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An Analysis of Unilateral and Cross-licensing Based on an Inventor Survey in Japan:

Effects of uncertainty, rent dissipation and a bundle of patents on corporate licenses

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An Analysis of Unilateral and Cross-licensing Based on an Inventor Survey in Japan: Effects of uncertainty, rent dissipation and a bundle of patents on corporate licenses

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Abstract

This paper analyzes the effects of uncertainty, rent dissipation, and a bundle of patents on corporate licenses. We use a newly developed data set, based on a large-scale survey (4,000 patents) of Japanese inventors, which uniquely covers the nature of the underlying research projects. Our major findings are the following. First, consistent with a theoretical prediction of our model, uncertainty of the licensing value of the patent increases significantly the licensor's willingness to license, for a given license possibility. This effect significantly accounts for a substantial part of the observed gap between unilateral and cross-licensing for upstream inventions. Second, a higher quality patent is more likely to be offered for a license and more likely to be licensed once offered for a license. Third, the positive effect of the importance of the first mover advantage upon the licensor's willingness to license is no weaker when the patent is used internally by the licensor. This suggests that the rent dissipation effect is significantly controlled contractually or is weak due to competition in the technology market. Fourth, the size of the bundle of the complementary patents enhances cross licenses and reduces unilateral licenses, with the former effect becoming increasingly dominant, and that inventions related to the core business of a licensor are more likely to be cross licensed.

Keywords: licensing, uncertainty, rent dissipation, complementarity, cross-licensing.
JEL Classifications: D45; O32; O31

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1. **Introduction**

Licensing plays an important role in the innovation process. Licensing opportunities allow a firm to enhance the appropriability of its R&D, given that a firm may not have complementary assets to fully exploit the invention. It would help avoiding the firms to make duplicative R&D investments, thus realizing the gains from knowledge sharing, enhancing the efficiency of R&D (some licensing might be motivated to reduce R&D competition, see Gallini (1984)). It allows the combination of complementary patents when the ownership of such patents is widely dispersed (As for license as a solution to a patent thicket problem, see Teece (1986) and Shapiro (2001))). Licensing has attracted renewed policy attentions in recent years, since whether stronger protection of intellectual property rights (IPRs) enhance welfare would significantly depend on whether stronger protection is associated with more licensing (Gallini (2002)). In particular, whether stronger protection would enhance cumulative innovation would depend significantly on whether the ex-ante contracting works efficiently (Scotchmer (1991, 2004)). Furthermore, whether stronger protection would enhance technology transfer would depend significantly on whether patent protection would facilitate the transfer of know-how (Arora(1995)).Licensing has also attracted managerial attentions too, given that it is one of the essential elements of “open innovation” strategy.

Key empirical research questions would be to understand the mechanism of the technology market, especially the constraints on licensing. Although there has been significant progress of empirical study on market for technology (see for an example, Arora, Fosfuri and Gambardella (2004)), an empirical analysis on licensing has been significantly constrained by the absence of comprehensive data on the characteristics of the inventions to be licensed, which could help identifying these constraints. Recently, Gambardella, Giuri and Luzzi (2007) has provided an important new analysis of the determinants of (unilateral) licensing, based on a very large scale collection of patent level information from European inventors (see Giuri et al (2007) for the design of a survey). One of their novel analyses is to disentangle the determinants of the willingness to license and the actual license. According to their findings, the willingness to license is almost 70% larger than actual license. In addition, they show that firm size of a licensor is the most important (negative) determinant of the willingness to license and the actual license conditional on the willingness to license. They also show that the value indicators of the inventions affect positively the willingness to license, suggesting no apparent sign of lemon problem in the market for technology.

