Understanding the Technology Market for Patents:
New Insights from a Licensing Survey of Japanese Firms

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Abstract

This paper provides an empirical analysis of the technology market for patents in Japan, by using a novel firm-level dataset that combines a Japanese Patent Office survey titled Survey of Intellectual Property Activities, the Institute of Intellectual Property patent database, and the Licensing Activity Survey conducted by the University of Tokyo. In this paper, we use a two-step model to estimate a firm's licensing propensities; the first step estimates the determinants of potential licensors (willingness to license) and the second step identifies the factors of the actual licensing out of technology (licensing propensity). We found that a significant number of patents held by firms are not licensed out, although the owners are willing to do so. Our econometric analysis reveals that a major factor behind this technology market imperfection is the potential licensors' difficulty in finding licensing partners.

JEL classification; D45, L22, O32

Keywords; technology market, licensing, patent, Japan

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1. Introduction

"Open innovation" is one of most frequently used key words in technology management literature, and the management of intellectual property forms an integral component in this strategy for technology-based firms (Chesbrough, 2006). A properly functioning technology market for patents, where patent trade takes place, is beneficial for firms that are eager to adopt the open innovation strategy. However, it is found that the technology market for patents is far from perfect because of high transaction costs and information asymmetry between potential licensors and licensees (Arora et al., 2001; Gans and Stern, 2003). A few years ago, an Internet-based technology market attracted great attention as an important IT application in the open innovation era. However, such an open system did not work well, and most firms providing technology marketplace services, such as yet2.com and Nine Sigma, changed their business model to confidentiality-based technology intermediary services (Lichtenthaler and Ernst, 2008).

Gambardella et al. (2007) show that a large number of firms do not license although they are willing to do so because such patents are less appealing; in addition, the high transaction costs associated with the market for patents hinders the licensing of even appealing patents. This paper addresses the issue of technology market imperfection that causes a substantial number of unlicensed patents. We use the qualitative survey data of factors hampering licensing activities, such as "difficulty in finding partners" and "licensing negotiation and contract cost," obtained from the University of Tokyo's Licensing Activity Survey (LAS). In order to estimate econometric models on the determinants of licensing and non licensing propensities, this data is combined with the quantitative data on firms' licensing activities, taken from the Japanese Patent Office (JPO) survey titled Survey of Intellectual Property Activities (SIPA) and individual Japanese patent data from the Institute of Intellectual Property (IIP) patent database (Goto and Motohashi, 2007).

The most important contribution of this study is clarifying the factors of ex-ante licensing motivation and ex-post licensing outcomes. The divergence between these two is derived from the patents that cannot be licensed out although a licensor is willing to do so. This paper moves one step beyond Gambardella et al. (2007) by investigating the factors directly influencing the owners' propensities to actually license out such potentially licensed patents. In addition, this paper adopts a contingency approach in determining actual licensing outcomes not only by firms' internal factors but also by external factors such as technology market conditions (Fosfuri, 2006; Grindley and Teece, 1997). It is found that reactive licensing is dominant over proactive for large companies in Europe, which suggests the importance of external factors that determine licensing outcomes (Lichtenthaler, 2010). In this study, a firm-level survey containing several variables of technology market conditions, such as market thickness and congestion, allows us to gain new insights into external factors not empirically investigated by previous research. We also found that a substantial number of patents are not licensed out, although a firm is willing to do so, because of technology market imperfections. A lack of market thickness, demonstrated by difficulty in finding partners, is found to be an important factor for market failure.

The Intellectual Property Strategy Headquarters, headed by the prime minister, was established by the Japanese government in 2003 and has introduced an annual review of the intellectual property rights (IPR) policies of various related ministries. This initiative is intended not only to strengthen patent rights but also to stimulate the technology market to spread knowledge in the form of IPR. In addition, licensing has become an important strategic tool for Japanese firms. According to the R&D Collaboration Survey conducted by RIETI in February 2004, firms have started treating external collaboration more positively than they did five years ago, across all industries and firm sizes (RIETI, 2004). Because of globalization of the economy and competition in innovation spurred by the growth of East Asian economies such as China and Korea, it has become increasingly difficult for large Japanese corporations to sustain their in-house innovation models. The increasing importance of scientific knowledge in the R&D process of enterprises in certain industries, such as pharmaceuticals, is also a factor in fostering external collaboration, particularly with universities and public research institutions (Motohashi, 2005). This paper meets this growing demand from both policy and business arenas to understand the technology market for patents in Japan.

The next section of this paper is devoted to the theoretical background of licensing propensity based on a survey of empirical analyses of the licensing and technology market. Section 3 describes this study's datasets and summary statistics. Section 4 presents the quantitative analysis, where the determinants of licensing and non licensing propensities are estimated by econometric models. Finally, Section 5 concludes with managerial and policy implications.

2. Literature review

To clarify the factors of ex-ante licensing motivations and ex-post outcomes, we need to understand the nature of the technology market where licensing negotiations take place. In this study, the Gans and Stern (2010) framework of the technology market for patents is used for our empirical analysis. This study is based on Roth (2008), who discusses three factors to characterize the nature of a market. The first is "market safety," which leads to market players' trust in a market and reveals truthful information about their products. The second is "market thickness," which is necessary for efficient seller–buyer interactions in a market. The third is “lack of congestion,” enabling market transactions to occur at a reasonable speed.

The patent system may suffice as a market safety condition in that sellers can disclose their information without risking imitation. However, the patent system is demonstrably far from perfect; hence, the degree of patent right enforcement is an important factor in determining technology market effectiveness and the licensing propensity. Strong patent protection can facilitate licensing activities by making it more difficult for others to develop peripheral technology without infringement of the original patent. For example, in the pharmaceuticals industry, compared with other industries, a patent may be used as a means of appropriating rents from a technological innovation (NISTEP, 1997; Cohen et al., 2002); therefore, the pharmaceuticals industry has a relatively high licensing propensity (Anand and Khanna, 2000). The effectiveness of patent protection is also found to be positively related to the licensing propensity even after controlling for industry difference (Arora and Ceccagnoli, 2006).

