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Examining the University Industry Collaboration Policy in Japan: Patent analysis

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Examining the University Industry Collaboration Policy in Japan: Patent analysis*

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Abstract

This study is a quantitative analysis of Japanese patent information to examine the changes in the nature and the outcome of university–industry collaborations (UICs) following the enactment of UIC policies in the late 1990s. By considering UIC patents not only in joint university–industry patent applications but also in joint inventions organized by university personnel and corporate researchers, we discuss the status of UICs before the incorporation of national universities. Our analysis indicates that these policies increased the number of UIC patents in the late 1990s. However, strong IP policies pursued by universities may reduce the incentive for firms to commercialize inventions resulting from UIC collaborations.

Keywords: university–industry collaboration, patent analysis, university reform, and Japan.

JEL classification: L14; O34

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1. Introduction

Since the enactment of the Act on the Promotion of Technology Transfer from Universities to Private Industry (the “TLO Act”) in 1998, Japan has implemented various policy measures to promote university–industry collaboration (UIC). Following the incorporation of national universities in 2004, the number of joint research projects nearly doubled: from 9,225 (funds received: 21.6 billion yen) in fiscal year (FY) 2003, before incorporation, to 17,638 (funds received: 42.0 billion yen) in FY 2009. Patent applications by universities increased as well: national universities that underwent incorporation witnessed a sharp rise in patent application numbers, from 918 in FY 2003 to 5,033 in FY 2009. The number of patent applications also increased at private universities also increased, suggesting that the series of UIC policies implemented since the late 1990s have achieved a certain measure of success (MEXT, 2010).

With most public research and development (R&D) funds currently earmarked for universities and public research organizations, promoting UIC is essential for converting this public R&D investment to industrial and economically significant innovations. Moreover, through joint research with companies, university faculty can gain a deeper understanding of R&D activities within industries that are related to their research interests and develop research agendas with concrete goals for innovation, such as designing a new product or a new manufacturing process. In turn, faculty exposure to industry activities can potentially increase the likelihood of universities and other public institutions that conduct R&D activities, leading to industrial innovations.

However, research activities in universities should not be limited only to the areas that leads to direct applications at industry. While universities, public research organizations, and corporations play individual roles in the system of national innovation, universities are generally expected to pursue research in basic areas in which companies are ill-equipped to address. The role of universities is to open up academic frontiers and produce research results with long-lasting and large spillover effects over a wide range of disciplines. Stronger university incentive to engage in UICs may affect research, giving it a more practical focus and possibly leading to the neglect of basic research, which is the natural domain of university research. Some research suggests that although the number of patent applications by universities increased in the US following the enactment of the Bayh–Dole Act in 1980, the quality of the patents declined, because excessive focus on commercializing research results led to a neglect of basic research, which universities should certainly focus on (Henderson et al., 1998; Rosell and Agrawal, 2009).

Drawing on Japanese patent database, this study provides a quantitative analysis of how UICs have changed since UIC policies were introduced in the late 1990s. In doing so, we examined not only joint patent applications filed by universities and industry but also patents resulting from UICs by tracing the path back to the inventors. This is due to the severe restrictions set by the national universities regarding the ownership of intellectual property before their incorporation in 2004. In many cases, companies ended up filing patent applications alone, even when the results were obtained through UIC. In such cases, we can more accurately grasp the status of UIC from patent data if we can determine that a university professor or any such individual is named as an inventor. We analyze how these UICs changed in nature after the introduction of UIC policy measures, what differences resulted from corporate partners of varying sizes, and whether the changes led to specific problems. We also compare these differences with the traditional process of patent applications by companies alone, even in cases where universities were involved in the invention process.

This paper is structured as follows. We begin by discussing the evolution of UIC policies in Japan in the next section, providing a historical review of UICs that predate the introduction of the US-style UIC system in the late 1990s and examining the institutional changes that followed. We then discuss the database used and the hypotheses assumed for the analysis. Using the IIP Patent Database, we identified patents for which a joint application was made by universities and industry as well as those for joint university–industry inventions for which university personnel and corporate researchers were jointly responsible. In Section 4, we discuss the results of our analysis and verify the hypotheses formulated in Section 3. Finally, we summarize the results of our research to date and discuss policy implications.

2. University–industry collaboration policy in Japan

UICs have been a policy focus in Japan since the late 1990s; however, this partnership has a long history. In pre-war Japan, when the main goal was to introduce advanced knowledge from foreign countries, UICs and technology transfers from universities were undertaken as a normal procedure. During this period, in numerous cases, university academicians played an active role in starting businesses, and technology transfers often involved the licensing of patents held by university teachers. These cases include the establishment of Hakunetsu-sha (current Toshiba) by Ichisuke Fujioka, Assistant Professor at Kogakuryo, and the development of *Ajinomoto* by entrepreneur Saburosuke Suzuki, who acquired exclusive rights to a patent on glutamic acid, the *umami* compound of a *kombu* seaweed broth, for which Tokyo University professor Kikunae Ikeda had applied (Baba and Goto, 2007).

Following the war, the number of UICs declined because of concerns related to the role played by the military, industry, academia, and government in Japan's militarization as well as student protests against UICs. Even during this period, however, the UIC system underwent revisions: The 1961 Act on Research and Development Partnership concerning Mining and Manufacturing Technology paved the path for government-led joint research by universities, industry, and the government. A contract research system with firmswas introduced in national universities in 1970. Moreover, university–industry relationships were informal at the level of individual faculties such as scholarship funding and student employment sponsored by companies (Branscomb et al., 1999).

The system of joint research involving universities and the private sector was launched in 1983, and marked the beginning of official joint research activities—as opposed to contract research—between researchers from industry and academia. Policies encouraged the establishment of joint research centers; joint research funding increased more than six-fold during the period 1983–1991 along with the number of projects and joint patent applications (Yamamoto, 1997).

At the beginning of the 1990s, Japan introduced a UIC system modeled on the basis of that of the US. The foremost driving factor for this change was the belief that high-tech areas receiving technology transfers from universities (e.g., IT and biotechnology industries) had become the drivers of growth in the US economy, which continued to grow in contrast to the Japanese economy, which continued to stagnate from the start of the decade. Another significant factor was the renewed recognition of the importance of UIC by corporations, as scientific research results obtained by universities began to find applications in corporate R&D processes (e.g., in the field of biopharmaceuticals). Furthermore, with Chinese and Korean firms rapidly closing the gap created by persisting economic weakness in Japan, companies encountered difficulties in maintaining their in-house R&D model. Against this backdrop, the Science and

Technology Basic Law was enacted in 1995. The First Science and Technology Basic Plan (1996–2000), which was based on this law, subsequently implemented various policies, including the UIC and the promotion of the transfer of research results achieved by the state to the private sector. In the context of these policies, attention was paid to the method of transferring research results to the private sector through the system of technology licensing organizations (TLO) adopted by US universities and through the application of US models to Japan, as exemplified in the 1980 Bayh–Dole Act.

