4 has

been lessened. We can observe that the trend in relative frequency citations has increased and the change started at the beginning of the 1990s.
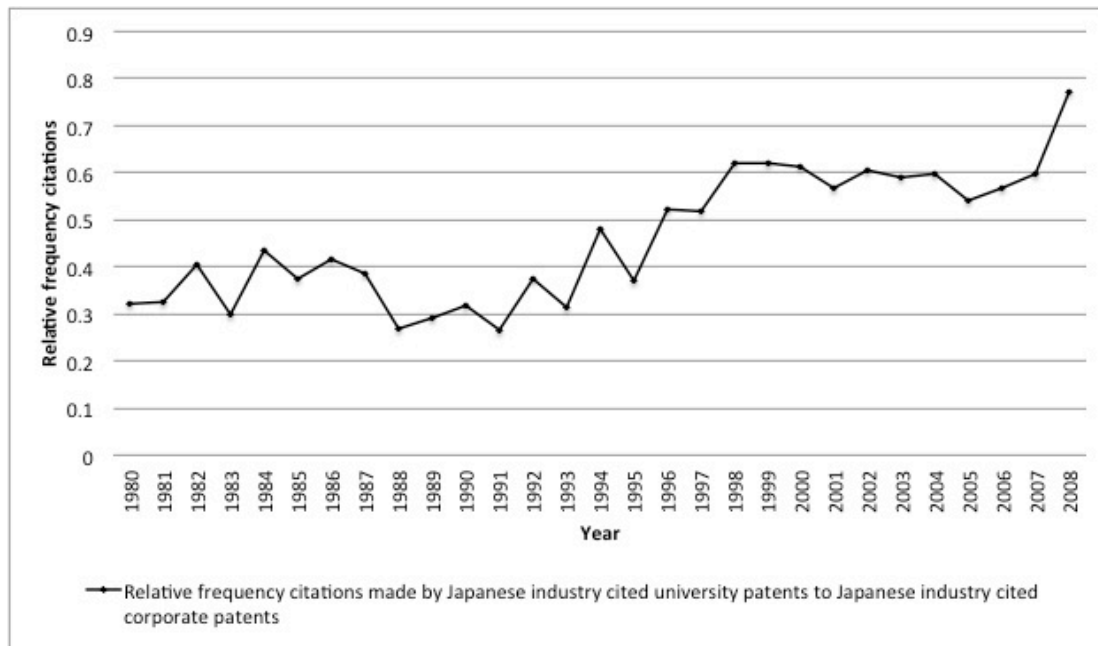
Source: Based on data obtained from the online records system of USPTO website; http://www.uspto.gov/patents/process/search/ (Updated 28 February 2014).

Figure 5.5: The trend in relative citation frequency made by Japanese industry cited university patents to Japanese industry cited corporate patents between 1980 and 2008

In order to understand the upward trend in Figure 5.5 that causes the reduced gap in Figure 5.4, a decomposition of Equation 3 to reveal how this upward trend derived is required. Two more graphical representations resulting from the expanded equation of Equation 3 have been created, which are described as Equation 4.

$$Relative\ citation\ frequency = \frac{P_{utT}}{P_{ctT}} = \frac{\dfrac{C_{utT}}{(n_{ut})(n_T)}}{\dfrac{C_{ctT}}{(n_{ct})(n_T)}} = \frac{\dfrac{C_{utT}}{C_{ctT}}}{\dfrac{n_{ut}}{n_{ct}}} \tag{4}$$

I decompose the ratio of citation frequency that Japanese industry cited university patents to citation frequency that Japanese industry cited corporate patents ($\frac{P_{utT}}{P_{ctT}}$). The numerator is the ratio of the number of citations in which Japanese industry

cited university patents to the number of citations in which Japanese industry cited corporate patents ($\frac{C_{utT}}{C_{ctT}}$) and the denominator is the ratio of the number of university patents to corporate patents ($\frac{n_{ut}}{n_{ct}}$). The trend of the ratio of the number of university patents to corporate patents ($\frac{n_{ut}}{n_{ct}}$) is presented in Figure 5.6 and the trend of the ratio of number of citations received by university patents from Japanese industry patents to citations received by corporate patents from Japanese industry patents ($\frac{C_{utT}}{C_{ctT}}$) is shown in Figure 5.7.
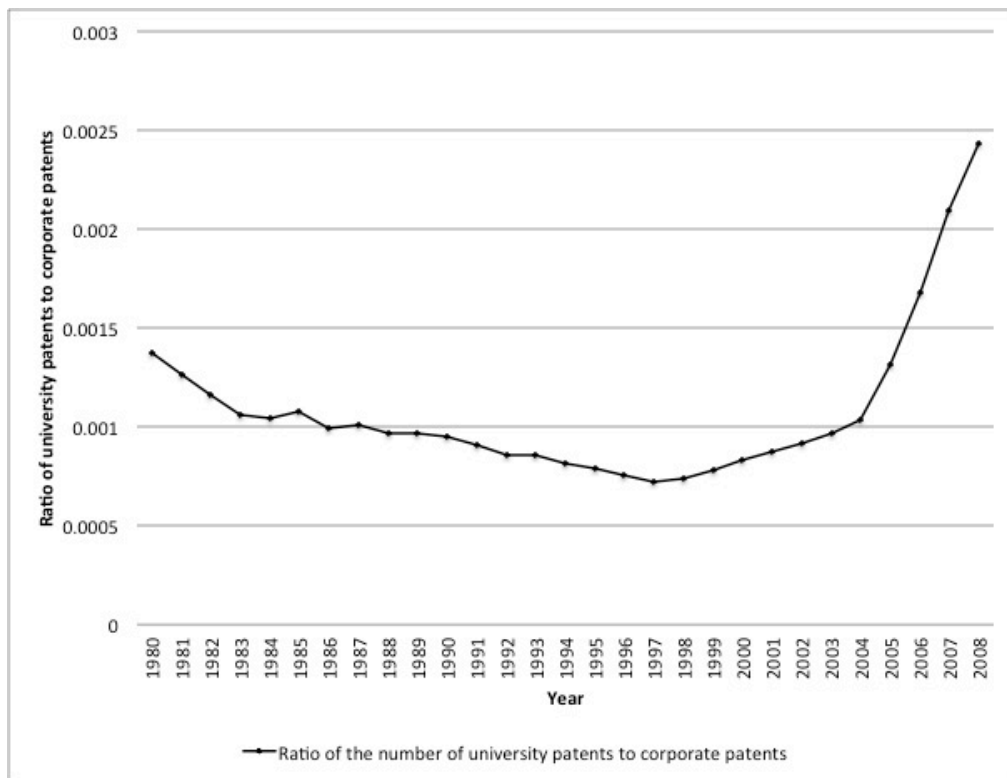
Figure 5.6: The trend in ratio of the number of university patents to corporate patents between 1980 and 2008
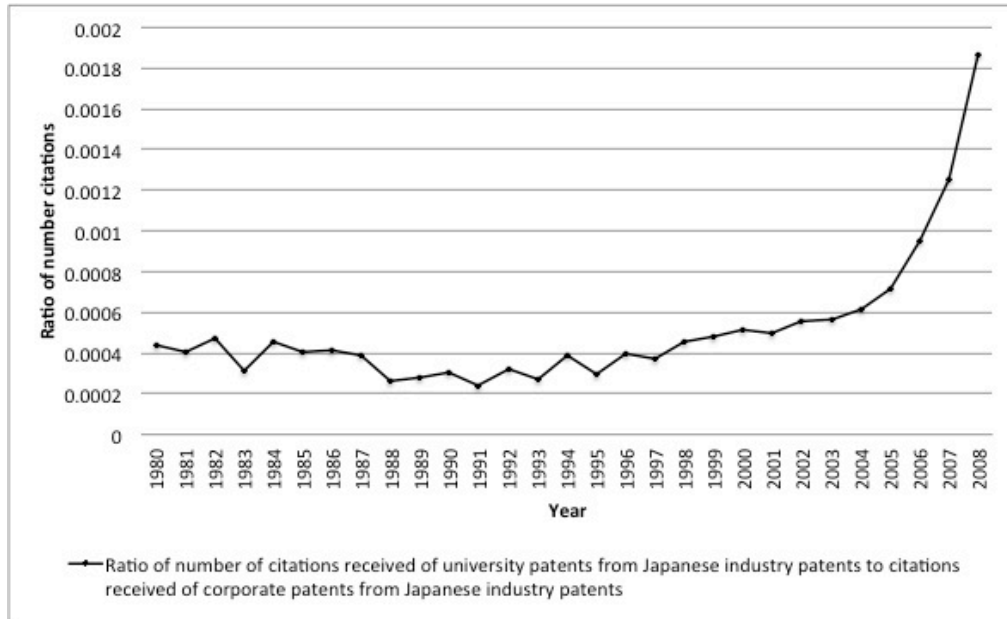
Figure 5.7: The trend of ratio of number of citations received by university patents from Japanese industry patents to citations received by corporate patents from Japanese industry patents