Although a patent document provides rich information about the invention, it is impossible to give an explicit description of all technological contents associated with the invention. Furthermore, some jurisdictions, such as US, require disclosing the best mode of applying the invention, whereas in Japan or Europe, there is no such requirement. Hence, firms in such countries are usually not willing to disclose all information, but wish to retain some information about the invention as trade secrets or propriety know-how. Therefore, a potential licensee is forced to make a licensing decision with only limited information about the overall technology, which explains the ineffectiveness of Internet-based technology-market services (Lichtenthaler and Ernst, 2008).

Another factor associated with technology market imperfection is information asymmetry between potential licensors and licensees. One exception is the science-based industry such as biopharmaceuticals, where scientific content is important for innovation, and the technological contents can be expressed more explicitly. This facilitates licensing deal-making because potential licensees can understand the technological contents more clearly (Arora and Gambardella, 1994; Arora and Ceccagnoli, 2006). Gambardella et al. (2007) list other patent characteristics affecting the licensing propensity, including the generality of a technology along the spectrum of potential applications, the economic value of a technology, and patent breadth measured by technology classes covered by the patent.

Roth’s (2008) other two criteria of market design, i.e., “market thickness” and “lack of congestion,” are also important factors in determining technology market effectiveness. We found that patent auction businesses such as Y2.com and Ocean Tomo have developed to only a limited scale because of lack of market thickness (Lichtenthaler and Ernst, 2008). In many cases, patented technology has only a limited scope of application, and it is quite rare to find multiple potential buyers for it so that an effective match between its buyer and seller cannot be made.

In addition to enough market thickness, “lack of congestion” is also required to attain efficient market transactions. Lack of congestion can be fulfilled when bilateral negotiation of a seller and a buyer takes place at a reasonable speed. However, this is not a typical case for the technology market due to technological complexity and limited information disclosure in a patent document. In addition, the intellectual property’s innate value rivalry, i.e., disclosing an idea to one potential buyer substantially reduces its value for others (Gans and Stern, 2010). As a result, an actual practice of license negotiation involves multiple sellers and buyers concurrently with series of bilateral non-disclosure agreements. This process usually takes a long time, and it is often the case that the negotiation may not lead to the actual licensing contract. Razgaitis (2004) empirically shows a number of relevant factors in licensing deal failures, such as the failure to reach a mutual agreement on licensing conditions for US and Canadian firms. Recently, the OECD has conducted a survey of European countries and Japan, finding similar factors relevant for those countries (Zuniga and Guellec, 2009).

In addition to these technology market conditions, the propensity to license also depends on the licensors’ and licensees’ characteristics. Many studies have investigated the interaction between a licensor’s complementary assets and IPR, such as marketing and production resources (Arora and Fosfuri, 2003). The licensing of patents may cause “rent dissipation” by a patent owner because of the creation of a potential competitor in a product market. Therefore, a small company (likely to be a minor player with a small amount of complementary assets in the product market) tends to license out more because the “revenue effect” from licensing fees is larger than the rent dissipation effect. Thus, the degree of market competition also has an important bearing on the licensing propensity. If a product market has close to perfect competition, a firm will be less concerned about the rent dissipation effect, because monopoly rent is already small. A firm in such a market competition environment is assumed to be more likely to license out. The balance of rent dissipation and revenue effects by a firm’s complementary assets and market competition has been empirically tested in many studies (Fosfuri, 2006; Gambardella et al., 2007; Motohashi, 2008).

The demand-side factors of the technology market (licensee’s characteristics) should also be considered. Arora and Gambardella (2010) list not-invented-here (NIH) syndrome, absorptive capacity, and the relationships between internal and external R&D as important factors in the in-licensing decision. According to the absorptive capacity theory, a potential licensee is typically a large firm that can conduct substantial in-house complementary R&D (Cohen and Levinthal, 1990). However, having internal R&D resources is likely to lead to NIH syndrome, in that close communication between in-house R&D and marketing functions prevents acquisition of external technology. Hence, the primary question is whether external R&D is a complement or a substitute for internal R&D (Teece, 1986). Empirically, evidences for both aspects are available, and this area requires considerable further investigation (Fosfuri and Giarratana, 2010).[1]

Finally, industry specific factors must also be considered. As described above, in the pharmaceuticals industry, a patent is largely a means of appropriating rents from a technology, and thus the licensing propensity is relatively higher. A high licensing propensity is also found in the electronics industry because of the substantial number of patents involved in cross-licensing (Grindley and Teece, 1997). Cross-industry variation of licensing propensity can be explained by the "discrete" or "complex" typology of innovation (Merges and Nelson, 1990). Typical discreet innovations can be found in the chemicals (including pharmaceuticals) industry, while complex innovations are found in electronics. Cross-industry differences in patent licensing management can also be ascribed to differences in patent density. Industries with high patent density have many patented inventions per product, tending to make cross-licensing essential (Pitketly, 2001). Therefore, while active licensing activities are found in both industries, the motivations for licensing differ.

3. Data and Variables

3.1 Data

In this study, we constructed a novel dataset combining three data sources: the Survey of Intellectual Property Related Activities (SIPA), the Institute of Intellectual Property Patent Database patent database (IIP-PD), and the Licensing Activity Survey (LAS). From the data linkage of these three at firm level and the data cleaning, we obtained a cross-section of data for 636 Japanese firms for the year 2006. The following is a description of these data sources.