This paper aims at covering three new grounds in the analysis of licensing. First, we develop a simple model on the licensor's willingness to license and the actual license, explicitly incorporating uncertainty, so as to account for the above substantial gap between them (which exists in Japan too, as will be described in section 2). The process of commercializing an invention is often very uncertain. In particular, the inventions from basic research or those exploiting scientific knowledge extensively are typically characterized by their high value uncertainty, since it has a low probability of commercialization due to the need of finding or developing the complementary assets but it may have a high return once commercialized due to its high novelty[1]. As one source of uncertainty for the licensor, ex-ante information asymmetry between the licensor and the licensee may be important. A licensee may have information which the licensor does not have ex-ante but can be revealed to him during the course of a licensing negotiation. Our simple model suggests that the uncertainty of licensing value increases the licensor's willingness to license (in our definition the licensor is willingness to license if he is willing to incur a fixed cost to engage in a search for a licensee) relative to the actual license, since it would increase the option value of such decision. We will empirically test the model by

[1] From an ex-ante perspective, a firm would engage in a research yielding an invention with low probability of commercialization, only if such invention generates high return once commercialized.

developing the variables characterizing the uncertainty, exploiting the rich data on invention characteristics which are newly available from the inventor survey in Japan, such as the stage of the research which yielded the invention. To the best of my knowledge, no studies have been undertaken from this perspective.

Second, we will assess the effect of rent dissipation due to product market competition in a novel manner. As discussed by Arora and Fosfuri (2003), a firm licenses a technology when the “revenue effect” from the licensing fees is higher than the “rent dissipation effect” , which is the loss of the firm’s profits due to the increased competition in the product market. However, a licensor can control the competition by a contractual mechanism such as the imposition of the output-based royalty on the licensee or the restriction of the market scope of the use of the patent. In fact, a substantial number of licensing involves royalty payments which are dependent on the output of the licensee (see Caves, Crookell, and Killing (1983). See also Nagaoka (2005) for more recent evidence in Japan). In addition, if competition in technology market is strong, rent dissipation effect itself may be weak. The past empirical studies have identified the rent dissipation mainly by looking at whether a large firm or a firm with a large market share or with large complementary assets is less likely to license (see for an example, Fosfuri(2006), Gambardella, Giuri and Luzzi (2007)). However, given that a large firm tends to have a higher patenting propensity, a large firm may have lower probability of licensing its patents simply because of its lower average patent quality (a higher quality patent is more licensed on average, as will shown in the Figure 5 in section 2). Thus, there may be a problem of identification in such approach. We employ a different and arguably more direct statistical test, exploiting the project level information available in our survey. One direct implication of rent dissipation due to licensing is that the marginal effect of patent quality on the willingness to license is lower if rent dissipation exists. Thus, we will analyze whether the marginal effect of patent quality on willingness to license is smaller if the patent is used internally by a licensing firm. If the difference is significant, we may conclude that although the rent dissipation is potentially an important constraint on licensing, it is nevertheless substantially controlled by a contractual mechanism, or the rent itself is small due to competition in technology market.

The third major focus of this paper is to assess how the determinants of the incidence of cross-license differ from those of the incidence of unilateral license. Although it is now well recognized that patents play a quite different role in "discrete" product industries, such as chemicals, versus "complex" product industries (Cohen, Nelson and Walsh (2000)) and that cross license is one of the most important solutions to “patent thicket” problem (Teece (1986) and Shapiro (2001)) in the latter industries, there is no systematic evidence available assessing the determinants of cross license in comparison with those of unilateral license, covering key invention characteristics, such as the size of the bundle of complementary patents. Anand and Khanna (2003) discusses the sector level determinants, in particular the relationship between the strength of intellectual property right protection and the incidence of cross license[2], and Nagaoka and Kwon (2007) focuses on firm level determinants, showing that the incidence of cross license increases with firm size. One major advantage of the current study is that it builds on project level information so that we can assess the impacts of key determinants such as the minimum size of the complementary patents to be jointly used with the invention. We inquire how the size of the complementary patents to be jointly used with the invention affects both the willingness to license as well as the actual license. If a firm owns the entire bundle of the patents, the probability of licensing such bundle would decline with the size of the bundle, since