Table 1 shows the evolution of the UIC policy in Japan since the late 1990s. The Act on the Promotion of Technology Transfer from Universities to Private Industry (the "TLO Act") was enacted in 1998. The policy of promoting TLOs to activate technology transfers was spelled out on the basis of this Act, and 47 TLOs approved by MEXT and METI were established by 2009. The Act on Special Measures for Industrial Revitalization (the "Japanese Bayh–Dole Act"), which was enacted in 1999 and modeled on the Bayh–Dole Act enacted in the US in 1980, allowed universities to retain title to inventions resulting from state-funded research. In Japan, however, many research universities were national universities; therefore, restrictions on retaining rights to invention were applied. As one of state organizations, national university had to comply with strict restrictions, applied to the assertion of their rights with regard to patent filing. Universities rarely filed patent applications, and in cases where inventing was a part of a university research scientist's academic duties, the rights to inventions were generally vested in the individual, i.e., the professor, and not the organization.

(Table 1)

To address these problems, national universities were incorporated in 2004, and restrictions on technology transfers were relaxed significantly. A mechanism was introduced to create competition among universities: University budget were paid in a lump sum as an institutional discretionary fund for operating expenses. The total amount of the institutional fund was steadily reduced while competitive funds were expanded. Because the funds for joint research undertaken with the private sector constitute an important source of income for universities, there was a shift in their identity as corporations significantly increased the incentive for universities to engage in UICs. In addition, incorporation made it possible for universities to own intellectual property as an organization. The 2002 Outline of Intellectual Property Strategy spelled out a principle whereby the title to inventions devised by university employees was vested in the university as a corporation, rather than in the individual inventor. From FY 2003, MEXT promoted the establishment of "Programs for the Establishment of University Intellectual Property Offices" to support intellectual property activities in universities, and the operational framework for and management of intellectual property in universities were put in place; principally at 34 universities whose programs were accepted in the MEXT's solicitation of bids.

As described above, the series of UIC promotion policies devised a method for establishing university ownership of university research results and transferring the resulting technologies to the private sector through licensing agreements with corporations. It has become a common practice for companies and universities to co-own the results of joint research as specified by contractual agreements. This arrangement transformed the nature of UICs from informal relationships between companies and individual researchers (that is, results of joint research would be owned by the company as intellectual property, while the academic researcher would be compensated through scholarship donations and other means) to formal collaborations on a contractual basis, with the university patent office serving as the intermediary.

Opinions regarding the appropriateness of this policy shift are divided. Critics indicated the following issues with the traditional informal method (Kneller, 2003).

- Because the format of the technology transfers was not accompanied by well-defined contracts between companies and universities, companies had a weak incentive to develop the transferred technologies to the point of commercialization.

- The transfer of intellectual property rights through informal technology transfers made it difficult for university spin-out firms to launch commercial operations based on the research results.

- Because the research results obtained in state-subsidized projects are vested in the state, they are not readily commercialized even for joint research.

While the enactment of the Japanese Bayh–Dole Act resolved the last issue, the items listed suggest that joint research in a framework of ambiguous contractual relationships can lead to significant delay on the part of companies at the time of commercialization.

On the other hand, research results under the informal UIC method depended on relationships of trust between university and corporate researchers (Zucker and Darby, 2001). With more direct involvement of universities, previously smooth cooperative relationships occasionally became awkward. For instance, when the results of joint research are jointly owned as intellectual property, the university typically demands that the company pay certain non-licensing fees (or an equivalent monetary compensation in place of licensing fees, should the company choose not to license the intellectual property in question). The company is also compelled to obtain consent from the university to license intellectual property, given the joint nature of co-ownership. A university is thus capable of halting progress regarding the practical application of research results by simply asserting its rights. Given the significant asymmetry of information between businesses and universities in UICs, a clear and proximate communication is essential. This is one reason why cases of collaboration between partners in geographical proximity are so common (Abramo et al., 2010). However, some believe that if considerable emphasis is placed on the contractual relationship, useful results will become less likely. Others believe that we are in a period of transition from the informal method to the contractual method and that the coexistence of the two systems understandably raises issues (Takata, 2009). Although the number of joint university–industry projects has increased with progress in UICs, the average size of such projects remains unchanged, at around 2.5 million yen. Takata claims that the sum is small because of the informal nature of the current relationships, and those companies are yet to work out how to best position a big budget, contractual approach to university collaborations.

3. Literature surveys

Numerous empirical studies have examined the nature of UICs. Here we survey studies that focus on how UIC policies have affected the nature of research in universities, the topic of this study. [1] The enactment of the Bayh–Dole Act in 1980 in the US sharply increased the number of patents held by universities, and several studies have analyzed the nature of these patents. The Bayh–Dole Act was based on certain assumptions, including the idea that valuable technologies generated by universities were left untapped, and converting such discoveries into intellectual property licensed by universities to the commercial sector would contribute to the industry. While the enactment of the measures did increase the number of university patents, the quality of

[1] For a survey covering UIC in general, see Foray and Lissioni (2010).

these patents is less certain.

Using 19,535 university patents registered with the USPTO (US Patent and Trademark Office) during the period 1965–1992 and a random sample of 1% of the patents registered with the USPTO during the same period (40,859 patents), Henderson et al. (1998) evaluated changes in the quality of university patents by examining changes in importance and generality, as measured by forward citations. University patents generally exhibited higher scores for importance and generality than ordinary patents. However, such differences existed at a statistically significant level only until around 1982. Neither indicator exhibited statistically significant differences thereafter, indicating that while the number of university patents had increased sharply, their importance and generality declined in relative terms. While possible explanations include the entry of universities lacking patent experience or a general decline in the quality of research, the research by Henderson et al. concludes that the Bayh–Dole Act and other policies strengthening the patent-filing incentives for universities also encouraged efforts to seek legal standing for low-quality patents.

Advancing a counterargument, Sampat et al. (2003) used the same sample as Henderson et al. (1998), but expanded the estimate beyond 1992 to include citation data through 1999. They observed no decline in the importance indicator and argued that the result obtained by Henderson et al. reflected a truncation problem in the citation data. Characteristically, university patents tend to have a longer citation lag compared to company patents, so the data must be obtained over an extended period to clearly assess the number of citations.[2]

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[2] While some studies argue that the significance of citations differs depending on when the citation was made, opinions are divided as to which ones are more significant. Lanjouw and Schankerman (2004), among others, maintain that early citations are more valuable, whereas Hall et al., (2005), among others, maintain that late citations are more valuable.