SIPA: SIPA is an annual statistical survey conducted by JPO. The JPO began this survey in 2002 to collect data on the various IP-related activities of Japanese individuals, companies, and public research organizations. The survey is conducted for two categories: (i) all domestic applicants who have more than five IPR applications (patents, utility models, designs, or trademarks) from the JPO in one of the previous two years and (ii) randomly sampled applicants for the remainder of the group, not including foreign applicants even though they filed

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1 One of the factors determining whether the relationship between external R&D and internal R&D is "complement" or "substitute" can be a firm's stage of technological development. Motohashi and Yun (2007) present the substitutional relationship as dominant in Chinese firms, while the complementary relationship is prevalent in Japanese firms (Motohashi, 2005). This difference can be explained as follows: As Chinese firms are less technologically competent, they have a greater incentive to acquire external technology, even if it requires decreasing their internal R&D investments.

applications.[2] In this study, we use the 2007 survey data, which refers to activities in 2006, consisting of approximately 8,000 applicants of category (i) and approximately 4,700 applicants of category (ii); note that the number of all applicants filing patent applications in 2005 is approximately 75,000. Our dataset consists of 5,821 samples of valid responses in category (i) and 5,318 samples after excluding individual investors and public research organizations.

SIPA covers a broad range of survey items. The survey consists of four parts: (1) applications for IPR, (2) usage of IPR, (3) information on IPR sections at firms, and (4) IP-related infringements as well as company profile data. In this paper, we primarily use the data from part (2), which covers data on the number and types of IPR usage, such as usage by the owner, licensing out, and licensing in by the type of licensing contract.

LAS: LAS was conducted by the University of Tokyo in 2007, which captures activities in 2006. It surveys three areas: (1) patent propensity and importance of appropriability, (2) licensing activities, and (3) changes in licensing activities and underlying factors.[3] The survey was conducted on 5000 Japanese firms sampled from the list of those filing a patent application in 2006 in the descending order of applications; 1640 firms responded.

IIP-PD: IIP-PD is an individual patent database that contains data of patent applications from 1964 to 2009, constructed from the JPO's Seiri Hyojunka Data (organized and standardized data) for innovation study researchers (Goto and Motohashi, 2007). For each patent, it includes data regarding the date of each stage from filing to the expiration of a right, data on applicants, right holders and inventors, technology classification, and citation. We derived the data of patents owned in 2006 from this database.

We linked the three databases by applicant code, which is an identification code assigned for each applicant by the JPO and used by the SIPA, LAS, and IIP-PD. As a result of the data linkage, we obtained a cross-section of data for 1,195 Japanese firms for the year 2006. The sample size is smaller than that of each survey because applicants need not have responded to both SIPA and LAS. Furthermore, we dropped the responses with certain numbers of blank fields and obtained 636 samples at the end.[4]

3.2. Dependent Variables

Based on this dataset, we analyzed the propensity to license. In this process, potential license

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2 Domestic applicants are identified by their addresses.

3 This survey was based on the international project coordinated by the OECD, and a common questionnaire was prepared for European and Japanese firms (Zuniga and Guellec, 2009). We use the data of only Japanese firms.

4 The average values of all variables before and after data arrangement are not significantly different; all but one data are statistically equal by Welch's t-test.

patents (patents whose owners are willing to license) and actually licensed patents are separated, following the methodology in Gambardella et al. (2007). In this study, the licensing propensity analysis is based on firm-level data, while Gambardella et al. (2007) used patent-level data. Our dataset ignores heterogeneity in the characteristics of patents owned by a firm, whereas firm-level data can represent the licensing propensity and strategy for an entire company. Therefore, we consider the ratio of the number of licensing patents against the number of all patents each company holds as a dependent variable. This index represents the firm's licensing propensity as the degree of firm-wide licensing focus (vs. internal use). A large firm with many patents is likely to license out more as an absolute number but the focus of this paper is understanding the technology market by considering the difference between firm-level licensing willingness and its licensing outcome by using ex-ante and ex-post licensing propensity indices.

Figure 1 represents our dependent variables. The full width of the box represents the total number of patents owned by each firm. The total number of patents can be split into two parts: (1) patents for which there is willingness to license and (2) patents for which there is no willingness to license. The first category can be further subdivided into two elements, (1-1) patents actually licensed out and (1-2) patents for which there is willingness to license but no actual licensing out. Two types of indicators serve as dependent variables in this paper, LICENSE and POTENTIAL, as follows.

LICENSE = The share of the number of actually licensed out patents to the total number of patents owned

POTENTIAL = The share of the number of patents not actually licensed out to the total number of patents owned

In LICENSE, both denominator and numerator variables are obtained from SIPA. POTENTIAL can be obtained from the following question in the LAS: "Share of your patent portfolio that you are willing to license out but cannot actually license out; share in total patents is 0%, 0%-2%, 2%-6%, 6%-15% or 15%-100%. Please rate the score of 0-4, where 0 indicates share of 0% and 4 indicates share of 15%-100%". The proportion obtained by adding LICENCE and POTENTIAL denotes the parts of the portfolio that a firm is willing to license out; however, we cannot use this number in our analysis because POTENTIAL is based on the categorical variable.

Although LICENSE represents the licensing activity of a licensor, it takes the value of zero for two types of firms. One is a firm that has no willingness to license out because the firm plans to use the patented technologies exclusively for its own production and obtain the technology monopoly rent. The other is a firm that was willing to license out but was not able to do so. In order to distinguish between these two types of firms, we created another variable called WILL, defined as follows.

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\begin{aligned}
WILL &= 0 \quad if\ \ LICENSE = 0\ and\ POTENTIAL = 0 \\
&= 1 \quad otherwise
\end{aligned}
$$

In this study, we consider the actual licensor and the potential licensor separately.[5] By using LICENSE and WILL, we derive the following three types of firms.

- Group A, where firms are actual licensors, WILL = 1 and LICENSE > 0. These firms actually license out; 296 samples.

- Group B, where firms are potential licensors but not actual licensors, WILL = 1 and LICENSE = 0. These firms are willing to license but are not able to license out; 260 samples.

- Group C, where firms are neither potential nor actual licensors, WILL = 0. Such a firm has no willingness to license out; 80 samples.