Figures 5.6 and 5.7 explain the upward trend in Figure 5.5 that causes a reduced gap between citation frequency of Japanese industry to corporate patents and to university patents in Figure 5.4. From Figure 5.6, we can see that the ratio of the number of university patents to corporate patents decreased from 1980 to 1997. However, after the decrease, the trend has continuously risen and significantly leaped up since 2004. Figure 5.7, meanwhile, reveals that the ratio of the number of citations received by university patents from Japanese industry patents to citations received by corporate patents from Japanese industry patents was stable at the beginning and then gradually increased. However, the trend has grown dramatically since 2004.

Regarding the decomposed equation, we can observe that since the mid-1990s both of the trends of the numerator and denominator have increased. However, the speed of the numerator is faster than the denominator, thus we can observe the upward trend in Figure 5.5. On the other hand, the upward trend in Figure 5.5 also can happen when both the numerator and denominator decrease but denominator decreases faster. Nevertheless, this analysis reveals the opposite side, in which the two factors both increase. Thus, this result is very healthy since there are growing trends in both of the

number of patents and citations that they received.[44]

The trend in Figure 5.6 reflects an aspect of quantity of patents since it provides the ratio of the number of university patents to corporate patents. On the other hand, the trend in Figure 5.7 represents the quality since it demonstrates the ratio of the number of citations received by university patents from Japanese industry patents to citations received by corporate patents from Japanese industry patents. The number of patent citations has long been presumed to indicate the link between the patents themselves and both the technological and economic value of innovations (Jaffe et al. 1993). Patent citations denote that the citing patents have found utility value in the cited patents (Yoshikane 2013). Thus, the number of citations received can specify the value of patents.[45]

Figures 5.6 and 5.7 provide evidence to confirm the result of the comparison of citation frequency trends between Japanese industry to university patents and to corporate patents (Figure 5.4). To explain the lessened gap, we can observe that the ratio of the number of university patents to corporate patents has risen since the mid 1990s. Correspondingly, we can also observe that the ratio of number of citations received by university patents from Japanese industry patents to citations received by corporate patents from Japanese industry patents has continuously increased since the beginning of the 1990s. This evidence corresponds to the trend of citation frequency of Japanese industry to corporate and university patents presented in Figure 5.4, where the gap has diminished since the early 1990s.

The trend in the ratio of the number of university patents to corporate patents (Figure 5.6) that declined between 1980 and 1997 then has increased since 1998; especially there has been a great increase since 2004 due to an increased number of Japanese university patents resulting from UIC policies.[46] In terms of citations received, the trend of ratio of number of citations received of university patents from Japanese industry patents to citations received of corporate patents from Japanese industry patents (Figure 5.7) reflects a similar result as the ratio of the number of university to corporate patents, where the ratio has been increased since the beginning of the 1990s.

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[44] For more detailed explanation to confirm this result, see Appendix 1.

[45] For a detailed explanation of the importance of patent citation, see Chapter 3.

[46] For a detailed explanation of the impact of UIC policies on the increased number of university patents, see Chapter 4.

The lower rate of citation frequency from Japanese industry to university patents than to corporate patents can be explained regarding the informal ties of university-industry linkage in Japan. Before the encouragement of UIC policies, in terms of knowledge contribution from universities, many university discoveries are transferred to the private sector informally and unaccounted for in any normal statistics (Kneller 1999). Sometimes the transfer of IPRs occurs with a short document that serves as an assignment, not an official or contract agreement. These unofficial documents lead to the problem that some productive faculty members do not know how many of their discoveries have been patented by companies (Kneller 1999).

Informal transfers of university technologies occur in many ways: companies consultant with professors; corporate researchers working in university laboratories communicate research results back to their companies; or graduates find employment in industrial sectors (Kneller 1999). These informal channels of technology transfer hardly provide us with the statistical number. Based on the foregoing analysis, we may conclude that there is the vast majority of technologies transferred knowledge that we cannot measure from the university contribution. Additionally, these unaccounted statistics of university contributions can affect the rate of citation frequency that Japanese industry made to university patents.

5.6 Conclusion

The main objective of this study is to develop a clearer picture of the diffusion of knowledge from Japanese universities to industries. Comparing to Japanese corporate patents, the study found that corporate patents are more cited by industrial sectors than the university patents; however, the gap between them has been continuously reduced since the mid-1990s, which correlated to the period of the first launch of UIC policies. The dramatically higher rate of citation frequency of Japanese industry patents to corporate rather than university patents between 1980 and the mid-1990s can be interpreted regarding the informal ties of university-industry linkage in Japan before the enactment of UIC policies. Since the UIC policies were implemented in the mid-1990s, we can observe the diminishing gap between the two different sources of potential cited patents.