In a reassessment, Mowery and Ziedonis (2002) classified the estimates by Henderson et al. (1998) into three groups: (1) universities that had applied for patents before the Bayh–Dole Act was enacted and held ten or more patents; (2) universities that had applied for patents before the Bayh–Dole Act was enacted but held fewer than ten patents; and (3) universities that had applied for patents only after the enactment of the Bayh–Dole Act. Demonstrating that the value of the patents declined only in categories (2) and (3), and not in (1), they argued that despite the apparent decline in the overall quality of university patents following the influx of universities lacking patent application experience following the Bayh–Dole Act, the quality of patents by top universities did not decline. Despite the spike in the number of university patents following the Bayh–Dole Act, these numbers declined after a peak around 2000, prompting some observers to argue that the importance of university patents may have declined (Leydesdorff and Meyer, 2010).

Did the Bayh–Dole Act affect the nature of university research? Did greater incentives to commercialize research results lead to neglect in basic research, the natural domain of universities and most companies' area of weakness? Rosell and Agrawal (2009) examined changes in the concentration of citations of university inventions, considering the signs of reduction in the flow of patented university knowledge. They observed that the citations of university patents showed statistically significant lower levels of concentration than those of corporate patents, a difference that disappeared from 1983 onward. While suggesting a reduction in the flow of university-generated knowledge, this tendency was particularly pronounced in the pharmaceutical and bio fields. No major differences were observed in other disciplines. On the other hand, based on the results of a questionnaire survey, Thursby and Thursby (2002) argued that universities adopted a more entrepreneurial approach by aggressively pursuing the commercialization of their technologies.

This US model for UIC has not only spread to Japan but also to Europe. Mowery and Sampat (2005) argued for the limited impact of the Bayh–Dole Act on university patents in the US, pointing out that patent applications filed by universities in the US had been already increasing before its enactment. Regarding the potential spread to other countries, they argued that US universities have traditionally enjoyed close relationships with non-government-owned organizations and the private sector. Adopting such policies in other countries that lack such environment might result in limited impact. They went on to argue that despite the adoption of policies inspired by the Bayh–Dole Act in OECD countries (Denmark, Germany, France, Canada, Japan), implementing such policies based on the US model tends to ignore the central premise of the Bayh–Dole Act, the transfer of publicly-funded research results from the state to universities, while focusing instead on "vesting inventions by university researchers in the universities."

Goldfarb and Henrekson (2005) compared the policies on commercializing university intellectual property adopted by the US and Sweden, countries that budget comparably higher for university R&D but use different models to commercialize research results. Analyzing the mechanisms for the technology transfer of university intellectual property, they argued that Sweden failed to commercialize university intellectual property because of ineffective incentive structures in universities. Although the transfer of technology from universities requires the active involvement of university inventors, the transfer of technology in and of itself does not constitute academic achievement. Although the US model through the Bayh–Dole Act and other means provides universities with incentives to address commercial opportunities, it usually adopts a bottom-up approach that allows universities to determine their own optimal solution through trial and error. They also argue that ownership of intellectual property rights by universities, rather than by inventors, provides inventors with incentives to commercialize technologies and that university TLOs provide effective support for patenting and intellectual property licensing activities. In the Swedish model, they argued that the government establishes intellectual property policies on behalf of the universities and leaves them with little autonomy, as in other European countries. Because the US model is premised on competition among university faculty and among universities, they effectiveness of Swedish approach, simply expands the rights of universities without changing whole university system, is questionable.

These studies focus on the different ways in which universities operate in the US, Europe, and Japan, as well as on their respective institutional aspects. They do not apply systematic analyses based on patent data, as in the case of the studies conducted in the US by Henderson et al. (1998) and Sampat et al. (2003). Tamada and Inoue (2007) investigated changes in the number of joint patent applications filed by universities or public research organizations and by the private sector, and demonstrated that UIC patents increased in number consistently after 1972 and accelerated in the late 1990s. Kanama and Okuwada (2008) performed a detailed analysis of university patent applications filed by Tsukuba University, Hiroshima University, and Tohoku University. Despite differences in the scale and area of focus with regard to intellectual property activities at the three universities, the authors noted a common phenomena; increase in the number of joint applications and decrease in the number of corporate patent applications naming university researchers as inventors.

Baba and Goto (2007) summarized the changes that occurred in universities with regard to UIC activities. Using a questionnaire survey of Tokyo University’s engineering and biological sciences faculties (questionnaires sent to 715 individuals and collected from

402), they examined how institutional reforms intended to promote UICs affected those collaborations that occurred during the five-year period of 1998–2003,while the reforms were occurring. Investigating whether university researchers engaged in joint research with researchers from other organizations, they showed that in 2003, university researchers often cooperated with researchers from other universities (85%) and researchers from large domestic firms (79%), and that relationships with small- and mid-sized enterprises (SMEs) increased notably following changes in the system (30%-51%). With regard to the activities that lead to commercialization and pursued by academicians in cooperation with companies, they showed that at least 60% researchers had filed at least one patent application, while 20% or more had executed a license agreement. Another finding was the continuing and widespread practice of traditional informal collaboration. Comparing top researchers (defined as those in the top 10% of the researchers covered by the study in terms of the average number of annual research publications in the preceding ten years) with other researchers, the authors observed that the former were more actively involved in commercialization. Overall, the study argued that at the level of the individual researcher, academic research and UICs are not necessarily bound in a trade-off relationship.

To analyze patents associated with UICs in Japan and Europe, we must trace inventor information, rather than simply examining joint applications. Until the introduction of the US-style contract model, patents resulting from UICs were often filed by companies alone. These cases can be identified as UICs because the academic inventors involved are named among the inventors. Lissioni et al. (2008) identified academic inventors named in patent data for Italy, France, Sweden, and Denmark, indicating that examining joint application data alone underestimates the role played by the universities in innovation. No similar study has been conducted for Japan. By taking a similar approach to identify university inventors in Japanese patent data, our study closely evaluates the UIC policies' effects on university research since their introduction in the late 1990s.

4. Data and underlining hypotheses

Using Japanese patent data, we quantitatively assessed how the technological value and the results of UICs changed in nature following the implementation of UIC policies in the late 1990s. Like Henderson et al. (1998) and Sampat et al. (2003), among others, we examine the changes brought about by UIC policies in patent characteristics.