In Group C, firms do not intend to use the license market because they plan to use patent technologies exclusively for their own production. In contrast, firms in Group B are willing to license but have not been able to realize an actual deal and are in the process of searching for possible licensees or formulating a licensing agreement. Although for firms in Groups B and C the number of patents licensed out is zero, firms in Groups B and C have different licensing out policies. We find that the number of firms in Group B is unexpectedly large and infer that the potential license market should be larger than the observed market size, as discussed by Gambardella et al. (2007).

3.3. Explanatory Variables

As explanatory variables to LICENSE and POTENTIAL, we prepared a set of variables on the nature of the technology market, discussed in Section 2, as well as other control variables. The mean scores of each explanatory variable (as well as dependent variables) by the type of group (A, B, or C) are provided in Table 1.

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[5] Note that we add a further issue, concerning whether a firm has been confronted with difficulties in realizing licensing deals (PARTNER and NEGOTIATE denoted in Section 3.3) in its licensing activity. Thus, WILL takes the value 0 if the firms having the values LICENSE=0 and POTENTIAL=0 have never encountered difficulties in realizing licensing deals.

(1) Technology market variables

Degree of patent right enforcement: PROTECT

Strong patent protection can facilitate licensing activities because of reduced transaction costs and difficulty in developing peripheral technology. The degree of patent right enforcement is assessed by the following question in the LAS.

"Of the four methods below, which is the best method to bring benefits to your company? Could you please rank patent protection?"

The four methods are patent protection, trade secret, complicated manufacturing or complicated products, and fast introduction of products in the market.

We convert the rank into a score. PROTECT assumes the value 4 if the response indicates that patent protection is the best method to obtain benefits. In Table 1, the average score is above 3, indicating that patent protection is the most or second-most powerful method.

Scientific nature of technology: SCIENCE

The proxy for the scientific nature of a technology is based on the number of non patent literature (typically, research paper) citations per patent. SCIENCE is an average of citation counts for patents owned by a firm (from the IIP-PD). As discussed in Section 2, the scientific nature of a technology is the nature of the technology per se, but it can be interpreted as more codified knowledge, which helps to achieve greater efficiency in the technology market. Table 1 shows that the value of SCIENCE for Group A (actual licensors) is larger than that for groups B and C (not actual licensors).

Difficulty in licensing out deals: PARTNER and NEGOTIATE

The following question in the LAS is intended to capture the difficulty in licensing out deals: "What factors have hampered your licensing activity?" The survey requests information concerning two factors:

- difficulty in identifying partners, PARTNER, and
- increasing complexity/ cost of drafting and negotiating contracts, NEGOTIATE.

Respondents were asked to rate the importance of each factor on a scale of 0–3 (0 indicates no relationship and 3 indicates that the factors are very important). PARTNER and NEGOTIATE represent high transaction costs in the license market. These factors cause a situation where a firm willing to license out is not actually able to do so. With regard to Roth’s (2008) market design criteria discussed in Section 2, PARTNER may reflect the degree of thickness of the technology market, i.e., it is more difficult to find a partner in a thinner market. In contrast, NEGOTIATE reflects the degree of transaction congestion. However, it should be noted that a firm’s perception of these variables is also influenced by the firm’s experience in negotiating licenses.

In Table 1, both PARTNER and NEGOTIATE take the value of zero in Group C because these firms are not willing to license out. Comparing Groups A and B, PARTNER shows approximately the same value of 1.6 in both cases, implying that it is difficult to find licensing partners. For NEGOTIATE, the score for Group B is somewhat higher than that for Group A. This factor is not considered to be as problematic as PARTNER.

Degree of competition in the technology market: TECH-COMP

The degree of competition in the technology market, measured by the extent to which a firm’s patent belongs in the same technology category as the others, plays an important role for the licensing propensity. We found that a firm licenses more in an increasingly competitive environment, because the rent dissipation effect from licensing is small (Fosfuri, 2006; Gambardella et al., 2007; Lichtenthaler, 2010). We calculate the Herfindahl–Hirschman Index (HHI) with respect to each IPC main group first by the IIP-PD and then construct a firm-level index using a firm-level weighted HHI average (by using the corresponding HHI of the IPC of each patent application). Finally, we subtract this figure from 1 to derive a firm-level index that reflects the extent to which a firm has patents whose technology classes are popular among other patent holders.

Potential demand for the technology: CITED

In this study, we consider the licensing activities of licensors; hence, most of the variables reflect the supply-side of the technology market. However, as a matter of course, demand-side characteristics also affect licensing outcomes. Therefore, we include the number of forward-citations per patent as one measure of the technology’s potential demand. CITED is the average number of forward-citations of the patent owned. Note that the number of citations received does not include self-citations and has been weighted using the fixed-effects approach of Hall et al. (2001). Citation data has been interpreted as a measure of patent quality in previous literature, and Hall et al. (2001) notes that “citations received may be telling of the importance of the cited patent.” The more the patent is cited in other patents, the higher the potential demand for the technology. In Table 1, the value in Group A is 1.9, and the patents owned by actual licensing firms are cited more than those of non licensing firms.

(2) Other control variables

Firm size: EMP

For firm size, we use the number of employees given in SIPA. This also represents complementary assets. We use the logarithm of EMP, log(EMP), in the econometric model. In Table 1, the firm size of actual licensors in Group A is three times larger than those of non licensors in Groups B and C.

Specialized R&D: RD

We use the dummy variable R&D for a firm specializing in R&D, if R&D costs exceed 30% of sales. The average in Table 1 shows the proportion of specialized R&D firms. The proportion of such firms in Group A is double that of non licensors in Groups B and C.