Regarding the quantity and quality of Japanese university patents, the quantity of patents based on the ratio of number of university patents to corporate patents has grown since the mid-1990s. For the quality, the ratio of number of citations received of university patents from Japanese industry patents to citations received of corporate patents from Japanese industry patents has increased since the early 1990s. Moreover the speed of citations received from university patents is much higher than the increased number of university patents, thus the trend in the relative frequency of citations made by Japanese industry cited university patents to Japanese industry cited corporate patents has risen since the beginning of the 1990s.

Based on this evidence, we clearly observe the growth in Japanese university patenting and technological knowledge diffusion from university patents to industry. The number of Japanese university patents is growing; also, the number of citations received is relatively increasing, thus both the quantity and quality of Japanese university patents are improving. It would be simplistic to conclude that there are flows of technological knowledge from universities to industry. We can perceive this diffusion as healthy since both of the number of patents and citations received increase. UIC policies reflect an impressive result in Japanese university patenting.

However, these results raise the question of why universities do not produce relatively more cited inventions. A possible explanation that can clarify these outcomes is related to the different property regimes of university patents in Japan. Japanese university-industry technology transfer occurs in many ways, including both the formal and informal ties. In the past, there was a large body of technological knowledge generated within universities but transfer to industry with an unaccounted for statistical number. Due to the informal ties of university professors and firms, most of these university-invented patents belong to companies. Therefore, we cannot conclude whether universities produce relatively more cited innovations or not.

However, the evidence of citation frequency from Japanese industry to corporate and university patents affects the lower gap between them since the mid-1990s that correlated to the period of the enactment of UIC policies. We may argue that UIC policies have some effects on the propensity of Japanese industry to cite corporate and university patents. Additionally, UIC policies have just been implemented since the mid-1990s; therefore, to conclude that universities fail to produce high quality innovations compared to corporations is too early to judge.

CHAPTER 6

DETERMINANTS OF PATENT VALUE IN JAPANESE UNIVERSITY PATENTS

6.1 Introduction

Radical changes have been observed in the academic patenting behavior over the past 30 years since the enactment of the Bayh-Dole Act in the US in 1980. For Japan, these changes have impacted the Japanese university patenting due to the emulation of the Act in 1999. Japan has adopted a Bayh-Dole Act-like model to enhance the effectiveness of university-industry technology transfer. As a consequence of this change, a higher propensity to patent academic inventions has been observed (see Motohashi and Muramatsu 2012). At the same time, scholars and policymakers have underlined the crucial role played by industry–university partnerships in the knowledge society (see Etzkowitz 1998; Jaffe 1989; Mansfield 1991, 1998; Mansfield and Lee 1996; Meyer 2003).

Although recent studies (see Guellec and van Pottelsberghe de la Potterie 2004; Mansfield 1998; McMillan et al. 2000; Narin et al. 1997) clearly illustrate the significant contribution of public research (performed in universities and public laboratories) to the innovation performances of the business sector, mainly through knowledge spillovers, the rapid increase in academic patenting has provoked new debates about the quality of these patents. Do they herald a surge in academic inventions, or do they merely reflect a higher propensity to patent inventions of lower quality or value?

This chapter intends to contribute to this debate. It aims to investigate the value of academic patents and compare their value determinants in US and Japanese university patents, as well as Japanese university patents with different assignees. In order to determine the value of patents, various measures have been developed. All of these measures can be derived from patent data directly. I consider four broad value determinants including the technical background of patents, the distance of technology from the application date to present, the breadth or scope of patent protection, and the technology classification. The key variables are the number of forward citations as a

dependent variable and independent variables composed of the number of backward citations, years, claims, and IPC classes.

In this study, a comparison analysis using zero-inflated negative binomial regression between US and Japanese university patents has been proved based on the notion of the determinants of patent value. Additionally, I provide detailed analyses of Japanese university patents with different institutional-type settings, including university assignee and UIC patents. The results reveal that both the US and Japanese university patents share common determinants of value and all of the provided variables significantly impact the value of patents. More precisely, in the case of Japanese university patents, the evidence suggests that the breadth of patent protection (claims) significantly affects valuations, but there is a difference in terms of the nature of patents between university assignee and UIC patents.

The remainder of this article is structured as follows: The summary of the determinants of patent value is presented in section 6.2. Section 6.3 explains the methods of this study. Section 6.4 provides data collection and data set, while Section 6.5 presents the empirical analysis and findings. The last section gives conclusions.

6.2 Determinants of Patent Value

It is known that on average only one to three patents out of 100 yield significant financial return.[47] This skewed distribution of patent value has been at the origin of a small but growing stream of economic research that attempts to discuss and identify the determinants of patent value (see Griliches 1990; Griliches et al. 1986; Pakes 1986; Pakes and Schankerman 1984; Sapsalis et al. 2006; Scherer 1965; Scherer and Harhoff 2000). Griliches (1990, 1702) summarized the insights from several studies on the skewness attribute of patents and concluded "these findings, especially the large amount of skewness in this distribution, lead to rather pessimistic implications for the use of patent counts as indicators of short-run changes in the output of R&D."

Regarding the skew distribution of patent value, additional information that correlated with the value of patent rights has been employed to estimate the valuation. Various indicators have been used as variables to determine patent value in the

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[47] For more detailed explanation, see Stevens and Burley (1997).

economic literature on the measurement of the value of patents, such as the number of times the patent is cited (forward citations of patents), or the length of its renewal, or the number of countries where it is taken (patent family size), or the breadth or scope of patent protection (patent claims). Different empirical strategies have been used in the literature to approximate the value of a patent. However, most studies use this available information on patents and apply econometrics functional forms to determine patent value.

Pakes (1986), Pakes and Schankerman (1984), and Schankerman and Pakes (1986) were the first to develop and estimate models in which the observed renewal decisions are used to estimate the distribution of patent values. Trajtenberg (1990) computed a measure of social returns to the computer-tomography scanner industry and relates that measure to citation indicators. Lerner (1994) examined the impact of patent scope on the market value of biotechnology firms and developed a proxy for the breadth of patent protection to determine the valuation. Putnam (1996) integrated application data into the analysis of the value of patent.