[2] There is a serious endogeneity problem for a sector level analysis. For an example, the negative correlation between the incidence of cross license and the strength of IPR protection at sector level may not represent any causality between the two but both may reflect the nature of technology which determines how many patentable inventions one product incorporates. One advantage of our study is that it is project level, so that we can control for sector level differences.

the technology becomes more specialized and the risk of rent dissipation (creating a closer competitor) is larger. At the same time, a patent in a larger bundle is more likely to be cross licensed, since the patentee is increasingly more likely to own only a part of such portfolio as the size of the bundle becomes large. In addition, a theoretical analysis suggests that, unlike the case of unilateral license, the propensity for cross license is higher for the invention for the core business of a firm and for an invention of a large firm. We will also confirm that these expectations are true.

The rest of the paper is organized in the following manner. Section 2 provides the explanation of data and descriptive statistics over key variables. Section 3 provides a simple theoretical model and the propositions to be tested. Section 4 provides explanations of estimation strategy and models. Section 5 provides estimation results and section 6 discusses the implications and the main conclusions.

2. Data and descriptive statistics

We use the novel dataset from the survey of Japanese inventors conducted by the RIETI (Research Institute of Economy, Trade and Industry) in 2007 (See appendix for the survey methodology as well as the descriptive statistics (Table A.1))[3]. In this survey we asked the inventor "Has this patent been licensed by (one of) the patent-holder(s)?" and If yes, "does it include a cross-license? ". Thus, the question focuses on the license of the Japanese patentand does not exclude the licenses to related firms in Japan. Since the Japanese patent law requires a firm to provide adequate compensation to an inventor especially when his invention is licensed, it is reasonable for us to assume that the Japanese inventors would know whether his invention is licensed or not for money. On the other hand, he may not always know whether his invention

[3] The author was the principal investigator.

is subject to cross licensing[4].

The sample we use cover around 4,000 patents, 70% of which are from the triadic patent families which have a US granted patent and applications for both the EPO and Japanese patent office. We focus on the patents owned by a single firm and exclude those applied by individuals or universities and those jointly applied. One unique feature of our survey is that it provides us with the characteristics of the R&D projects that yielded these inventions as well as the other invention characteristics. In particular, it provides us the information on the stage of R&D: basic, applied, development or implementation stage such as technical service as well as on the types of the business objectives of the underlying R&D project: for enhancing the core business of a firm, the non-core business of a firm, creating a new business line or enhancement of the technology base of the firm unrelated to the existing business line.

Figure 1 shows the distribution of the research stage of the R&D projects from which the invention is generated (we classified the stage by the most downstream stage involved in the research yielding the invention). More than 60% of the inventions are from the development stage, followed by the inventions from applied stage (19%). Inventions from non-R&D stage (technical service and the others) account for 10% and those from the basic research less than 10%. Figure 2 shows that the incidence of the internal use of the inventions decline as the R&D becomes more upstream (more than 50% if the invention is from development and less than 30 % if it is from basic research). Thus, the inventions from more upstream R&D projects are more risky. At the same time, the incidence of a high-value patent (belonging to top 10% in economic value, according to the assessment by the inventor) does not vary significantly across R&D project categories, although it tends to be high at both ends. This implies that inventions from more upstream R&D projects tend to generate higher values once commercialized. That is,

[4] We show later that an inventor does not know whether his invention is cross_licensed or not for around 30% of the licensing cases.

the return is significantly more uncertain and skewed for upstream R&D projects (we will discuss this in more detail later).