The patent data used in this study was extracted from the IIP Patent Database, a database published for research use and based on the *Seiri Hyojunka Data* (organized and standardized data) released by the Japan Patent Office (Goto and Motohashi, 2007). The data in the IIP Patent Database is generally updated once a year. We use the database version containing the data released in September 2009.

When dealing with patents as the outcome of UICs, one must examine corporate patents that involved university personnel (known as *jointly-invented* university–industry patents) by tracing inventor information, as well as the patents for which applications were filed jointly by industry and academia (known as *joint-application* university–industry patents). Postal address information is used to identify inventor attributes. Corporate inventors often use company addresses, such that it is relatively easy to determine their attributes. In contrast, university researchers tend to give personal residential addresses, particularly in cases where national universities are involved before incorporation, thereby making identification more difficult. Inventors giving personal residential addresses are individual inventors, corporate inventors, or inventors belonging to universities or public research organizations. Corporate inventors or inventors at public research organizations are less likely to give personal residential addresses, while individual inventors generally name themselves as applicants. Therefore, a patent, applied by a corporate and co-authored by inventors with corporate address and ones with personal residential addresses, is likely to be a joint inventions university-industry patent. Certainly, this is only a rule of thumb. Close investigation of data identifies certain corporate patents in which the inventor is not affiliated with the corporation. In this study, we extract joint invented patents by minimizing errors associated with the rule of thum above, by using the information of the share of joint application university and industry patents by company and application year. The methodology for extracting jointly invented university–industry patents is detailed in the appendix.

Figure 1 shows changes in the number of extracted UIC patents. The number of patent applications filed jointly by universities and companies increased, whereas the number of jointly-invented patents decreased after 2003. This is due to the incorporation of national universities in 2004, when national universities started to claim joint-applicant status, and when informal UICs were being supplanted by formal arrangements. Despite changes in patent applications, the overall number of UIC patents increased.

(Figure 1)

This study focuses on the effects of UIC policies around 2000, so that we use only patents applied in or after 1990. We extracted a total of 87,927 patents, consisting of 72,050 joint university–industry inventions and 15,877 joint university–industry applications. We performed our assessments using a “difference in difference” model: that is, we compared the characteristics of these patents, as expressed in relative patent value indicators (the “difference”)—relative to the value of patents resulting from research by companies without university collaboration, called unassisted corporate patent, hereafter—before and after the introduction of UIC policies. Moreover, for each UIC patent, we randomly extracted unassisted corporate patents belonging to the same IPC sub-classification and year of application, using these patents as a control group. Using patents of the same technology classification and year of application allows us to avoid the differences attributable to the technological classification of patent-citing data and data truncation biases.

We used the following six indicators to evaluate patent value and characteristics:

- Number of claims
- Number of inventors
- Number of forward citations (further classified into the number of forward self-citations and the number of forward non-self citations)
- Generality index

The number of claims refers to the number of claims contained in one patent; this figure may be regarded as the volume of technologies to which the patent claims rights. In 1988, Japan introduced a revised multiple claims system, which caused the number of claims per patent to increase gradually. By using control groups consisting of patents for which applications were filed in the same year, we avoid biases resulting from changes in the system. The number of inventors refers to the number of inventors named in one patent. In corporate patents, this refers to the number of individuals participating in the project related to the patent, indicating the significance of the project. It is worth noting that in the case of university patents, some argue that major patents tend to be associated with fewer inventors for confidentiality considerations (Sapsalis et al., 2006). A patent cited in numerous subsequent patents is regarded as having had a more significant technological impact. Thus, many studies use the number of forward citations as an indicator of a patent's technological value (Trajtenberg, 1990; Lanjouw and Schankerman, 1994; Trajtenberg et al., 1997). Our study uses the number of forward citations as an index of a patent's technological value, further classifying this number into the number of forward self-citations and the number of forward non-self citations in order to determine the parties impacted by the technology. Where Patent A is cited by Patent B, and the applicants for Patents A and B are identical, the citation is a forward self citation. The citation is a forward non-self citation if the applicants are different. Where the number of forward self-citations is large, we may assume that the patent is valuable, particularly for the applicant, and that in the case of a company, the technology most likely involves a field that is closely related to the company's commercial or R&D domains. In contrast, if the number of forward non-self citations is large, the patent is more likely to be a general-purpose technology that also happens to hold value for companies and entities other than the applicant. Generality indicates the breadth of fields in which the patent is cited: the higher the value, the more general and fundamental the technology (Trajtenberg et al., 1997).

Table 2 presents descriptive statistics for the six indicators for each patent pair extracted above. While all patent indicators used in this analysis are calculated on a patent-by-patent basis, the number of forward self-citations and forward non-self citations are calculated on a patent-by-patent-and-applicant-by-applicant basis. We create these indicators by simply summing the citation combinations on both the citing side and the cited side, rather than by partial counting; that is, by allocating the number of citations proportionally on the basis of the number of applicants. The figures for forward citations, forward self-citations, and forward non-self citations include zero values.

There are many missing values when the number of forward citations is zero because generality cannot be calculated in such cases. The technology classification used to calculate generality here comprises the 33 groups used in the IIP patent data (Goto and Motohashi, 2005). The mean values in Table 2 indicate that UIC patents have higher values than unassisted corporate patents for the number of inventors, the number of forward citations, and generality, while showing lower values for the numbers of claims and forward self-citations. In short, UIC patents tend to be more for general-purpose, with wider spillover effects than unassisted corporate patents.

(Table 2)

In our analyses based on this data, we establish three broad hypotheses. First, we expect UIC patents to have higher technological value than unassisted corporate patents, as measured by the number of forward citation patents, because UIC patents constitute the results of research tapping a broader knowledge base through collaboration with universities. From a company's perspective, R&D in core technology areas tends to be conducted in-house, whereas R&D conducted in collaboration with universities and other external parties tends to focus on areas that expand the company's technological frontiers by involving new technologies (Motohashi, 2008). UIC patents are supposed to have wider spillover effects that extend beyond the involved companies compared to corporate patents. Furthermore, universities engage in basic research, which tends to lead to broader applications for the resulting technologies. In light of these findings, we would expect UIC patents to be more fundamentally valuable (have greater applicability and potential for future research) than unassisted corporate patents. We would also expect that increased incentive to commercialize university technologies resulting from UIC policies in the late 1990's would weaken the strengths of UIC patents. These hypotheses are summarized below:

H. 1-1 UIC patents have greater technological value than unassisted corporate patents.

H. 1-2 UIC patents have far-reaching spillover effects extending beyond the companies that invented them.

H. 1-3 UIC patents tend to be more fundamentally valuable.

H. 1-4 These trends have weakened since 2000, when UIC policies were implemented.

The next hypothesis is based on the supposition that the purpose and outcome of UICs vary depending on the size of the company, among other factors. Motohashi (2005) argued that the objective of UICs for SMEs, which have limited in-house R&D resources, is to acquire technologies that can be readily incorporated into their product development. In contrast, large companies seek basic/fundamental technologies based on long-term innovation strategies. Motohashi showed SMEs experience larger productivity gains than large companies, reflecting the different focus of each group's R&D activities. However, given the more rigorous management of intellectual property by universities and more contracts governing joint research, particularly with the incorporation of national universities, we may assume that companies have shifted their joint research from fundamental areas to more practical areas involving product development. In contrast to the focus on more wide-ranging joint basic research of previous years, this shift has made more efficient use of UICs and can be seen more in smaller firms; we can see that UIC activities have intensified after the late 1990s, particularly for SMEs (Baba and Goto, 2007; Motohashi, 2005). These UIC activities are summarized as follows:

H. 2-1 UICs in small firms have more application orientation, while those in large firms have a fundamental focus.

H. 2-2 After 2000, the contents of UICs shifted toward application orientation, and this shift can be found more in SMEs, as compared to large firms.

Lastly, with the introduction of a UIC system based on a contractual method modeled on that in the US, what would previously have been filed by companies alone as joint university–industry invention patents are now filed jointly. Analyzing the differences in the filing pattern is also helpful in evaluating the US model. From a company's perspective, joint ownership of rights through joint patent application indicates that the company must obtain the university's consent to apply for patent through licensing agreements. Thus, we would expect companies to have a strong incentive to undertake R&D in areas important to their own in-house needs, rather than to collaborate with universities. We would expect joint-application university–industry patents to generally score lower on the value indicator than jointly-invented university–industry patents generated by informal UICs.

H. 3-1 The patent value indicator is higher for jointly-invented university–industry patents than for jointly-applied university–industry patents.

H. 3-2 Jointly-invented university–industry patents are more actively used in-house than jointly-applied university–industry patents.

5. Results

It is well known that a patent quality indicator such as the number of forward citations has skewed distribution, and we cannot assume normal distribution for testing hypotheses in the previous section. We have checked the normality of distribution of our variables by the Skewness and Kurtosis (S–K) test and determined that the normality hypothesis is rejected for all variables. Therefore, we use the non-parametric method for the following statistical analysis.

Table 3 shows the mean differences of our variables between UIC patents and matched patents by a single corporate applicant, and the results of the Wilcoxon signed rank test. UIC patents have higher statistically significant values than those filed by single corporate applicants for the number of inventors, the number of forward citations, and the number of forward non-self citations. It should be noted that the number of claims have different signs for the mean difference and Wilcoxon test result, where negative mean claims may be explained by outliers. In contrast, UIC patents have statistically significant lower values for forward self-citations. The number of forward citations, the most widely used indicator of technological value, has higher statistically significant values for UIC patents, indicating higher technological value. In comparison to patents filed by corporate applicants alone, these patents have lower number of forward self-citations and higher number of forward non-self citations, indicating far-reaching spillover effects on companies other than those participating in the collaboration, thereby supporting hypotheses H. 1-1 and H. 1-3. With regard to generality, which measures the reach of a patent's technological application, UIC patents have statistically higher values than those filed by single corporate applicants for patent applications filed through 1999. However, no statistically significant differences were observed for patent applications filed since 2000. Thus, while hypothesis H. 1-2 holds for the entire time period, the trend has weakened. In contrast, UIC patents are consistently superior for the other indicators (particularly the indicator for the number of forward citation patents) both before and after 2000. Hence, we find no support here for hypothesis H.1-4. While UIC policies have strengthened incentives for universities to commercialize technologies, no decline in the quality of their achievements has been observed. Given the increasing number of UIC patents, we would conclude that the results of university research have contributed significantly toward corporate innovation and resulted in significant positive effects.

(Table 3)

For the second hypothesis, we defined corporate applicants who are associated with a total of 100 or more patents filed during the entire period as “large-scale businesses.” All other businesses are classified as “small-scale businesses.” We compared the patent indicators for each group as the results of UICs (Table 4). In order to evaluate the second hypothesis, we first construct the following indicator *d* for all patent pairs.

d = (patent value indicator of UIC patents)－(patent value indicator of patents filed by single corporate applicants)

We then compared the value of *d* between the samples for small and large firms. The first column of Table 4 shows the mean differences (in difference value *d*s) between small and large firms (mean of small firms − mean of large firms). The second column shows the result of the Mann–Whitney U-test, which is the signed rank test used to compare two groups (small and large firms).

(Table 4)

We observe that UIC patents filed by small firms have less number of claims, fewer forward citations, and fewer forward self citations than those filed by large firms; an opposite pattern is observed in the number of inventors and forward non-self citations for all the periods covered. This finding contradicts H 2-1, in the sense that UIC patents filed by small firms have greater spillover effects on others, while those filed by larger firms tend to contribute more to their own innovative activities. There is significant heterogeneity in small firms, and a large number of high tech start-up companies such as university spin-outs may explain higher forward-non-self citations for smaller firms. When we compared the results before and after 2000, the positive difference for small firms in terms of non-self citations disappeared, and the total number of forward citations for small firms became negative after 2000. This finding suggests that UIC patents filed by small firms become application-oriented faster than those filed by large firms. Hence H2-2 is supported.

Finally, Table 5 shows the results from analyzing the differences in patent indicators between jointly-invented university–industry patents and joint-application university–industry patents. The same methodology is used to compare small and large firms. Mean differences (in difference value *d*s) between joint inventions patents and joint application patents (joint invention group − joint application group) are presented in the first column, and the Mann-Whitney U-test results for the two groups are described in the second column.

(Table 5)

It was observed that joint inventions had statistically significant higher values than joint applications in terms of the number of inventors and all forward citation indicators. In other words, jointly invented university–industry patents express a greater premium attributable to UICs than joint-application university–industry patents, a result supporting hypothesis H. 3-1. Table 5 shows that joint inventions also have higher statistically significant values in terms of forward self-citations for all sample groups, indicating that jointly invented university–industry patents have a more significant impact on the companies involved. In other words, many patents with significant implications for corporate product development were filed as joint inventions and not joint applications. We demonstrate that this result supports hypothesis H. 3-2.