Harhoff et al. (2002) estimated patent value using a broad set of indicators, which are composed of the number of citation received from subsequent applications, the number of references to prior patents (backward citations), the number of references made to the non-patent literature, the outcome of opposition proceedings, the patent family size, and the number of different four-digit IPC classifications. They found significant correlations between patent value and citations received from subsequent patents as well as backward citations. They also found that the observed outcomes of opposition cases and the measure of international patent families are particularly valuable.[48]

Sapsalis et al. (2006) compared corporate and academic patents to assess whether they have similar value distributions and share common determinants of value. To evaluate the value determinants of patents, they used the number of non-patent citations, backward citations, co-assignees, and members in the patent family as indicators. They found that the value distribution of academic patents is very close to that for corporate patents and the determinants of patent value are broadly similar for the two sectors. Backward citations, non-patent citations, the number of inventors and

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[48] For a more detailed explanation, see Harhoff et al. (2002).

co-assignees all affect the value of both academic and corporate patents.[49]

Guellec and van Pottelsberghe de la Potterie (2000) observed the probability of getting a patent granted to approximate the value of a patent. They used the indicators of the patenting strategy, the domestic and international R&D collaboration, the technological diversity (the number of IPC classifications), and the mix of designed states for protection (the patent family size) to determine the value of patents. They found that the strategic decision provides the useful information about the grant probability, while the technical diversity has a negative impact on the probability of grant, and the link between patent value and family size is ambiguity.[50]

The type and number of explanatory variables that have been used as determinants of patent value vary widely across studies. The most frequently used determinants are the number of forward patent citations (when it is not used as a dependent variable), the number of backward patent citations, and the geographical scope for protection (the number of countries in the patent family). Other variables rely on the concepts of opposition procedures, renewal data, application scope (the number of claims) and non-patent citations.

6.3 Methodology

This study examines the determinants of patent value. For this purpose, multiple regression through zero-inflated negative binomial (ZINB) regression was employed. In most patent applications, the value of the forward citation, which is used as the response variable, is zero in a large number of patents, as presented in Figures 6.1 and 6.2. Figures 6.1 and 6.2 provide frequency distributions of forward citations of US university patents and Japanese university patents, respectively. We can observe that the empirical distributions of forward citations in US and Japanese university patents are extremely skewed.

This fact may make it difficult to successfully apply linear regression to the data. Thus, this study is based on a logistic model, wherein patents whose forward citation is equal to or beyond a certain threshold can be differentiated from others. Furthermore, ZINB regression is applied. ZINB models, which are robust against over-

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[49] For a more detailed explanation, see Sapsalis et al. (2006).
[50] For a more detailed explanation, see Guellec and van Pottelsberghe de la Potterie (2000).

dispersion caused by a large number of zero counts, are used in bibliometric studies, including patent analyses (Foltz et al. 2000; Lee et al. 2007; Tang and Shapira 2012; Yoshikane 2013).
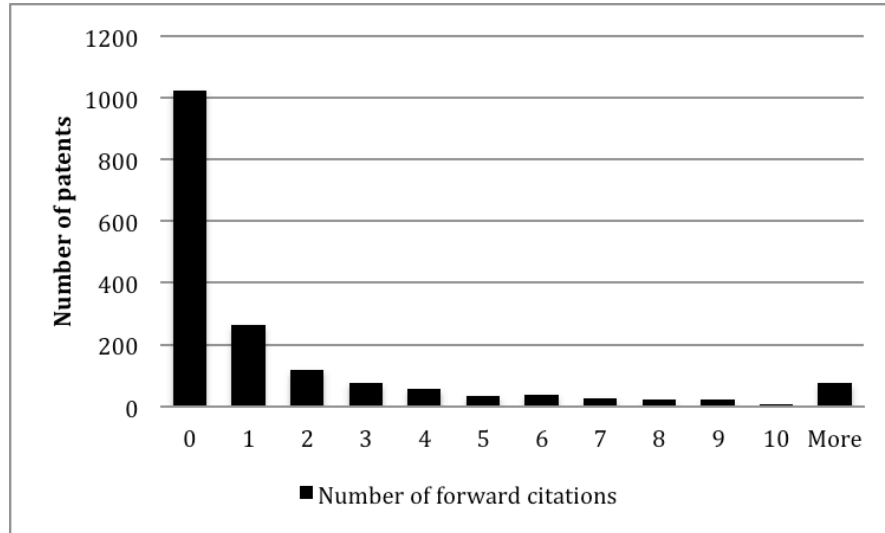
Source: All data were obtained from the online records system of USPTO website;
http://www.uspto.gov/patents/process/search/
(Update 20 November 2013).

Figure 6.1: Frequency distribution of forward citations of US university patents
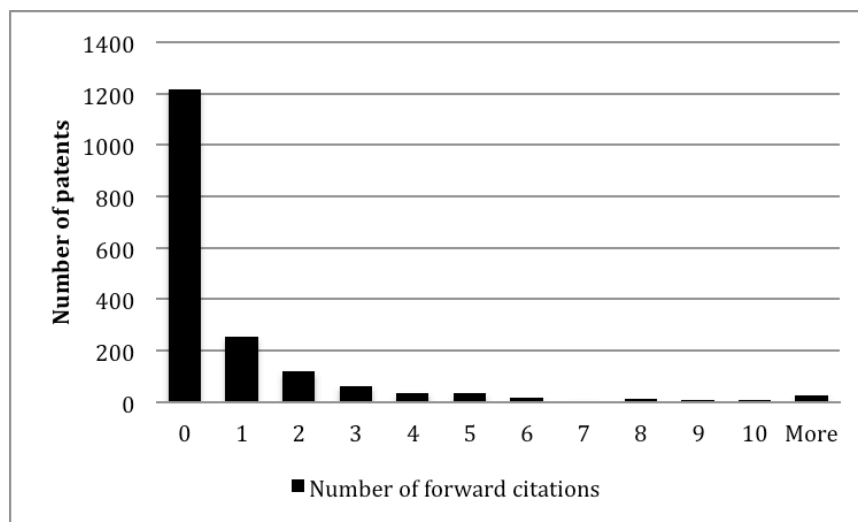
Source: All data were obtained from the online records system of USPTO website;
http://www.uspto.gov/patents/process/search/
(Update 20 November 2013).

Figure 6.2: Frequency distribution of forward citations of Japanese university patents

ZINB regression with the response variable is the number of forward citations was employed. This is the most commonly used proxy for the value of patents. For the explanatory variables, I develop four broad value determinants to determine patent value as follows: (1) the technical background of a patent (measured by the number of backward citations); (2) the distance of technology from the application date to present (measured by the year filed of patents); (3) the breadth or scope of patent protection (measured by the number of claims); (4) the technology classification (measure by the number of IPC classes).

Despite the heterogeneity of previous studies, some similarities emerge. The most important is probably the fact that the number of forward patent citations is closely associated with the value of a patent; all studies using forward patent citations reach this conclusion (Sapsalis et al. 2006). Thus, I use forward citations represent patent value and estimate their value determinant through four independent variables including backward citations, years, IPC classes, and claims.

Future citations received by a patent (forward citations) are one indication that an innovation has contributed to the development of subsequent inventions. For this reason, citations have been used as a measure of the value of an invention (Trajtenberg 1990). An inventor must cite all related prior US patents in the patent application. A patent examiner who is an expert in the field is responsible for insuring that all appropriate patents have been cited. Like claims, the citations in the patent document help to define the property rights of the patentee (Lanjouw and Schankerman 2001).

A patent comprises a set of claims that delineate the boundaries of the property rights provided by the patent. The principal claims define the essential novel features of the invention in their broadest form, and the subordinate claims are more restricted and may describe detailed features of the innovation claimed. The patentee has an incentive to claim as much as possible in the application, but the patent examiner may require that the claims be narrowed before granting (Lanjouw and Schankerman 1999).