Figure 2 also shows the incidence of a firm being willing to provide a license and the incidence of the actual license (non-conditional on the willingness to license). While firms are willing to provide a license for 38 % of the inventions from development, only a half of these inventions (19%) are actually licensed[5] and such gap is larger for upstream inventions (36% vs. 14% for the inventions from basic research). Although both the incidence of the internal use and the incidence of the actual license declines as the underlying R&D project becomes more upstream, the license rate declines less both absolutely and relatively. Consistent with this, the incidence of the willingness to license is almost independent of the stage of the underlying research. These results suggest the importance of the variation of uncertainty across the stages of the underlying R&D. The next section provides a coherent framework understanding these patterns.

(Figure 1, Figure 2)

Figure 3 shows the share of the inventions, the incidence of being willing to license and the actual license by the business objective of an R&D. The business objective of enhancing the core business, its non-core business, unclassified existing business, new business, and enhancing technology base not directly linked to its business line accounts for 50%, 15%, 4%, 22%, and 8% of the underlying R&D projects respectively[6]. A firm is most willing to provide a license to the invention from the R&D the objective of which is to enhance its core business than that from the R&D for its non-core business. This may be contrary to what we expect from the rent dissipation effect (Arora and Fosfuri (2003)), since an applicant firm would have more

[5] According to the European survey, 60% of the inventions which the owner is willing to license are actually licensed (Gambardella, Giuri and Luzzi (2007)).
[6] "The others" account for 1%. We do not use the sample of the patents with "the other" business objective in our estimations.

complementary assets in its core business. However, an invention developed for the core business of a firm may involve less uncertainty or may have higher quality. We control these variables in our statistical estimations.

(Figure 3)

Figure 4 shows the willingness to license (WTL) and actual license (AL) by firm size and by patent quality. The actual license rate of triadic patents is higher than that of non-triadic patents by a significant margin for all firm size (except for medium size firms). Thus, higher quality patent is more licensed. The licensing rate of the smallest firms with employment 100 or less is the highest, but beyond that there is no significant relationship between firm size and the licensing rate. The willingness to license seems to rise with firm size except for the smallest firms.

(Figure 4)

Figure 5 shows the incidence of licensing and the incidence of cross-licensing conditional on licensing, by the size of the bundle of complementary patents, which is defined by our survey as the number of domestic patents jointly used in the commercial application of the invention under the survey. Cross-licensing plays a quite different role from that of a unilateral license. Its main objective is to have access to the patents of the other firms to obtain the freedom of design, the freedom of business, but often not to obtain licensing revenue. According to our survey, it is extensively used in communications, information storage and semiconductor industry where many patents are involved in the production process or in the design of the products. The information on the size of the bundle of complementary patents is available only for the inventions which are used internally by the applicant, so that this figure covers only such sample. One quarter of the inventions exploited can be used on a stand-alone basis. 28% of these inventions are also licensed and 9% of the licensed inventions involve cross-licensing. The share of the inventions used for cross-licensing among the licensed inventions (that is, the incidence of cross-license conditional on license) increases monotonically with the size of the bundle of the complementary patents to be used together. It exceeds 40% if an invention requires more than 11 patents as a bundle for the internal commercialization. In addition, the incidence of licensing by itself increases very sharply once the size of the bundle exceeds 50.

(Figure 5)

3. Theoretical framework and the propositions to be tested

3.1 Uncertainty

We first consider the following simple two-stage setup for licensing, focusing on unilateral license. In the ex-ante first stage before the licensor's encounter with a licensee, a licensor classifies his patents according to his expectation of whether it can expect to earn a profit more than the setup cost for licensing, which is incurred in the first stage and becomes sunk in the second (ex-post) stage. In the second stage, the licensor actually decides whether he is going to give a license to a specific licensee. We assume an encounter with only one licensee for each patent for simplicity. We assume that neither a licensor nor a licensee knows the true quality of the patent, which is denoted by $\tilde{q}$ with mean the population $\overline{q}$. The patent quality is measured by marginal cost reduction due to a process patent or a marginal increase of the consumers' willingness to pay due to a product patent, both as applied to a unit of the output of a firm[7]. The licensor and the licensee have the noisy signals for the true quality (q is the licensor's signal and q^* is the licensee's signal), which are assumed to have normal distributions with mean $\tilde{q}$.