6. Discussion and policy implications

Using patent data, this study analyzes how the results of UICs differ from that of R&D conducted by businesses alone, and how the contractual UIC system, modeled on that of the US introduced in the late 1990s, have affected these collaboration results. We defined and extracted UIC patents as both joint applications and joint inventions, and observed that UIC patents proved more valuable than patents filed by single corporate applicants in a statistically significant manner, even after considering the year of application and the field of technology by pairing UIC patents with patents filed by single corporate applicants from the same year of application and IPC classification. UIC patents, in particular, are associated with more forward non-self citations and fewer forward self-citations than patents filed by single corporate applicants, indicating wide-ranging spillover effects going beyond the companies involved. We also found that UIC patents were associated with higher statistically significant scores than patents filed by single corporate applicants with respect to generality, a measure of technology's fundamental nature. The higher scores also reflect the continuing fundamental nature and generality of university research. With respect to the impact of the US-style UIC policies, UIC patents lost their superiority in the generality indicator from 2000 onward, but their technological value, as measured by the number of forward citations, remains unchanged. The number of university patent applications and UIC patent applications increased sharply in the early 2000s, which according to our estimation, has not resulted in decline in the overall quality. Following the adoption of UIC policies from the second half of the 1990s, the results of scientific research at universities and other dominant recipients of public R&D funds began to contribute more toward corporate innovation.

While observing the value of UIC patents based on the scale of operations of the partnering business, we found that small businesses produced higher-value patents in their UICs than large-scale businesses. The generality index of patents for smaller firms' UIC patents indicates relatively greater value than that of large firms. It can be interpreted that a significant number of high-tech start-ups, typically university spinoffs, explain our results of higher non-self-citations for UIC patents by smaller firms. In addition, the shift to application orientation after UIC policy reforms in the late 1990s is more noticeable in small firms, because the population of small firms with UIC activities is expanded to include SMEs with regular business activities (Baba and Goto, 2007; Motohashi, 2005).

Finally, comparing jointly invented university–industry patents and joint-application university–industry patents, we found that the former had greater value regardless of company size, as measured by the number of forward citations. Similarly, jointly-invented university–industry patents exhibit higher statistically significant values for forward self-citations and forward non-self citations than joint-application university–industry patents. From company's viewpoint, jointly invented patents are solely owned by the company, while patent right for joint applied patents are shared with university. Therefore, firm's incentive for collaborative research with university may be smaller when its expected results are supposed to be filed as jointly application patents. In addition, a license fee to the university will be incurred when those results are used by the company. This may be the reason why jointly invented university–industry patents, which are more readily applicable to products being developed, have proven more commercially valuable than joint-application university–industry patents.

Based on the foregoing analysis, we may conclude that the US-style contractual UIC system introduced in the late 1990s has helped the research results at universities, often financed by tax money, to contribute to development of economy and society as a whole. Furthermore, while UICs have primarily involved major and large companies, participation by SMEs carries great value. However, the difference between the value of jointly invented university–industry patents and the value of joint-application university–industry patents raises questions about the recent pro-UIC policies, which have focused on strengthening the management of intellectual property by universities. Informal collaborations between universities and businesses have occurred in Japan in the past, as discussed in Section 2, and the resulting jointly invented university–industry patents have produced significant value as well. Strengthening the management of intellectual properties by universities via recent pro-UIC policy measures may have, to some degree, transformed universities into commercial entities, while hindering the original purpose: facilitating the transfer of research results to the private sector. University research results generated by publicly funded efforts should be returned to the society at large in the appropriate manner. For these reasons, it may be worth reconsidering a uniform policy—like the one currently in place—that encourages joint ownership of all the results produced by UICs.

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Table 1: Evolution of Japan's UIC policy

1998	Formulation of the Act on the Promotion of Technology Transfer from Universities to Private Industry (the TLO Act) → Promoted the establishment of TLOs (Technology Licensing Organizations) Amendment of the Law for Facilitating Governmental Research Exchange → Made it possible to use government-owned land at low cost for joint university–industry research
1999	Creation of the Small Business Innovation Research Program ("Japanese SBIR") Formulation of the Act on Special Measures for Industrial Revitalization → Japanese version of the Bayh–Dole Act/licensing fee halved for approved TLOs Establishment of the Japan Accreditation Board for Engineering Education (JABEE)
2000	Formulation of the Industrial Technology Enhancement Act → Enabled gratis use of national university facilities by approved/certified TLOs, allowed university researchers to serve concurrently as TLO directors, board directors of companies commercializing research results, and statutory auditors of stock corporations
2001	"Hiranuma Plan" announced "Plan for 1,000 university-originated ventures in three years"
2002	Revision of the Ministry of Finance Property Administration Bureau Notification No. 1 → Allowed university-originated ventures to use national university facilities Revision of the TLO Law Notification → Made it easier for businesses to start approved TLOs
2003	Formulation of the Intellectual Property Basic Act → Obligated universities to voluntarily and actively seek to develop human resources, research activities, and disseminate research results

	Amendment of the School Education Law → Created special emphasis graduate school systems, increased flexibility in establishing university faculties/departments
2004	Implementation of the National University Corporation Law → Status of university researchers: "non-civil servant type," capital contributions to approved TLOs Implementation of the Act for Partial Revision of the Patent Act → revision of patent-related charges relating to universities and TLOs.

Source: "History of UIC" (extracted from the Ministry of Economy, Trade and Industry's website)