The number of claims is another, underutilized, indicator of the *bits of information* contained in a patent, and therefore of its value. Supporting evidence for the relationship between claims and value is found in the fact that claims are positively correlated with forward and backward citations (Lanjouw and Schankerman 1999). Tong and Frame (1994) suggested that patent claims might be a better indicator of

technological effort than straight patent counts. Certainly, claims correlate better with other technology-related indicators than patent counts.

To categorize the technology files associated with an invention, each patent is assigned by the patent examiner to 8-digit categories of the IPC system.[51] The IPC is a technology-based classification system, and patents may be assigned to more than one subclass. In the empirical analysis, I use the set of all 4-digit IPC subclasses to which each patent was assigned.[52]

6.4 Data Collection and Data Set

This study focuses on the analysis of the determinants of patent value by providing a comparison between US and Japanese university patents. Additionally, the study also investigates in detail Japanese university patents with different institutional types of assignees. Since the Japan UIC policy initiatives that have been implemented since 1998 and the number of Japanese university patents owned by universities are limited by institutional and regulatory disincentives, the data in this analysis cover the period after the enactment of UIC policies from 1998 to 2008. For Japan, the data set consists of all Japanese national university-granted *US Utility Patents* that were applied from 1998 to 2008.[53] For the US, the data set is composed of a 5% random sample of the US university patents granted at USPTO between 1998 and 2008.[54]

I employ ZINB regression where the dependent variable is the number of forward citations. The explanatory variables include the number of IPC classes, the number of claims, the number of years filed, and the number of backward citations. Table 6.1 presents the descriptive statistics of variables of US and Japanese university patents. Tables 6.2 and Table 6.3 show correlations between explanatory variables and between each of these and the response variable in the case of US and Japanese university patents.

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[51] For a detailed explanation of the IPC system, see Chapter 4.
[52] For a detailed explanation of the use of 4-digit IPC subclass, see Chapter 4.
[53] All data were obtained from the online records system of USPTO website; http://www.uspto.gov/patents/process/search/ (Update 20 November 2013).
[54] All data were obtained from the online records system of USPTO website; http://www.uspto.gov/patents/process/search/ (Update 20 November 2013).

Table 6.1: Descriptive statistics of variables of US and Japanese university patents

	Count number	Mean	Std. Dev.	Maximum	Minimum
US university patents					
Forward citations	1755	1.89	4.36	40	0
IPC classes	1755	1.68	0.98	9	1
Claims	1755	20.61	16.56	127	1
Years	1755	9.18	3.19	15	5
Backward citations	1755	11.99	15.60	98	0
Japanese university patents					
Forward citations	1779	0.98	2.85	46	0
IPC classes	1779	1.51	0.84	7	1
Claims	1779	11.56	7.88	100	0
Years	1779	7.50	2.52	15	5
Backward citations	1779	5.41	6.05	123	0

Table 6.2: Correlations between measures-US university patents

	Forward citation	IPC class	Claim	Year	Backward citation
Forward citation	1.000				
IPC class	0.013	1.000			
Claim	0.142	-0.043	1.000		
Year	0.285	0.207	-0.015	1.000	
Backward citation	0.226	-0.036	0.167	0.028	1.000

Table 6.3: Correlations between measures-Japanese university patents

	Forward citation	IPC class	Claim	Year	Backward citation
Forward citation	1.000				
IPC class	0.051	1.000			
Claim	0.091	-0.015	1.000		
Year	0.374	0.201	0.017	1.000	
Backward citation	0.065	-0.034	0.137	-0.069	1.000

Table 6.4 presents the descriptive statistics of variables of Japanese university assignee and UIC patents. Tables 6.5 and 6.6 show correlations between explanatory variables and between each of these and the response variable in the case of Japanese university assignee and UIC patents.

Table 6.4: Descriptive statistics of variables of Japanese university assignee and UIC patents

	Count number	Mean	Std. Dev.	Maximum	Minimum
University assignee patents					
Forward citations	916	1.17	3.04	38	0
IPC classes	916	1.59	0.88	7	1
Claims	916	11.05	7.59	57	0
Years	916	8.31	2.86	15	5
Backward citations	916	4.95	6.64	123	0
UIC patents					
Forward citations	863	0.78	2.63	46	0
IPC classes	863	1.42	0.78	6	1
Claims	863	12.09	8.15	100	1
Years	863	6.65	1.73	15	5
Backward citations	863	5.90	5.32	36	0

Table 6.5: Correlations between measures-Japanese university assignee patents

	Forward citation	IPC class	Claim	Year	Backward citation
Forward citation	1.000				
IPC class	0.070	1.000			
Claim	0.116	0.014	1.000		
Year	0.383	0.238	-0.016	1.000	
Backward citation	0.056	-0.030	0.105	-0.096	1.000

Table 6.6: Correlations between measures-Japanese UIC patents

	Forward citation	IPC class	Claim	Year	Backward citation
Forward citation	1.000				
IPC class	0.011	1.000			
Claim	0.075	-0.034	1.000		
Year	0.370	0.069	0.139	1.000	
Backward citation	0.095	-0.023	0.171	0.063	1.000

The count number of US university patents is 1,755 and the count number of Japanese university patents is 1,779, respectively. Additionally, in the case of Japan, the patents were classified according to assignees and institution type. Specifically, the patents were divided into university assignee patents and university co-assignee patents. The latter group comprises UIC patents that result from joint research

collaborations between universities and corporates. The number of university assignee patents is 916, while the number of UIC patents is 863.

6.5 Empirical Analysis and Findings

The results of zero-inflated negative binomial (ZINB) regression analyses are presented in Tables 6.7 and 6.8. The results reveal that patent values for US and Japanese university patents seem to react to almost similar determinants. Older patents receive more citations than younger patents. Backward citations have positive and significant impact on the number of forward citations. Claims have positive impact to patent value; however, it reveals significance only on US university patents. IPC classes have no impact on the number of forward citations, as demonstrated in Table 6.7.

Table 6.7: Regression coefficients for response variable: Number of forward citations for US and Japanese university patents

	US university patents	Japanese university patents
Number of IPC classes	-0.005	-0.071
	(0.034)	(0.043)
Number of claims	0.007***	0.005
	(0.002)	(0.004)
Number of years	0.135***	0.159***
	(0.013)	(0.013)
Number of backward citations	0.011***	0.018***
	(0.002)	(0.006)
Number of observations	1755	1779
Constant	-0.315	-0.453
Log likelihood	-1812.669	-1186.419
LR chi 2(4)	178.11	146.47

Note: *** represent statistical significance at the 1% level; standard errors in parentheses

However, the result of Japanese university patents in Table 6.7 is an aggregate number of patents that combine both the university assignee and UIC patents. To investigate why the measure of claims has no impact on Japanese university patents, while this factor has a positive and significant impact on US university patents, a detailed analysis of determinants of patent value in Japanese university patents was

created. Table 6.8 provides the results of a comparison analysis between Japanese university assignee and UIC patents.