Affiliate dealing: AFFIL

The number of licensing deals with affiliated firms causes LICENSE to increase artificially; hence, we include control variables for this in our model. AFFIL80-100, AFFIL60-80, AFFIL40-60, AFFIL40-60, AFFIL20-40, and AFFIL0-20 take the value 1 if the LAS respondent indicates that the share of licensing out with affiliated partners is 80%–100%, 60%–80%, 40%–60%, 20%–40%, and 0%–20%, respectively. All five dummy variables take the value 0 if the firm does not license out, as in Groups B and C. Any one of the five dummy variables takes the value 1 if the firm licenses out, as in Group A. That is, the proportion of firms in Group A sum to 1.

Cross-licensing: CROSS

The number of patents licensed includes three types of license contracts: licenses for license revenue, cross-licenses, and patent pools. Unlike licenses for license revenue, cross-licenses and patent pools are used for co-ordination with other firms.[6] Therefore, we consider that these

[6] A typical case of substantial cross-licensing can be found in the semiconductor industry, where it has become difficult to create a product using only in-house technology. Thus, it has become necessary for all firms to use in-licensed technology. A working solution in this case is to create cross-licensing agreements between large players (Grindley and Teece, 1997). In order to prepare for future cross-licensing agreements, firms are motivated to build up a strong patent portfolio. Therefore, the share of unused patents for future cross-licensing deals tends to be large. In contrast, because cross-licensing involves a substantial number of patents, the licensing propensity may

contracts could show a different structure of licensing activity and control for the share of cross-licensing out, with the CROSS variable. To identify the type of firm, we use the share of cross-licensing out in the LAS. CROSS80-100, CROSS60-80, CROSS40-60, CROSS40-60, CROSS20-40, and CROSS0-20 take the value 1 if an LAS respondent indicates that the share of cross-licensing out is 80–100%, 60–80%, 40–60%, 20–40%, and 0–20%, respectively. All five dummy variables take the value 0 if the firm does not license out.

Industry dummy variables:

In order to control for industry characteristics of licensing activities, we included six industry dummy variables: CHEMICALS, PHARMACEUTICALS, ELECTRONICS, MACHINERY, TRANSPORTATION, and INSTRUMENTS.

4. Econometric analysis and discussion

4.1 Determinants of LICENSE

We estimate the determinants of licensing propensity (LICENSE) to analyze which factors determine actual licensing activity, as reported in Table 2. We start by estimating the Tobit model for the licensing propensity using the full sample, as reported in Model (1) in Table 2. First, we find a positive and significant effect for PROTECT, suggesting that stronger patent protection would be an advantage in licensing out. For patent technology, potential demand would exist because it is difficult to develop peripheral technology around more strongly protected patent technology. Second, TECH-COMP, which shows the number of firms holding patents in the same technology fields, has a positive and significant effect on the licensing propensity. In a more competitive technology market, there is less concern about rent dissipation effect of the licensing out of technology. Third, log(EMP) is negative and has a significant effect on the licensing propensity, which is consistent with the hypothesis of complementary assets (Arora and Fosfuri, 2003; Fosfuri, 2006; Gambardella et al., 2007; Lichtenthaler, 2010).

In contrast, difficulties in licensing out deals (PARTNER, NEGOTIATE) are not statistically significant. In addition, we did not find statistically significant results for SCIENCE or CITED.

As in Section 3.2, we classify firms into three groups according to the number of patents licensed and the willingness to license out, which consists of actual licensors (Group A), potential but not actual licensors (Group B), and non potential licensors (Group C). In the econometric model, where we analyze the determinants of licensing propensity, the firms in

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increase for cross-licensing firms (Motohashi, 2008).

Groups B and C have a licensing propensity of zero. That is, a zero realization of the dependent variable represents a corner solution (in Group C) or a negative value for the underlying latent dependent variable (in Group B) (Blundell and Meghir, 1987). However, in the Tobit model, all zero values taken by the dependent variable would correspond to a corner solution, and this assumption is too restrictive for our study. Thus, we use the double-hurdle model proposed by Cragg (1971) in order to overcome restrictive assumption. Blundell and Meghir (1987) label the double-hurdle model a bivariate model, against the standard univariate Tobit model, because "bivariate" defines a separate process determining zero-one discrete behavior from determining continuous observation. When we apply the double-hurdle model to our data, the willingness to license and actual licensing are classified separately. That is, two hurdles must be cleared in order to observe the nonzero licensing propensity, the first hurdle being whether a firm is willing to license out and the second hurdle being whether the firm clearing the first hurdle is actually able to license out deals.

Model (2) in Table 2 shows the results of the double-hurdle model with independent, homoskedastic, and normally distributed error terms.[7] The Cragg (1971) model used in this paper assumes that the two error terms are independent. The first hurdle (willing to license or not) and the second hurdle (actually licensing propensity) are differentiated by using PATRNER, NEGOTIATE, AFFIL, and CROSS dummies only for the second step explanatory variables, because all these variables are irrelevant to the first hurdle. PARTNER and NEGOTIATE represent a factor exogenous to a licensor's ex-ante licensing decision but both affect ex-post licensing outcomes. In addition, AFFIL and CROSS can be obtained only for a firm actually licensing out. In contrast, the remainder of the explanatory variables can affect the potential licensor's ex-ante licensing decision. The sizes of the coefficients for the results of a LICENSE equation in Model (2) are quite different from the results of the Tobit model in Model (1). This suggests that the result of either the Tobit model or the double-hurdle model has an estimation bias. Therefore, when estimating the licensing propensity, we should show both estimation results that control for willingness of licensing out and those that do not control.[8]

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[7] The estimation program of the double-hurdle model has not been incorporated into the standard statistical software, and user-written programs are used. We used the program written for STATA by Julian Fennema, http://www.sml.hw.ac.uk/somjaf/Stata/.