In the first (ex-ante) stage, the licensor evaluates whether licensing of his patent

[7] If we focus on an incremental invention, the invention of quality q generates marginal profit qa for a firm with complementary manufacturing capability with size a.

enhances its profit, based only on his signal. In the second (ex post) stage, the licensor and the licensee decide whether they can develop a profitable license contract, based on two shared signals on the quality of his patent. That is, they aggregate the signals at that stage. We denote the asset of the licensor (the licensee) by a (a^*)[8], its complementarity with the patent by θ (θ^*), and the cost of technology transfer (which may include a duplication of the business development cost by the licensee for incorporating the invention) by k^s. We regard the decision of the licensor to use the invention internally as exogenous.

First, we consider the ex-post license decision. Whether a licensor will provide a license or not depends on whether the licensed patented invention can generate the net value (the sum of the licensee's profit and the rent lost due to more competition)[9] and/or incurring technology transfer cost. There is a rent dissipation effect for the licensor with respect to the profit from the focal invention or the other substitute inventions of the licensor if it cannot control the competition with the licensee by a contractual mechanism such as the imposition of the output-based royalty on the licensee or the restriction of the market scope of the use of the patent. Denoting the quality of the licensed patent as jointly estimated by the two parties in the second stage by q_2^e, we have the following ex-post profit for the licensor:

$$\pi_{license} = \lambda[\{\beta_0 + (\beta_1 q_2^e + \beta_2)(\theta^* a^*) - k^s\} - h(\beta_3 q_2^e + \beta_4)(\theta a) + \varepsilon] \qquad (1)$$

, where λ $(0 < \lambda < 1)$ is the share of the licensor's profit, the first term in the above bracket represents the profit for the licensee from exploiting the invention, and the second term represents the competitive loss of the licensor, which increases with the level of the profit which the licensor will get from the exclusive use of the invention, with h representing the level of rent

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8 The variable with * is that of the licensee.

9 We can consider the problem in the framework of Nash Bargaining. In this framework, the threat points are the profit of the two firms without a license. The Nash bargaining results in the split of the increase of the joint profit due to a license (subject to antitrust regulation such as the prohibition of reverse payment), while compensating fully the loss of the licensor due to rent dissipation. λ in equation (1) is the share of such surplus for the licensor.

dissipation due to product market competition (h is zero either when the invention is not used internally, the rent dissipation is fully controlled or the rent dissipation from the license is absent due to competition in technology market). The third term (ε) represents uncertainty unknown to the licensor in the first stage and gets realized in the second stage, such as market characteristics affecting the licensing profit of the patent (we assume market uncertainty ε is resolved in the second stage for simplicity). It has a zero mean ex ante and is independently distributed from the rest of the variables.

The licensor and the licensee combine their signals for estimating the quality of the patent in the second stage. Their contract builds on the following expectation of the patent quality:

$$q_2^e = E(\tilde{q} \mid ex-post) = \delta q + \omega q^* + (1 - \delta - \omega)\overline{q} \quad (2).$$

It is the weighted average of the two signals and the mean, and is normally distributed with the common mean $\overline{q}$. The weights δ and ω ($0 \le \delta, \omega \le 1$) are determined by the accuracy of the two signals. Denoting the right hand side of equation (1), excluding uncertainty term, by $\mu(q_2^e)$, which depends on the expected quality of the patent, we can simplify the expression (1) in the following manner:

$$\pi_{license} = \mu(q_2^e) + \lambda\varepsilon = \mu(q_1^e) + \lambda A(q_2^e - q_1^e) + \lambda\varepsilon \quad (3)$$

, where q_1^e is the licensor's ex-ante estimation of the quality based on his signal alone and $A = \beta_1(\theta^* a^*) - h\beta_3(\theta a)$. The licensor`s expected mean of the licensing profit can differ from its realization, both due to the difference of the ex-ante and ex-post expected mean value of the quality of the patent as well as due to a realization of market characteristics ε.