We can observe almost similar results as the comparison of value determinants between US and Japanese university patents in Table 6.7, except that the impact of claims on the patent value is different between university assignee and UIC patents. In the case of university assignee patents, the number of claims has a significantly positive impact on patent value but the number of claims has no impact on patent value in the case of UIC patents.

Table 6.8: Regression coefficients for response variable: Number of forward citations for Japanese university assignee and UIC patents

	Japanese university assignee patents	Japanese UIC patents
Number of IPC classes	-0.049	-0.083
	(0.054)	(0.073)
Number of claims	0.011*	-0.003
	(0.006)	(0.005)
Number of years	0.134***	0.213***
	(0.019)	(0.023)
Number of backward citations	0.013*	0.023*
	(0.007)	(0.010)
Number of observations	916	863
Constant	-0.301	-0.773
Log likelihood	-685.6705	-494.8158
LR chi 2(4)	58.15	86.30

Note: ***, * represent statistical significance at the 1% and 10% levels, respectively; standard errors in parentheses

It is interesting that when analysis is performed separately between Japanese university assignee and UIC patents, we can observe the result of the impact of claims on the patent value in the case of university assignee patents, which show the similarity to the US university patents, which show positive significance. On the other hand, this is opposite to the case of UIC patents, when the number of claims has no impact to patents' value.

The results of this analysis correspond to the existing study of Harhoff et al. (2002) and Lanjouw and Schankerman (1999), where a number of indicators are significantly correlated with patent value. The measure for references to the patent

literature or backward citations carries significant positive coefficients to patent value, similar to the evidence in the study of Harhoff et al. (2002). Likewise, the number of years filed has significantly positive impact to patent value.

The claims number is a particularly good predictor of patent value when it reveals a positive correlation with the increased number of forward citations. Supporting evidence for the relationship between claims and value is found in the fact that claims are positively correlated with forward and backward citations in the study of Lanjouw and Schankerman (1999).

Contrary to the previous results of Lerner (1994), I find that the number of four-digit IPC classifications has a negative impact on the patent value. However, the relationship between the indicator of IPC class and patent value is ambiguous since Harhoff et al. (2002) found that the number of four-digit IPC classifications does not have any explanatory power.[55] The ambiguity of IPC class as a variable in the study of patent value is found in the analysis of Guellec and van Pottelsberghe de la Potterie (2000) when the technical diversity has a negative impact on the probability of patent grant. The higher the number of IPC classes listed in an application, the lower the chance to get a grant. The explanation is due to the fact that it is possible that a high number of classes may reflect not only the technological diversity of the invention, but also the perplexity of the examiner facing a somewhat unclear technology (Guellec and van Pottelsberghe de la Potterie 2000).

The explanation of the relationship of the breadth of patent protection and patent value can be explained regarding the links between an innovation and its technological *antecedents* and *descendants*. For claims, the number of claims in an existing patent has some relation to the technological innovation of previous patents. Strictly speaking, patents do not measure fundamental units of inventiveness. This privilege lies in the domain of patent claims. An inventor's invention is embodied in his or her claims (Tong and Frame 1994).

Claims appear in their own section of the patent. Based on the USPTO, the claims section is identified with the lead words, "The invention claimed is", followed by the number of claims that describe *state of the art* of that invention. For the clear picture of how claims are a true measure of invention, consider the following example

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[55] For detailed analysis on the impact of IPC classification on patent value, see Harhoff et al. (2002).

provided by Tong and Frame (1994). Martha invents the first stool and applies for a patent. Her invention includes two claims as follows: (1) a device that can be used for sitting and (2) this device is comprised of a seat that is elevated off the ground by means of legs. After that, George observes Martha's work and creates an improvement of the invention. He invents a chair, which has a back support attached to it. In his claims, he can only claim the back of the chair, since the sitting component is already covered in Martha's stool patent. Thus, George's true inventive contribution is simply the seat back, not the whole chair.

Regarding the provided instance, we can observe that a new invention based on the existing notion will have a few claims since the knowledge of that invention relates to the antecedent technology. In contrast, for the new discovery, the number of claims tends to be excessive. For the explanation of the different impact of claims on university assignee and UIC patents consider the following. In the case of UIC patents, when the number of claims increases, the number of forward citations decreases. In general, when the number of claims increases, the value of patents decreases.

Since UIC patents are the results of the collaborative research between university and industry that have commercialization purposes, the number of claims can cause difficulty of accessibility of invention in the future. Thus, a small number of claims is better for the broader targets. In contrast, in the case of university assignee patents, when the number of claims increases the number of forward citations also increases. This result corresponds to the existing study when the number of claims reflects the value of patents (Lanjouw and Schankerman 1999). Important inventions gain many citations received. Moreover, the number of claims reflects freshness that means new inventions provide some incentives to researchers and the researcher would like to catch up new technology. Considering this point when the number of claims increases, the number of forward citations also increases.

For IPC classes representing the technology fields, in the previous finding (Lerner 1994), the number of IPC classes has a positive impact on the number of forward citations. This is understandable since a patent that falls into many technology fields provides many possibilities for researchers in many areas to cite. In this case, the number of IPC classes indicates the quantity aspect. However, in this result, when the number of IPC classes decreases, the number of forward citations increases, so the number of IPC classes indicates the quality aspect. The explanation is that it is possible

that a high number of classes may reflect not only the technological diversity of the invention, but also the perplexity of the unclear technology (Guellec and van Pottelsberghe de la Potterie 2000).

The measure for references to the patent literature or backward citations carries significant positive coefficients to patent value similar to the evidence in the study of Harhoff et al. (2002). This evidence reflects the relationship between technological antecedents and descendants or backward and forward citations of innovation when an invention based on an existing technology represents the important innovation.[56]

In light of the findings of this study, considering the information derived from patent data is important since it provides not only the technological antecedents and descendants of innovation, but also the determinant of patent value. Information on the value of a patent is contained not only in forward citations as recognized in previous studies, but also in other variables such as the technical background of patents and the breadth or scope of patent protection.

When concentrating on commercialization, to increase the number of forward citations, the claim should be minimized since the number of claims represents the difficulty to use the patent, so with a large number of claims the number of forward citations is small. For the strategy of university patenting, a university focus more on one specific technology field can attract more citations. If the university focuses on one specific technological area, most of the effort will contribute to the focused field and could produce new inventions. A small number of IPC classes has high quality because researchers focus on just one particular area of study.