[8] Flood and Grasjo (2001) show the bias of estimated parameters in the Tobit type 1 (standard Tobit model), the Tobit type 2 (Heckman's generalized Tobit model and Heckit), and the double-hurdle model underlying a Monte Carlo simulation. Comparing the bias in estimated marginal effects, the bias for the double-hurdle model is much smaller than that for the Tobit model. However, the Tobit type 1 model can produce smaller bias than the more advanced methods, e.g., the Tobit type 2 and double-hurdle models, if the first hurdle equation is incorrectly specified. Because the first hurdle equation is not used in the Tobit type 1 model, an error in this relationship has no effect on this estimator. Therefore, our estimation results are demonstrated using the Tobit type 1 (or the Tobit model) and the double-hurdle model.

In the double-hurdle model, the signs and statistical significances in the LICENSE equation are largely similar to those in the Tobit model (Model (1)). We therefore compare the results of the first hurdle (WILL) and second hurdle (LICENSE) in Model (2). First, we find that PROTECT has a positive correlation with both WILL and LICENSE. A firm that, for any reason, believes that the patent system is a strong tool for appropriating rent from its technological innovation may be willing to make greater use of the technology market for patents. In addition, stronger patent protection leads to more ex-post licensing deals through greater technology market efficiency.

SCIENCE has a positive effect on WILL but has no significant effect on LICENSE. The scientific nature of an invention is well understood by its inventor, which is already considered in ex-ante licensing expectations, eliminating surprise in the technology market for patents. It should be noted that SCIENCE is statistically significant even after controlling for RD, a dummy variable for a specialized R&D firm, which has a strong incentive to license out (with fewer complementary assets such as production and marketing resources).

TECH-COMP is not statistically significant in influencing willingness to license but relates positively to the actual licensing propensity. If a smaller rent dissipation effect through more intense competition is well perceived by a potential licensor, this factor should affect willingness to license. TECH-COMP also represents the degree of licensing opportunity, based on the assumption that potential licensees are more likely to be found in firms operating in similar technology fields. The results in Table 2(2) may capture this effect.

Finally, log(EMP), representing the firm size, has a negative effect on the licensing propensity but a positive effect on willingness. The firm size could influence the willingness to license out in two ways. One is that a large firm may be less willing to license out because it has sufficient complementary assets for production using its patent technology. This is described as "complementary assets such as production and market facilities" in Section 2. The other is that a large firm may be willing to license because the firm may patent noncore innovations in order to build a sizable patent portfolio for use in cross-licensing negotiations, increasing the firm's likelihood of licensing out noncore technology (Gambardella et al., 2007). Alternatively, larger firms may be older and may have patent portfolios including patents covering older, no longer core technology, which the firms are now very willing to license out to generate revenue. Thus, we reasonably find a positive effect of firm size on willingness. The negative effect of size on the licensing propensity suggests that a large firm has a sizable patent portfolio, resulting in a large denominator of licensing propensity.

In summary, we have found statistically significant coefficients with predicted signs for certain technology market variables for PROTECT, TECH-COMP, and SCIENCE. However, the pattern of statistical association with WILL and LICENSE differs across these variables. PROTECT affects both dependent variables, SCIENCE influences only WILL, and TECH-COMP has an effect on LICENSE. The factors having a statistically significant relationship with WILL simply validate firms' rational decision making, which is consistent with the theoretical background. From a policy perspective, the factors affecting LICENSE are more important, because policy actions influencing these factors may induce more active licensing activities among firms.

4.2 Determinants of POTENTIAL

As suggested in Gambardella et al. (2007), the observed number of licensing deals is smaller than the potential number of licensing deals, and the potential licensing market may be larger because potential licensors do not always conclude licensing deals. Why is it that not all potential licensors are able to license out deals? We estimate the determinants of POTENTIAL by using the same specification as that the LICENSE equations.[9] The results are reported in Table 3, which consists of Model (1) using the full sample and Model (1-2) using a subsample of potential licensors with an ordered probit model.[10] Model (2) shows the results of using the double-hurdle model.[11]

First, PROTECT does not play a significant role here, in contrast to licensing regressions in Table 2. This result contrasts against with our initial expectation that the stronger patent right reduces the share of patents which cannot be licensed out. But is should be noted that a firm perceives stronger patent right has higher willingness to license, so that the share of patents used for licensing negotiation to total patents is relatively large. Therefore, the share of patents which ended up with no licensing contract could become large, too. This logic is supported by the figures in Table 1, showing the mean value of POTENTIAL of group A (with positive licensing patents) is much greater than that of group B (with willingness to license but no actual licensing patents). This factor suggesting positive association between PROTECT and POTENTIAL is

9 The two dependent variables, LICENSE and POTENTIAL, are not necessarily linked because the sum of them, the share of the number of patents that they are willing to license, varies by firm, as shown in Figure 1. The correlation coefficient of LICENSE and POTENTIAL these variables is 0.12.

10 Model (1) includes firms that are not potential licensors, that is, have no willingness to license out. These firms have a value of zero for POTENTIAL. The subsample for Model (1-2) consists of firms that are willing to license out.

11 It should be noted that POTENTIAL is a categorical value, scored from 0 to 4, as is described in the section 3.2. We have conducted the robustness check by using representative shares, i.e., 1% for 0-2%, 4% for 2%-6%, 10% for 6%-15% and 50% for 15%-100%, instead of the score, and found that key findings do not change. The regression results will be provided upon request to the authors.

cancel out with the factor of our initial expectation, which leads to not statistically significant coefficient to PROTECT in Table 2.

Second, as for SCIENCE, we can find the positive and statistically significant coefficients for WILL but not for POTENTIAL, which is consistent with the result of LICENSE regression. It is confirmed that the scientific nature of invention is already well perceived by the licensor so that it affects the licensing willingness propensity but not additional surprise in licensing outcomes. We cannot find a statistically significant coefficient to TECH-COMP, in contrast to LICENSE regression.

Finally, PARTNER has a positive and significant effect on POTENTIAL. We can therefore, conclude that “finding a licensing partner” is an important technology market factor that cannot be managed at the level of the individual firm. In addition, thinness of technology market can be a major factor affecting the substantial number of patents that cannot be licensed out, although a firm is willing to do so.