In the first stage, the signal of the licensee is not available, so that the licensor uses only his signal to decide whether it would incur a set up cost for the license. The ex-ante expectation of the patent quality is given by the following expression:

$$q_1^e = E(q_2^e \mid ex - ante) = \delta q + (1-\delta)\overline{q} \quad (4)$$

$$q_2^e - q_1^e = \omega(q^* - \overline{q}) \quad (5)$$

Assuming normal distributions for both the expectational correction and the licensing profit uncertainty ε, and noting that the licensor will provide a license only when it can produce a positive net profit (that is, a license is an option), we have the following condition for a licensor to be willing to incur the set-up cost (*f*):

$$\pi_{license}^{ex\_ante} = E(\pi_{license} \mid \pi_{license} \geq 0) - f = \mu(q_1^e) + \sigma\phi(\mu(q_1^e)/\sigma)/F(\mu(q_1^e)/\sigma) - \mathrm{f} \geq 0 \quad (6)$$

, where $\mu(q_1^e)$ (>0) represents the unconditional expectation of $\pi_{license}$, and *F* represents the cumulative distribution of the normalized licensing profit. Variance σ is equal to the sum of the variance of $\lambda\varepsilon$ and that of the correction of expectation with respect to the quality ($\lambda A(q_2^e - q_1^e)$). It is clear that this condition is more likely to be satisfied when the variance σ is large, given that the inverse Mills ratio declines with its argument (c= μ / σ) :

$$\partial\{\phi(c)/F(c)\}/\partial c = -(\phi/F)(c + \phi/F) < 0 \quad \textbf{(7)}$$

The marginal value of the ex-ante profit from a license with respect to its expected value μ is less than 1, but it can also be shown that it is still positive[10]. Thus, we have

$$1 > \partial\pi_{license}^{ex-ante}/\partial\mu > 0 \quad (8.1)$$

$$\partial\pi_{license}^{ex-ante}/\partial\sigma > 0 \quad (8.2)$$

The condition that Equation (6) is zero gives the threshold patent quality for a firm expressing a positive willingness to license, for a given setup cost. As uncertainty increases, the threshold quality declines as shown in Figure 6, assuming that the expected profit of a license rises with the patent quality. In the second stage, a licensor actually decides to give a license when he encounters the licensee, the contract with whom can generate a positive profit from the license, which depends on the realization of the uncertainty, according to equation (3). Noting

[10] See Wooldridge (2002, page 522)

that both $\mu(q_1^e)$ and $\mu(q_2^e)$ have the common mean $\mu(\overline{q})$, the ex-ante condition is located below the ex-post condition on average in Figure 6, unless the search cost (*f*) is very large or uncertainty is small. The gap between them rises with uncertainty. When the line for the ex-ante condition is located above that for the ex-post condition, all patents meeting such conditions will be licensed ex-post.

(Figure 6)

It is very important to note that the rent dissipation effect is absent either when a contractual mechanism can fully control the competition, when the competition itself is absent since the patent is not used internally by a licensor or when the rent dissipation effect itself is absent due to competition in technology market. The effect of the patent quality on the willingness to license depends on the strength of rent dissipation effect, since

$$\partial\pi_{license}^{ex-ante}/\partial q = \lambda(\beta_1\theta^* a^* - h\beta_3\theta a)\partial q_1^e/\partial q + \sigma\partial(\phi/F)/\partial q_1^e(\partial q_1^e/\partial q) \quad (9)$$

We can assess the strength of the rent dissipation effect by investigating whether the responsiveness of the willingness to license to the patent quality declines substantially, when the focal patent is internally used. If the estimated coefficients do not change, we may conclude that the rent dissipation effect is significantly absent. As for the effect on the gap between the willingness to license and the actual license, since we have $\partial q_1^e/\partial q = \partial q_2^e/\partial q = \delta > 0$, increase of q has an effect of reducing the ex-ante value relative to the ex-post value by reducing the size of the Mill`s ratio for a given variance, compared to the case there it is not.