6.6 Conclusion

This chapter has been an attempt to use information from patent applications to determine patent value. The analysis of these data has been quite promising. Clear evidence of the significant correlation between the provided indicators and patent value has been observed. The results reveal that patent value for US and Japanese universities seems to react to almost similar determinants. Older patents receive more citations than younger patents. Backward citations and claims have positive and significant impact on the patent value; however, IPC classes reflect no impact on the

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[56] For the correlation between backward and forward measure, see Trajtenberg et al. (1997).

value of patents. Moreover, considering the breadth of patent protection in terms of claims, the results reveal the difference between Japanese university assignee and UIC patents. In the case of university assignee patents, the number of claims has a significantly positive impact on patent value but the number of claims has no impact on patent value in the case of UIC patents.

These results have a number of implications for the measurement of patent value. First, I show that relying on citations received from later patents alone is not likely to lead to the best possible approximation of patent value. Other measures, such as citations to previous patents and the breadth of patent protections, are also important in statistical terms. Additionally, these variables are even more appealing on purely practical grounds, since they are available relatively soon after the patent has been granted (Harhoff et al. 2002). Clearly, some of our results pose a number of questions for further studies. I cannot claim that the set of value correlates used here is complete, and additional variables or refinements of those I used already should be tested. However, at least the results of this study can improve our understanding of what determines the value of patents.

CHAPTER 7

MAJOR FINDINGS AND CONCLUSION

7.1 Summary of Findings

Radical changes have been observed in the patenting behavior of Japanese universities over the past 15 years. These changes have been driven by UIC policies regarding the Science and Technology Basic Plan that aimed at fostering the university-industry technology transfer and commercialization. As a consequence of these changes, this study provides empirical analyses of the impact of UIC policies on Japanese university patents. The summary of findings is as follows:

Chapter 3 provides a quantitative analysis of the attributes of university patents. Comparing between US and Japan, the analytical focus is on the attributes of university patents in terms of innovation basicness, appropriability, and time distance using patent citation data. A comparison of the two countries reveals remarkable differences in their patent attributes. The contrast in university patents between US and Japan includes both the difference in institutional type of assignee and in technology fields of patents.

Japanese university patents compose of a 50% of university assignee patents and a 50% of university co-assignee or UIC patents resulting from UIC policies while most of the US university patents are university assignee patents. The Majority of US university patents are associated with the technological fields of chemistry, human necessities, and physics. The majority of Japanese university patents are associated with chemistry, electronics, and physics, respectively. Additionally, I find evidence that US university patents have a higher degree of basicness than Japanese university patents; however, the spillover effect of Japanese university patents is faster.

Chapter 4 discusses the impact of UIC policies on the changes in Japanese university patents. The objective is to systematically construct, quantify, and characterize the unique attributes of Japanese university patents under different types of assignees through quantitative analyses of university patents before and after UIC policies implementation. The attributes of innovation basicness, appropriability, and time distance of patents were analyzed.

Using patent citation data, I find evidence that the measures of importance and time distance capture characteristics of the basicness of innovations underlying university assignee patents. Moreover, the attributes of UIC patents indicate that they have superior appropriability, and thus better enable inventors to benefit relative to university assignee patents. Additionally, the results indicate that UIC policies significantly impact the increase in university patents, including both UIC and university assignee patents.

Comparing the situations before and after the implementation of UIC policies, before 1998 UIC patents had greater significant value of *IMPORTF* than university assignee patents. However, this is due to there was a small number of UIC patents in that period but they had a large impact to *IMPORTF* value. After 1998, university assignee patents presented the higher value of *IMPORTF* than UIC patents. This result confirms the underlying presumption regarding basicness of university assignee patents. In addition, university assignee patents also reflect the characteristic of basicness with the significantly longer in producing offspring. However, after the implementation of the policy, UIC patents exhibit stronger appropriability than university assignee patents.

Chapter 5 analyzed knowledge diffusion from universities to industry using patent citation. Regarding a large increase in the number of university patents that we have observed, this effect has addressed the concern as to whether this growing number of university patents has facilitated increased technology transfer and spillover effects or whether it represents simply increased patents on marginal inventions. Concerning this issue, the study focuses on a model to describe knowledge diffusion as the process of generating subsequent citations of patents.

In this chapter, the institutional comparisons between two distinct sources of potentially cited patents were analyzed. The first involves Japanese corporations; the second is Japanese universities. This study finds that Japanese corporate patents are cited more often compared to Japanese university patents. However, the gap between them has continuously lessened since the mid-1990s, which correlated to the period of the first launch of the UIC policies in Japan. Additionally, evidence also reveals the growing number of both Japanese university patents and citations received that cause the diminishing gap between the citation frequencies with which Japanese industry cited corporate and university patents.

Chapter 6 provides detailed analyses on the patent value and value determinants. This chapter investigated the value of academic patents and compared their value determinants in US and Japanese university patents, as well as Japanese university patents with different assignees. In order to determine the value of patents, various measures have been developed and all of them can be derived from patent data directly.

I consider four broad value determinants including the technical background of patents, the distance of technology from the application date to present, and the breadth or scope of patent protection. The keys variables are the number of forward citations as a dependent variable and independent variables composed of the number of backward citations, years, claims, and IPC classes.

In this study, a comparison analysis using zero-inflated negative binomial regression has been proved based on the notion of the determinants of patent value. The results reveal that both the US and Japanese university patents share common determinants of value and all of the provided variables significantly impact the value of patents. More precisely, in the case of Japanese university patents, the evidence suggests that the breadth of patent protection (claims) significantly affects valuations but there is a difference in terms of the nature of patents between university assignee and UIC patents.

7.2 Policy Implications

The Japanese government has strongly committed itself to promote collaboration between universities and industry and has embarked on a series of reforms aimed at stimulating technology transfer from universities to industry. Since 1998, important reforms have been implemented to UICs in Japan. Significantly, Japanese universities have become autonomous corporations, able to assert ownership over their inventions. Evidence derived from all empirical analyses reveals that UIC policies are important for the effective enhancement of university-industry linkages in technology transferral. Japanese university patenting activities were heavily influenced by the dramatic growth and dispersion of government support for UIC policies. The characteristic of growth of Japanese university patenting after 2004 is the remarkable effect of UIC policies.

There are two possibilities to specify the growth in Japanese university patenting. First, UIC policies provide incentives for Japanese universities to expand their performance in pursuing the development of patent inventions as well as their patent portfolios. Second, UIC policies reduce the obstacles that inventors face in patenting their inventions and support them by encouraging universities to establish TLOs to assist patenting activities and to commercialize the inventions. However, Japan's UIC policies have only been implemented for a decade and a half, and effective patenting activities to support university–industry technology transfer remain a challenge for all those involved in innovation.

These findings have illuminated the Japanese university patenting debates and have important policy implications. Based on the above analysis, we can argue that Japan's new UIC policies have made it easier for research results at Japanese national universities to be patented. Patenting in Japanese universities has grown continuously since the Japanese government began to encourage UIC, and Japan's UIC policies have yielded impressive results in terms of collaboration and technology transfer between universities and industries. The comprehensive evidence deriving from a growing number of Japanese university patents and citations received from industry indicates the effective implementation of UIC policies.