5. Conclusion

In this paper, we provided an empirical analysis of the Japanese technology market for patents by using a novel firm-level dataset combining a JPO survey titled SIPA, the IIP patent database, and the University of Tokyo’s Licensing Activity Survey (LAS). We used a two-step model to estimate firms’ licensing propensities; the first step analyzes the determinants of potential licensors (willingness to license) and the second step identifies the factors of the actual licensing out (licensing propensity). We found that significant numbers of patents at firms are not licensed out, although the owner is willing to do so. This may result from that the fact that the technology market is far from perfect and that there are obstacles to the trading of patents in the market (Gambardella et al., 2007).

Our econometric models focus on understanding the characteristics of the technology market. We tested the impact of the nature of the technology market for patents on both firms’ propensities to license patents and willingness to license without actually licensing out any patents. The technology market variables include (1) the degree of patent right enforcement, (2) the scientific nature of technology (reduced information asymmetry between a licensor and a licensee), (3) difficulty in realizing licensing deals (related to market thickness and transaction congestion), (4) the degree of technology competition, and (5) the potential demand for technology. It is found that the degree of patent enforcement is related to both ex-ante and ex-post licensing propensity, whereas it is not related to POTENTIAL, the share of patents in firms that have willingness to license but do not actually license out. The scientific nature of technology influences firms' ex-ante licensing decisions and is not related to the licensing (or not licensing) outcomes after controlling for firms' ex-ante willingness to license. The market thickness factor (captured by difficulty in finding partners) is found to be important for POTENTIAL. Finally, the technology competition factor affects licensing outcomes but not licensing willingness.

A direct policy implication from our study is that information dissemination activities are important for stimulating the technology market for patents because the difficulty in finding partners is the primary factor behind a substantial number of unlicensed patents, despite the owners' willingness to license out. In addition, the degree of technology's scientific nature leads to greater willingness to license, which in turn leads to more licensing deals. This finding reconfirms the importance of the role of patent system's information dissemination in reducing the degree of information asymmetry between potential licensors and licensees. Finally, strengthening patent rights leads to stimulating the technology patent market. Both the reduction of information asymmetry and strong patent rights contribute to the technology patent market's perceived "market safety" (Roth, 2008).

The present study has certain limitations, and further research is required. First, this paper is based on cross-section data because the LAS was conducted only once. We plan to conduct this survey again to investigate in detail the interaction between firm-specific and technology market factors. In addition, the current LAS instrument focuses on the technology market's supply-side information. Given the importance of considering its demand-side factors, we will improve our next study by incorporating information on potential and actual licensees.

The second direction of further study is the international comparison of firms' licensing behavior. Although most of our study's results are consistent with existing empirical literature, largely European, there may be some differences across countries. For example, Japanese firms have been found to use patent information more extensively as compared to European firms (Pitketly, 2001). It will be interesting to observe the impact of cross-country differences in firms' patent information activities on licensing behavior and outcomes in both countries/regions. The LAS was conducted by an OECD project and the same datasets are available for European firms (Zuniga and Guellec, 2009), which may be used for international comparisons.

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Figure 1. Licensing and nonlicensing indicators

<table>
<tr><td colspan="2"># of patents for which there is a willingness to license</td><td rowspan="2"># of patents for which there is no willingness to license</td></tr>
<tr><td>Actually licensed</td><td>Not actually licensed</td></tr>
</table>

Total number of patents owned by a firm

LICENSE = Share of the number of actually licensed patents to the total number of patents owned

POTENTIAL = Share of the number of patents not actually licensed to the total number of patents owned

Table 1. Descriptive statistics

Variable		Data source	A(296)		B(260)		C(80)	
			Mean	S.D.	Mean	S.D.	Mean	S.D.
WILL	Dummy	SIPA&LAS	1	0	1	0	0	0
LICENSE	Value	SIPA	0.121	0.197	0	0	0	0
POTENTIAL	Score	LAS	1.922	1.566	1.396	1.550	0	0
PROTECT	Score	LAS	3.459	0.731	3.327	0.822	3.250	0.974
SCIENCE	Value	IIPDB	0.239	0.657	0.120	0.424	0.052	0.171
PARTNER	Score	LAS	1.611	1.093	1.615	1.005	0	0
NEGOTIATE	Score	LAS	0.655	0.853	0.904	0.935	0	0
TECH-COMP	Value	IIPDB	0.938	0.042	0.940	0.036	0.934	0.049
CITED	Value	IIPDB	1.956	1.828	1.527	1.123	1.575	1.269
EMP	Value	SIPA	2217	4412	558	523	778	3408
RD	Dummy	SIPA	0.024	0.152	0.008	0.088	0.013	0.112
AFFIL80-100	Dummy	LAS	0.355	0.479	0	0	0	0
AFFIL60-80	Dummy	LAS	0.051	0.220	0	0	0	0
AFFIL40-60	Dummy	LAS	0.051	0.220	0	0	0	0
AFFIL20-40	Dummy	LAS	0.051	0.220	0	0	0	0
AFFIL0-20	Dummy	LAS	0.493	0.501	0	0	0	0
CROSS80-100	Dummy	LAS	0.078	0.268	0	0	0	0
CROSS60-80	Dummy	LAS	0.020	0.141	0	0	0	0
CROSS40-60	Dummy	LAS	0.051	0.220	0	0	0	0
CROSS20-40	Dummy	LAS	0.051	0.220	0	0	0	0
CROSS0-20	Dummy	LAS	0.801	0.400	0	0	0	0

Note: Values in parentheses are the number of firms in Groups, A, B, and C.