Based on these analyses, we have the following proposition 1 and 2.

Proposition 1. (Effects of uncertainty)

Since licensing is an option, uncertainty of the licensing profit increases the willingness to license and the gap between the willingness to license and the actual license. One source of such uncertainty is an ex-post correction of the patent quality expectation by a licensor *through incorporating the licensee's signal.*

Proposition 2. (Effect of rent dissipation due to product market competition)

If the internal use of a patent does not significantly reduce the responsiveness of the willingness to license with respect to the value of the focal patent, the rent dissipation due to more product market competition is effectively controlled or absent.

3.2 Bundle of patents and cross license

In the following, we would like to introduce cross license into the analysis. We consider the situation where a firm needs to use a bundle of complementary patents for its product or process. Whether the ownership distribution of the complementary patents is fragmented across firms depends on the size of the bundle of such patents. Denoting the number of complementary patents used by a firm for its product or process by N and the probability that a patent of such bundle is not owned by a firm by p (we assume independence of such event across the bundle of patents), the probability y that the ownership is fragmented (that is, not all of N patents are owned by a single firm) is given by

$$y = 1 - (1 - p)^N \cong pN \qquad \text{(if } p \text{ is small).} \qquad (10)$$

Thus, the probability of the fragmentation of patent ownership, and therefore the necessity of cross licensing, increases with the size of the bundle of complementary patents (N). When the ownership of the patents is fragmented, the consolidation of the ownership of such patents to a single firm could be an alternative solution. It can effectively avoid the duplicative investments and rent dissipation. However, if each firm owns significant complementary assets necessary for commercializing the patent and the competition with the other firms are strong, sharing the patents through cross license for each firm to exploit the technology and the complementary assets can become a better choice.

On the other hand, in the case where a single firm owns all complementary patents, the probability of licensing such a bundle of patents will decline with the size of the bundle. This is because it becomes less likely that a licensee would own specialized complementary assets to exploit such bundle of patents, similar to those of the licensor. We can interpret such effect as that of larger bundle making θ^* in equation (1) smaller. In addition, licensing such a bundle of patents can make the licensee a closer competitor, so that the rent dissipation effect could become larger (higher *h* in equation (1)). Thus, as the size of the bundle increases, a unilateral license becomes less likely to be offered and, even if offered, it becomes less likely to be realized. Thus, we have the following proposition.

Proposition 3. (Effect of the size of the bundle of complementary patents on cross and unilateral license)

As the size of the bundle of the complementary patents necessary for commercializing a product or a process patent increases, the probability of cross license increases, while that of unilateral license declines.

In order to analyze how the invention characteristics and the firm characteristics affect cross licensing decision, we describe a simple model of a cross licensing, focusing on the case where each of two firms (firm A and firm B) owns an essential patent for a product or for a process. Thus, unless there is a cross license between the two firms, such patent cannot be commercialized. A cross-license would result in the sharing of the increase of the joint profit due to technology sharing, which is given by the sum of the profit increase of the licensor due to its access to the licensee's technology as well as that of the profit increase of the licensee due to the use of the licensor's technology. If we assume no output based royalty is imposed[11] while the side payment (such as initial payment) can be paid[12], the profit from cross licensing for the focal licensor firm A is given by

$$\pi_{cross\_license}^{ex-post} = \lambda[\{\gamma_0 + \gamma_1 q^s(\theta a) - k\} + \{\gamma_2 + \gamma_3 q^s(\theta^* a^*) - k^*\} + \varepsilon] \qquad (11)$$

Here q^s represents of the quality of the combined patents of the two firms and k (k*) represents the cost of implementing the shared technology by firm A (firm B), such as the development cost of embodying the shared technology into the existing complementarity assets of each firm.

