

# Knowledge Diffusion from Japanese Universities to Industry Using Patent Citations

Kallaya Tantiyaswasdikul

**Abstract**—This study focuses on a model to describe knowledge diffusion from universities to industries by the process of generating subsequent citations to patents. 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 between 1980 and 2008 using a panel data of the United States Patent and Trademark Office (USPTO). The study 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 the mid-1990s, which correlated to the period of the first launch of the university-industry collaboration (UIC) policies in Japan.

**Keywords**—Knowledge diffusion, Japanese university patents, Japanese industry, patent citations.

## I. INTRODUCTION

**I**N the knowledge-based economy, innovation and new technological progress is 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 increasingly viewed as proactive contributors to technological development and economic growth [1]. 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 increased expectations that universities should contribute to the commercialization of research have led to several initiatives at the university level.

Regarding this importance, the Japanese government has considered and administered various policies to stimulate university-industry technology transfer for commercialization [2]. University-industry collaboration (UIC) policies have been implemented toward a network-based approach to revitalize the national innovation system [2]–[4]. 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 UICs and intellectual property (IP) management,

and the Third Science and Technology Basic plan (FY 2006-2010) that reorganized the major tools for innovation.

The significant laws resulting from UIC policies include (1) The 1998 Law to Promote the Transfer of University Technologies, which supports the establishment of technology licensing organizations (TLOs); (2) The 1999 Law of Special Measures to Revive Industry (The Japanese Bayh-Dole Law), which allows universities to obtain intellectual property rights (IPRs) to inventions acquired from publicly funded research; (3) The 2000 Law to Strengthen Industrial Technology, which simplifies procedural requirements for external funding in Japanese national universities; and (4) The 2004 University Incorporation Law, the most important law, which the Japanese government incorporated the national universities as independent administrative entities [2], [4].

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 Ministry of Education, Culture, Sports, Science and Technology (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 [5]. Additionally, based on data obtained from the online records system of the United States Patent and Trademark Office (USPTO) (Accessed 28 February 2014), 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.

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. The remainder of this paper is organized as follows: Section 2 describes patent citations as indicator of knowledge diffusion. Section 3 outlines the model specification used to estimate the citation frequency of industry patents to corporate patents and university patents. Section 4 presents empirical analysis and findings. The last section is the conclusion.

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## II. PATENT CITATIONS AS INDICATOR OF KNOWLEDGE DIFFUSION

Knowledge diffusion has received significant attention in the economics, management, and public policy literature, especially since the works of Romer [6] and Grossman and Helpman [7] discussed models of how endogenous economic growth with knowledge was treated as completely diffused within an economy. To estimate knowledge flow and knowledge 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 [8]–[12].

Patent analysis has long been considered a rich data source from a few standardized approaches for the study of innovation and technical change [13]–[16]. Additionally, patent citations have been used increasingly in the study of knowledge flows and knowledge diffusion. Citations can be used for many purposes, including tracing the process of technology development and evaluating the importance of a patent [13], [16]. Moreover, citation data can provide significant evidence that reveals the links between an innovation and its technological antecedents and descendants clearly [16], [17].

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 [9], [10], [18]–[20]. Moreover, Sampat [21] 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. Regarding this argument, this paper focuses on the investigation of knowledge diffusion from Japanese universities to industry using a model to describe knowledge diffusion by the process of generating subsequent citations to patents.

### III. 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 [10], adapted from the formulation of Caballero and Jaffe [22] that was created to estimate parameters of the diffusion process while controlling for variations over time in the propensity to cite of patents.

In this paper, I consider the following as attributes of the cited patent 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 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 as in

$$P_{itT} = \frac{C_{itT}}{(n_{it})(n_T)} \quad (1)$$

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 (1) 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.

### IV. EMPIRICAL ANALYSIS AND FINDINGS

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. 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).

The comparative result of citation frequency between Japanese industry patents and university patents and corporate patents is presented in Fig. 1. The trend reveals that corporate patents are more cited by industrial sectors than the university

patents. The trends in Fig. 1 derived from (1), which is an equation to calculate the propensity to cite or citation frequency ( $P_{utT}$ ). It must be emphasized that Fig. 1 does not show the tendency of citation frequency from 1980 to 2008; it demonstrates a comparison of citation frequency that Japanese university patents and corporate patents received from industry at one time.

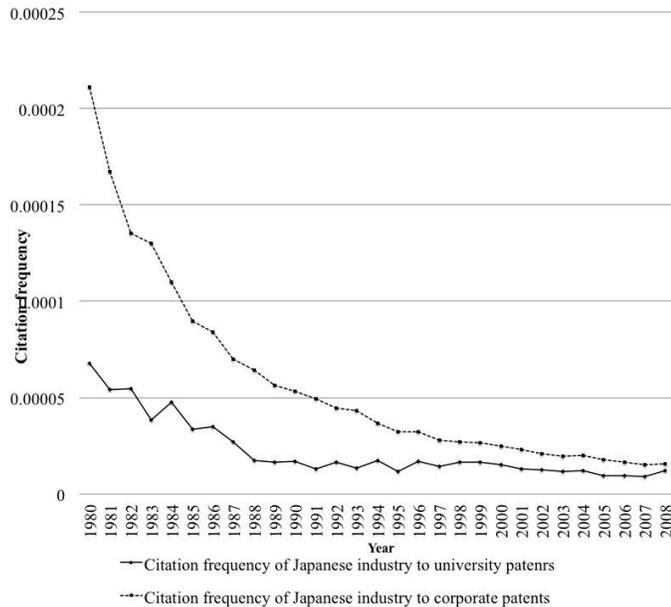


Fig. 1 A comparison of citation frequency trends between Japanese industry to university patents and corporate patents from 1980 to 2008

Source: Based on data obtained from the online records system of USPTO website; <http://www.uspto.gov/patents/process/search/> (Updated 28 February 2014).