Table 2. Estimation of licensing propensity:
The Tobit model and the double-hurdle model

	(1)		(2)			
Dependent var.	LICENSE		WILL		LICENSE	
PROTECT	0.036	(0.012)***	0.026	(0.014)*	0.015	(0.007)**
SCIENCE	−0.008	(0.023)	0.130	(0.032)***	−0.001	(0.017)
PARTNER	−0.014	(0.01)			0.010	(0.01)
NEGOTIATE	−0.015	(0.012)			0.007	(0.009)
TECH-COMP	0.654	(0.247)***	0.407	(0.274)	0.271	(0.16)*
CITED	0.004	(0.007)	0.008	(0.007)	0.006	(0.005)
log(EMP)	−0.031	(0.009)***	0.041	(0.014)***	−0.019	(0.008)**
RD	−0.011	(0.105)	0.056	(0.092)	−0.005	(0.084)
AFFIL80-100	1.354	(0.174)***			0.130	(0.017)***
AFFIL60-80	1.356	(0.17)***			0.109	(0.026)***
AFFIL40-60	1.347	(0.17)***			0.143	(0.042)***
AFFIL20-40	1.335	(0.165)***			0.122	(0.02)***
AFFIL0-20	1.367	(0.166)***			0.159	(0.016)***
CROSS80-100	0.098	(0.05)**			0.107	(0.055)*
CROSS60-80	0.238	(0.126)*			0.194	(0.129)
CROSS40-60	0.004	(0.04)			0.023	(0.04)
CROSS20-40	0.044	(0.055)			0.047	(0.05)
CHEMICALS	−0.110	(0.03)***	−0.002	(0.032)	−0.045	(0.022)**
PHARMACEUTICALS	0.053	(0.081)	2.652	(0.05)***	0.048	(0.05)
ELECTRONICS	−0.029	(0.034)	−0.046	(0.031)	−0.019	(0.016)
MACHINERY	−0.083	(0.026)***	0.128	(0.032)***	−0.038	(0.019)**
TRANSPORTATION	−0.075	(0.023)***	−0.059	(0.039)	−0.040	(0.017)**
INSTRUMENTS	0.172	(0.122)	0.050	(0.078)	0.037	(0.036)
Constant	−1.727	(0.324)***	4.895	(0.244)***	−0.232	(0.127)*
Log likelihood	98.982		283.502			
Wald test	229.95					
No. samples	636		636			

Note: *, **, *** denote significance at the 10%, 5%, and 1% levels, respectively. Values in parentheses are robust standard errors. Inference (1) is the result of the Tobit model, and inference (2) employs the double-hurdle model. Inference (2) consists of the first hurdle (WILL) and the second hurdle (LICENSE). CROSS0-20 is dropped for inferences because of multicollinearity.

Table 3. Estimation of POTENTIAL: The ordered probit model and the double-hurdle model

	(1)	(1-2)	(2)	
Dependent var.	POTENTIAL	POTENTIAL	WILL	POTENTIAL
PROTECT	0.052 (0.059)	0.055 (0.063)	0.049 (0.043)	0.057 (0.081)
SCIENCE	0.014 (0.092)	-0.008 (0.092)	0.140 (0.047)***	0.047 (0.126)
PARTNER	0.284 (0.047)***	0.158 (0.049)***		0.479 (0.064)***
NEGOTIATE	0.008 (0.052)	-0.081 (0.053)		0.094 (0.072)
TECH-COMP	0.521 (1.108)	0.728 (1.146)	0.187 (0.419)	1.589 (1.51)
CITED	0.014 (0.034)	0.013 (0.036)	0.021 (0.015)	0.015 (0.038)
log(EMP)	0.051 (0.036)	0.044 (0.037)	0.065 (0.015)***	0.060 (0.051)
RD	0.511 (0.408)	0.646 (0.425)	0.348 (0.132)***	0.613 (0.522)
AFFIL80-100	0.129 (0.13)	-0.055 (0.131)		0.319 (0.175)*
AFFIL60-80	0.421 (0.161)***	0.311 (0.167)*		0.694 (0.282)**
AFFIL40-60	0.939 (0.225)***	0.677 (0.237)***		1.680 (0.316)***
AFFIL20-40	0.987 (0.264)***	0.794 (0.275)***		1.562 (0.336)***
AFFIL0-20	0.724 (0.127)***	0.528 (0.131)***		1.191 (0.173)***
CROSS80-100	-0.176 (0.267)	-0.226 (0.262)		-0.175 (0.367)
CROSS60-80	-0.072 (0.559)	-0.125 (0.57)		-0.042 (0.747)
CROSS40-60	-0.086 (0.311)	-0.159 (0.333)		-0.075 (0.392)
CROSS20-40	0.429 (0.292)	0.411 (0.3)		0.417 (0.377)
CHEMICALS	-0.052 (0.138)	-0.117 (0.142)	0.004 (0.038)	0.026 (0.19)
PHARMACEUTICALS	0.346 (0.281)	0.280 (0.273)	2.622 (0.06)***	0.556 (0.404)
ELECTRONICS	0.290 (0.136)**	0.377 (0.147)**	-0.134 (0.064)**	0.361 (0.194)*
MACHINERY	0.043 (0.149)	-0.020 (0.15)	0.134 (0.032)***	0.116 (0.204)
TRANSPORTATION	0.224 (0.195)	0.290 (0.206)	-0.046 (0.067)	0.297 (0.267)
INSTRUMENTS	-0.041 (0.232)	-0.080 (0.238)	0.005 (0.065)	0.041 (0.33)
CONSTANT			4.766 (0.34)***	-2.065 (1.46)
Log likelihood	-853.715	-812.009	-1090.484	
Wald test	141.66	79.75		
No. samples	636	556	636	

Note: *, **, *** denote significance at the 10%, 5%, and 1% levels, respectively. Values in parentheses are robust standard errors. The data for Inference (1) is the result of the ordered probit model using the full sample, and inference (1-2) uses a subsample of firms that have a willingness to license out (WILL = 1). Inference (2) employs the double-hurdle model and consists of the first hurdle (WILL) and the second hurdle (POTENTIAL). CROSS0-20 is dropped for inferences because of multicollinearity.