However, the limitations of this analysis are apparent. In assessing the effect of UIC polices on Japanese university patents, the time lag to analyze the impact of the policies is quite short and may be not enough to provide concrete evidence since UIC policies have only been implemented for a decade and a half. Nevertheless, I believe that the results of this analysis underscore the importance of complementing analyses of aggregate data on Japanese university patents.

7.3 Contributions

This study provides a framework and builds a foundation for the study of academic patenting and UIC policies in Japan. Considering the impact of UIC policies on Japanese university patenting, this study is the first attempt to construct, quantify, and characterize the unique attributes of Japanese university patents under different institutional settings and provide a comparison analysis with its US counterpart. Additionally, this research is also the first effort of an investigation on the

technological knowledge diffusion from Japanese universities to industry.

This study has made a significant contribution to scholarship in UIC policies and academic patenting, as well as contributed to policy and practice. Through a methodological and a comprehensive empirical investigation of UICs and academic patenting, this study provides insight into the key impact of UIC policies affecting Japanese university patents and clarifies the university-industry technology transfer and spillover effects of university patents in Japan.

7.4 Limitations and Future Work

There is a limitation in the use of patent data, as mentioned in the literature review of patent analysis and the use of patent data: not all inventions meet the patentability criteria set by USPTO, thus not all patentable inventions are patented. Another drawback is the fact that informal tie of UIC in Japan and the difficulties of technology transfer previously affect the Japanese university patenting. Many university discoveries are transferred to the private sector informally and unaccounted for in any normal statistics. These informal channels lead to the problem that some productive faculty members do not know how many of their discoveries have been patented by companies (Kneller 1999). Additionally, these unaccounted statistics of university contributions can affect the rate of Japanese university patents.

However, the methods analyzed in this study could be used in order to further explore a number of patent analyses and make comparisons among different technological fields, geographic boundaries, and institution arrangements. This will provide an opportunity to extend the line of IP research into an interesting new area in the period that new technological development is becoming increasingly important and collaboration among innovative actors becomes an effective mechanism to drive economic growth.

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APPENDIX 1: Decomposition of Relative Citation Frequency

In this appendix, further results that can be derived from Equation 4 are presented. In Table A1, the growth rate of the relative citation frequency is shown in column LnR-LnR(-1). Even though some of them are negative, most of the figures present positive growth rate. The negative growth rate derives from the fact that the number of patents in that year grows faster than the number of citations that they received. This positive tendency is depicted as the upward trend in relative citation frequency in Figure 5.5.

The figures in column LnC-LnC(-1) represent the growth rate of the ratio of the number of citations received by university patents from Japanese industry patents to citations received by corporate patents from Japanese industry patents. We have clearly observed the positive growth rate since 1998 except only in 2001. Likewise, since 1998, we have obviously observed a continuously growing in the ratio of the number of university patents to corporate patents as reflected in the figures in column LnN-LnN(-1).

As these observations indicate that the year 1998 is the period that remarks the turning point of Japanese university patents, which correspond to the beginning of UIC policies. Both of the quantity and quality of Japanese university patents have increased and improved since 1998.

Table A1. Decomposition of relative citation frequency made by Japanese industry cited university patents to Japanese industry cited corporate patents between 1980 and 2008

	LnR	LnC	LnN	LnC-LnN	LnR-LnR(-1)	LnC-LnC(-1)	LnN-LnN(-1)
1980	-1.1334	-7.7237	-6.5903	-1.1334			
1981	-1.1256	-7.8002	-6.6745	-1.1256	0.0077	-0.0765	-0.0842
1982	-0.9080	-7.6643	-6.7564	-0.9080	0.2177	0.1358	-0.0819
1983	-1.2113	-8.0616	-6.8503	-1.2113	-0.3033	-0.3972	-0.0940
1984	-0.8322	-7.7009	-6.8687	-0.8322	0.3791	0.3607	-0.0184
1985	-0.9827	-7.8142	-6.8315	-0.9827	-0.1505	-0.1132	0.0372
1986	-0.8771	-7.7884	-6.9113	-0.8771	0.1055	0.0257	-0.0798
1987	-0.9573	-7.8559	-6.8986	-0.9573	-0.0801	-0.0674	0.0127
1988	-1.3077	-8.2510	-6.9433	-1.3077	-0.3504	-0.3951	-0.0447
1989	-1.2326	-8.1728	-6.9402	-1.2326	0.0750	0.0782	0.0031
1990	-1.1449	-8.1063	-6.9614	-1.1449	0.0877	0.0665	-0.0212
1991	-1.3234	-8.3307	-7.0073	-1.3234	-0.1784	-0.2243	-0.0459
1992	-0.9846	-8.0501	-7.0655	-0.9846	0.3387	0.2806	-0.0582
1993	-1.1628	-8.2268	-7.0640	-1.1628	-0.1782	-0.1767	0.0015
1994	-0.7305	-7.8479	-7.1174	-0.7305	0.4324	0.3789	-0.0535
1995	-0.9890	-8.1309	-7.1419	-0.9890	-0.2586	-0.2830	-0.0245
1996	-0.6513	-7.8417	-7.1904	-0.6513	0.3377	0.2893	-0.0485
1997	-0.6550	-7.8906	-7.2356	-0.6550	-0.0037	-0.0489	-0.0452
1998	-0.4772	-7.6933	-7.2161	-0.4772	0.1778	0.1973	0.0195
1999	-0.4757	-7.6320	-7.1563	-0.4757	0.0016	0.0613	0.0598
2000	-0.4900	-7.5784	-7.0885	-0.4900	-0.0143	0.0535	0.0678
2001	-0.5646	-7.6050	-7.0404	-0.5646	-0.0746	-0.0265	0.0480
2002	-0.5049	-7.5006	-6.9957	-0.5049	0.0597	0.1044	0.0447
2003	-0.5271	-7.4722	-6.9451	-0.5271	-0.0222	0.0284	0.0506
2004	-0.5177	-7.3895	-6.8717	-0.5177	0.0093	0.0827	0.0734
2005	-0.6140	-7.2465	-6.6325	-0.6140	-0.0962	0.1430	0.2392
2006	-0.5696	-6.9600	-6.3905	-0.5696	0.0444	0.2865	0.2421
2007	-0.5140	-6.6839	-6.1700	-0.5140	0.0556	0.2761	0.2205
2008	-0.2619	-6.2821	-6.0202	-0.2619	0.2521	0.4018	0.1497

Note:

LnR indicates the log of the relative citation frequency (P_{utT}/P_{ctT} in Equation 4). *Ln R(-1)* is the one-year lagged value.

LnC indicates the log of the ratio of the number of citations received by university patents from Japanese industry patents to citations received by corporate patents from Japanese industry patents (C_{utT}/C_{ctT} in Equation 4). *Ln C(-1)* is the one-year lagged value.

LnN indicates the log of the ratio of the number of university patents to corporate patents (n_{utT}/n_{ctT} in Equation 4). *Ln N(-1)* is the one-year lagged value.