Figure 1: Trends in UIC Patents

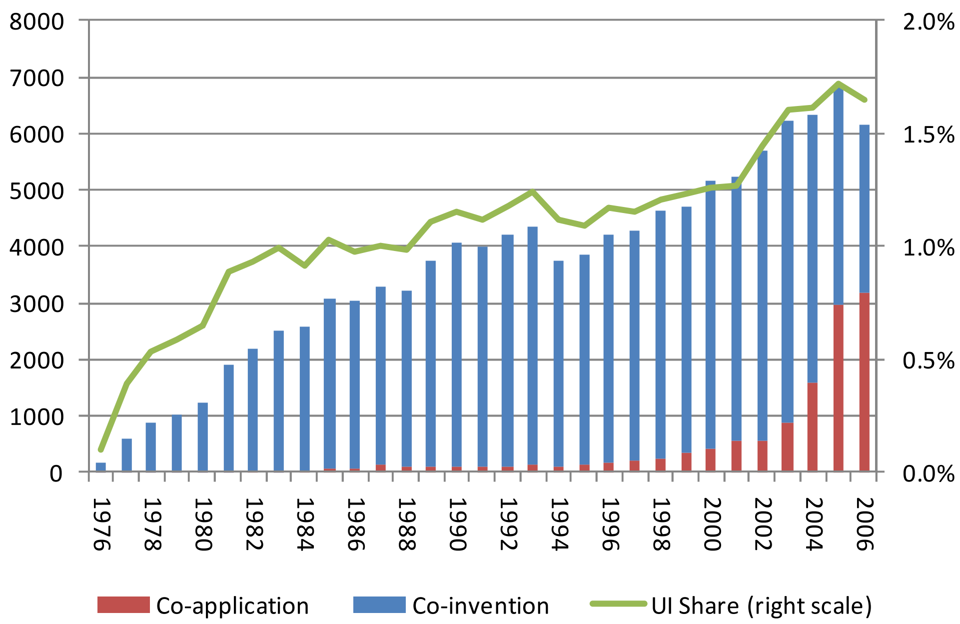


Table 2: Descriptive Statistics

UIC patents	Obs	Mean	Std. Dev.	Min	Max
Numbers of claims	114566	5.669	7.391	1	286
Number of inventors	117218	3.890	1.790	1	22
Number of forward citations	117218	1.395	2.940	0	115
Number of forward self-citations	162303	0.191	1.040	0	107
Number of forward nonself-citations	162303	1.234	2.508	0	74
Generality index	50761	0.221	0.317	0	1

Matching firm patents	Obs	Mean	Std. Dev.	Min	Max
Numbers of claims	115070	6.016	9.611	1	999
Number of inventors	116514	2.339	1.571	1	38
Number of forward citations	117218	1.194	2.570	0	123
Number of forward self-citations	162303	0.198	0.860	0	50
Number of forward nonself-citations	162303	1.011	2.248	0	85
Generality index	46869	0.197	0.307	0	1

Table 3: Characteristics of UIC patents

Variable	Mean difference UIC-matched	Wilcoxon signed rank test
Overall sample		(obs=162303)
Numbers of claims	-0.321	+++
Number of inventors	1.553	+++
Number of forward citations	0.201	+++
Number of forward self-citations	-0.007	---
Number of forward nonself-citations	0.223	+++
Generality index	0.021	+++
application year ~1999		(obs=102489)
Numbers of claims	-0.030	+++
Number of inventors	1.622	+++
Number of forward citations	0.240	+++
Number of forward self-citations	-0.032	---
Number of forward nonself-citations	0.293	+++
Generality index	0.022	+++
applied after 2000		(obs=59814)
Numbers of claims	-0.825	
Number of inventors	1.446	+++
Number of forward citations	0.142	+++
Number of forward self-citations	0.037	++
Number of forward nonself-citations	0.103	+++
Generality index	0.009	

Note:

+: UIC>matched, +++: 1% level, ++: 5% level, +: 1% level statistically significant

-: UIC<matched, ---: 1% level, --: 5% level, -: 1% level statistically significant

Table 4:Comparison of UIC patents filed by small and large firms

Variable	Mean difference small-large	Mann-Whitney U-test
Overall sample		
Numbers of claims	0.192	--
Number of inventors	0.108	+++
Number of forward citations	-0.079	---
Number of forward self-citations	-0.131	---
Number of forward nonself-citations	0.052	++
Generality index	0.004	
application year ~1999		
Numbers of claims	0.354	+++
Number of inventors	0.225	+++
Number of forward citations	0.000	
Number of forward self-citations	-0.170	---
Number of forward nonself-citations	0.170	+++
Generality index	0.011	
applied after 2000		
Numbers of claims	0.289	--
Number of inventors	0.073	+++
Number of forward citations	-0.128	---
Number of forward self-citations	-0.117	---
Number of forward nonself-citations	-0.012	
Generality index	-0.038	

Note:

+: small>large, +++: 1% level, ++: 5% level, +: 1% level statistically significant

-: small<large, ---: 1% level, --: 5% level, -: 1% level statistically significant

Table 5: Comparison of co-invented and co-applied patents

Variable	Mean difference inv-apply	Mann-Whitney U-test
Overall sample		
Numbers of claims	0.332	
Number of inventors	0.185	+++
Number of forward citations	0.204	+++
Number of forward self-citations	0.010	++
Number of forward nonself-citations	0.204	+++
Generality index	0.027	

Note:

+: inv>apply, +++: 1% level, ++: 5% level, +: 1% level statistically significant

-: inv<apply, ---: 1% level, --: 5% level, -: 1% level statistically significant

Appendix: Method for extracting UIC patents

How should jointly invented university–industry patents be identified in any study analyzing UIC patents and corporate performance based on patent information? Since every patent can potentially fall within the scope addressed by such a study, it is impractical to identify inventor attributes via the Internet or other such means. We consider ways to mechanically identify jointly invented university–industry patents on the basis of inventor information found in patents. As mentioned above, we may assume that a patent is a jointly invented university–industry patent if its application filed by a corporation mentions both corporate researchers and a researcher with a personal address as inventors. At a certain point in time, some companies have revised their policies regarding addresses, giving the company's address instead of a personal address for reasons of privacy and other considerations. This implies that depending on the year of application, even patents filed by the same company can exhibit different patterns of inventor attributes. Furthermore, the proportion of companies citing just a personal address for inventor information when the patent has been filed by a single corporate applicant has rapidly declined. Thus, assuming that all patents with both a corporate address and a personal address are UIC patents would overstate the growth in the proportion accounted for by UIC patents.

In the case of patents filed by single corporate applicants, we eliminate from the scope of this analysis data believed to have a large bias (assuming that "patents having both a personal address and a corporate address" are jointly invented university–industry patents) by using for each applicant/year of application sample either "the proportion of patents with just a personal address" or "the proportion of patents with just a corporate address." In other words, we screen each applicant/year of application sample for cases involving too many patents with just a personal address or too few patents with just a corporate address. To do this, we determined which criteria to apply and what percentage level is "too many" or "too few." We examined the screening criteria, using the correlation with the proportion of patents determined to be joint inventions of corporate inventors and public university inventors (i.e., patents that are clearly jointly invented university–industry patents). We gathered patents filed by single corporate applicants by applicant and year of application, tallied the number of applications corresponding to the six types of patents given below, and presented the correlation coefficients for the share of each type in Supplementary Table A. Since the share data appears to have large errors in the case of applicants with very small numbers of applications, we presented the results for applicant/year of application samples with 10 or more (10+) applications, and applicant/year of application samples with 100 or more (100+) applications.