Fig. 1 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 Fig. 1 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 (1), 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 presented as in

$$Relative\ citation\ frequency = \frac{P_{utT}}{P_{ctT}} \tag{2}$$

Fig. 2 shows the results deriving from (2), 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 Fig. 1. 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 Fig. 1 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.

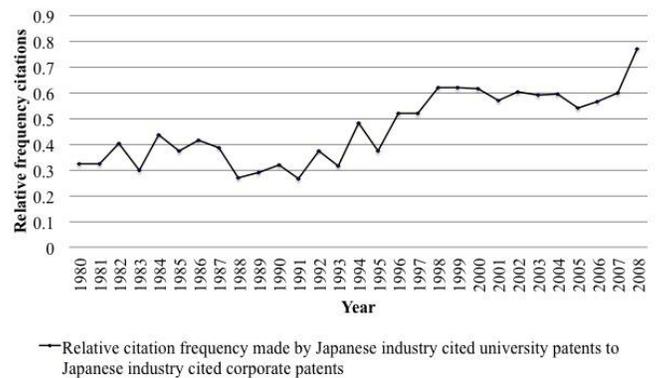


Fig. 2 The trend in relative citation frequency made by Japanese industry cited university patents to Japanese industry cited corporate patents between 1980 and 2008

Source: Based on data obtained from the online records system of USPTO website; <http://www.uspto.gov/patents/process/search/> (Updated 28 February 2014).

In order to understand the upward trend in Fig. 2 that causes the reduced gap in Fig. 1, a decomposition of (2) to reveal how this upward trend derived is required. Two more graphical representations resulting from the expanded equation of (2) have been created, which are described as in

$$Relative\ citation\ frequency = \frac{P_{utT}}{P_{ctT}} = \frac{\frac{C_{utT}}{(n_u)(n_T)}}{\frac{C_{ctT}}{(n_c)(n_T)}} = \frac{C_{utT}}{n_c} \cdot \frac{n_c}{n_u} \tag{3}$$

(3) I decompose the ratio of citation frequency that Japanese industry cited university patents to citation frequency that Japanese industry cited corporate patents. 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 and the denominator is the ratio of the number of university patents to corporate patents. The trend of the ratio of the number of university patents to corporate patents is presented in Fig. 3 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 is shown in Fig. 4.

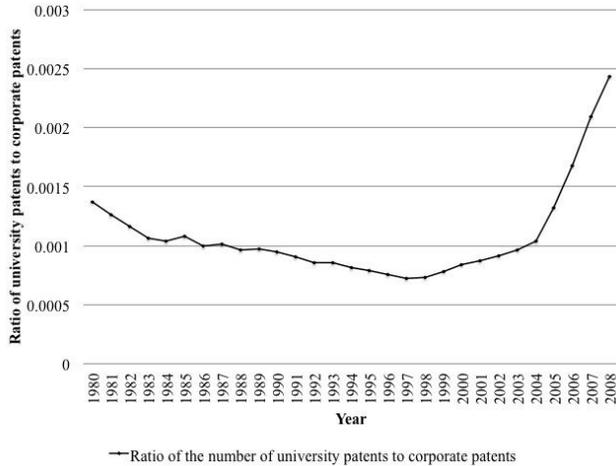


Fig. 3 The trend in ratio of the number of university patents to corporate patents between 1980 and 2008

Source: Based on data obtained from the online records system of USPTO website; <http://www.uspto.gov/patents/process/search/> (Updated 28 February 2014).

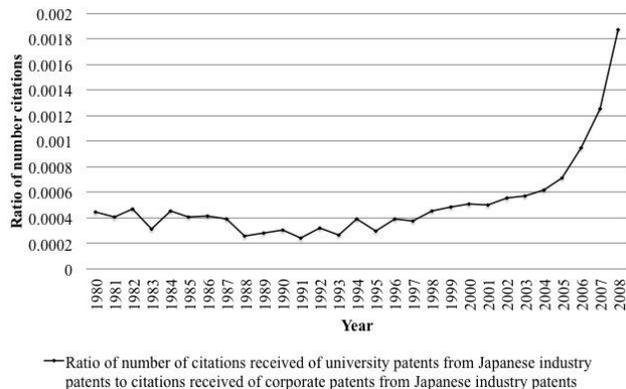


Fig. 4 The trend of ratio of number of citations received by university patents from Japanese industry patents to citations received by corporate patents from Japanese industry patents

Source: Based on data obtained from the online records system of USPTO website; <http://www.uspto.gov/patents/process/search/> (Updated 28 February 2014).

Fig. 3 and 4 explain the upward trend in Fig. 2 that causes a reduced gap between citation frequency of Japanese industry to corporate patents and to university patents in Fig. 1. From Fig. 3, 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. Fig. 4, 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 Fig. 2. On the other hand, the upward trend in Fig. 2 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.

The trend in Fig. 3 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 Fig. 4 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 [23]. Patent citations denote that the citing patents have found utility value in the cited patents [24]. Thus, the number of citations received can specify the value of patents.

Fig. 3 and 4 provide evidence to confirm the result of the comparison of citation frequency trends between Japanese industry to university patents and to corporate patents. 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, where the gap has diminished since the early 1990s.

The trend in the ratio of the number of university patents to corporate patents (Fig. 3) 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. 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 (Fig. 4) 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.

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 [25]. 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 [25]. Additionally, these unaccounted statistics of university contributions can affect the rate of citation frequency that Japanese industry made to university patents.

#### V. 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.

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