(1) patents associated with just a personal address

(2) patents associated with just a corporate address

(3) patents with public university address only

(4) patents with both personal and corporate addresses

(5) patents with both corporate and public university addresses

(6) other patents

The key point here is the correlation between patents corresponding to (4) and (5) above. In the case of applicant/year of application, we found a low but positive statistically significant correlation coefficient at the 1% level (0.050) for samples with more than 10 applications (marked with *). For applicant/year of application samples with more than

100 applications, the correlation coefficient was somewhat higher (0.063), and the likelihood of accurately identifying joint university–industry inventions using patents corresponding to (4) became greater.

(Annex Table A)

We then screened each applicant/year of application sample using either the "proportion of patents associated with just a personal address" or the "proportion of patents associated with just a corporate address" to examine how the relationship between the two changed. In particular, we performed the following regression analysis for different samples while adjusting these thresholds and comparing their coefficients (α).

Share of corporate & public university patents = α (share of individual & corporate patents)＋β

Supplemental Charts A and B show how α changes with changes in the thresholds in "proportion of patents associated with just a personal address" and "proportion of patents associated with just a corporate address." Ideally, α approaches 1; actual values are significantly below this, due to measurement errors. We determined that a higher α corresponded to a better fit of the above model (i.e., higher validity for interpreting the share of individual and corporate patents to be the proportion of jointly invented university–industry patents). Supplemental Charts A and B show the results of estimates that used only samples having more than 10 applications and the results of the estimates that used only samples having more than 100 applications. For samples screened using "proportion of patents associated with just a corporate address," we observed that compared to the case without constraints, the coefficient increases if we eliminate samples having a low proportion of patents associated with just a corporate address. For example, for samples with more than 10 patent applications, the coefficient rises from 0.014 “without constraints” to 0.018 when we eliminate samples having a fewer than 10% proportion of corporate-address-only patents. This proportion increases as we strengthen the control. At 50%, the coefficient reaches its highest point. In the case of companies with relatively large numbers of patent applications, this implies that the proportion of “individual and corporate addresses” patents can be used as an index of the proportion of jointly invented university–industry patents only for those years of application when the “proportion of patents associated with just a corporate address” is 80% or above. In the case of samples with more than 100 applications, we did not observe patterns similar to the ones observed in samples with more than 10 applications. In addition, the size of the coefficient is generally lower for samples with more than 100 applications.

(Annex Figure A), (Annex Figure B)

Next, we consider the change in the coefficient with the “proportion of patents associated with just a personal address” as the threshold. In this case, the lower the threshold, the more rigorous the constraining condition with which we narrow the samples. Thus, we read the graph from the right end where there are “no constraints (100%).” The coefficient decreases as we apply stricter restrictions on the selected 100+ and 10+ samples.

Based on the results of the foregoing test, in the case of applicant/year of application samples having more than 10 patent applications, we deemed the proportion of “patents with personal and corporate addresses” + the proportion of “patents with corporate and public university addresses” to be the proportion of jointly invented university–industry patents for samples in which corporate-address-only patents account for 50% or more. We treated the other data as missing values. We used “patents associated with just a corporate address” as the screening criterion because the coefficients obtained through regression analysis are generally higher than those for “patents associated with just a personal address.” In this analysis, we examined only patent applications filed by a single company. In reality, patents are occasionally filed jointly by multiple companies. Adjusting the threshold on the basis of company size (number of applications) complicates the handling of such joint-application patents.

Annex Table A: Correlation matrix of patents by inventor type

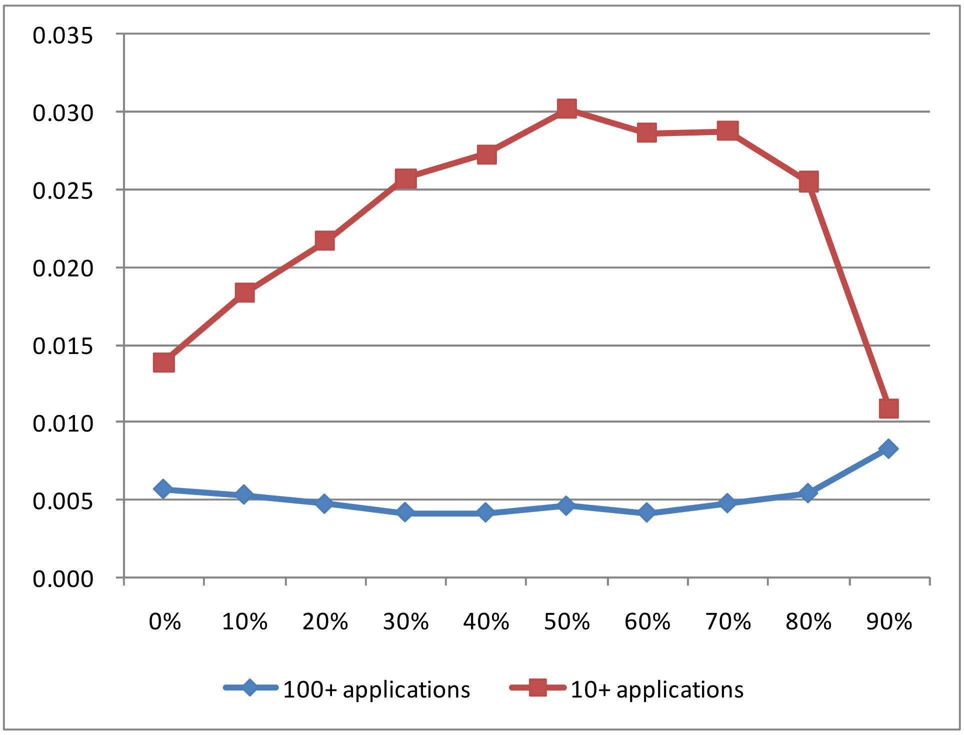
10+ applications

	Individual only	Firm only	University only	Ind+Univ	Firm+Univ	Other
Individual only	1					
Firm only	−0.7801*	1				
University only	−0.0133*	−0.0198*	1			
Ind+Univ	−0.1337*	−0.0713*	0.0007	1		
Firm+Univ	−0.0553*	−0.0117*	0.0485*	0.0229*	1	
Other	−0.2542*	−0.3498*	−0.0013	−0.0923*	−0.0163*	1

100+ applications

	Individual only	Firm only	University only	Ind+Univ	Firm+Univ	Other
Individual only	1					
Firm only	−0.8061*	1				
University only	−0.0008	−0.0275*	1			
Ind+Univ	−0.0245*	−0.0433*	0.0329*	1		
Firm+Univ	−0.0750*	0.0479*	0.2520*	0.0760*	1	
Other	−0.1263*	−0.4682*	0.0002	−0.1238*	−0.0328*	1

Annex Figure A: α by the restriction of individual inventor shares



Annex Figure B: α by the restriction of corporate inventor shares