Equation (11) implies that the profit of the licensor firm A due to a cross-license increases with the complementarity of the shared technology with its own assets,

$$\partial \pi_{cross\_license} / \partial(\theta a) = \lambda \gamma_1 q^s > 0 \qquad (12)$$

That is, the licensing profit increase with complementarity (θ) of the shared technology with the licensor's asset[13] and with the size of the licensor's asset (a) In the case of unilateral licensing, however, differentiating equation (1) with respect to the licensor's complementary assets, we have

$$\partial \pi_{license} / \partial(\theta a) = -\lambda h(\beta_3 q^e + \beta_4) \leq 0 \qquad (13)$$

Thus, if the rent dissipation effect is not fully controlled (h is non-zero), the licensing profit declines with complementarity (large θ) of the shared technology with the licensor's asset[14] and

[11] Most common industry practices seem to net out the mutual payments, so that no payment is required if two parties own the patents with equal aggregate values, according to the author's interviews. When the competition with a third party is important, imposing output based royalty on each other tends to reduce the profit of the insiders in the case of Cournot competition.

[12] The similar conclusions hold even if we assume no side payment, so that the firm gains only from implementing the shared technology.

[13] In an empirical setting, it is important for us to note the possibility that an invention useful for a licensor could also be useful for a licensee so that there can be a positive correlation in complementarity for the licensor and that for a licensee.

[14] In an empirical setting, it is important for us to note the possibility that an invention useful for a licensor could also be useful for a licensee so that there can be a positive correlation in complementarity for the licensor and that for a licensee.

with the size of the licensor's asset *a* (see Arora and Ceccagnoli (2006)). Thus, there exist fundamental differences between the unilateral and cross-license in this respect. Furthermore, a higher quality of a licensor firm A always results in more cross license, since we have:

$$\partial \pi_{cross\_license} / \partial q = \lambda [\gamma_1 (\theta a) + \gamma_4 (\theta^* a^*)](\partial q^s / \partial q) > 0. \tag{14}$$

Note, however, that what matters is the combination of the patents of the two firms and not that of the focal firm. On the other hand, the effect of the quality of a patent on unilateral license depends on the balance between more appropriation through the use of the complementary assets of the licensee and the rent dissipation when rent dissipation is not fully controlled, as shown in equation (9).

The willingness to cross license is determined by the following equation.

$$\begin{aligned}\pi^{ex\_ante}_{cross\_license} &= E(\pi^{ex-post}_{cross\_license} \mid \pi^{ex-post}_{cross\_license} \geq 0) - f_{cross} \\ &= \mu_{cross}(q) + \sigma\phi(\mu_{cross}(q)/\sigma_{cross})/F(\mu_{cross}(q)/\sigma_{cross}) - \mathrm{f}_{cross}\end{aligned} \tag{15}$$

It increases not only with the increase of the expected value μ_{cross} of the profit from cross license but also with its variance. We can summarize the above discussions by the following proposition on the incidence of cross license.

Proposition 4 (Effect of the licensor's complementary assets on unilateral and cross license)

The incidence of a cross license increases with the size of the complementary asset of a licensor firm and with the degree of the complementarity between the asset of the firm and the shared technology, unlike a unilateral license.

4. Estimation strategy and models

4.1 Empirical implications of the propositions and the estimation models

In order to test the empirical implications of Propositions 1, we estimate the following two types of models. The first model (Model 1 in Table 1) is a logit model for the willingness to license, where the dependent variable (*will_license*) is equal to one if the firm is willing to license its patent or if it has licensed and zero otherwise. This corresponds to the ex-ante decision as specified in equation (6) for a unilateral license. The sample covers all patents with non-missing data (although our data on the willingness to license does not differentiate a unilateral license and cross-license[15]). The second model (Model 2) is a logit model for an actual license conditional on the licensor being willing to license, where the dependent variable (*licensed2*) is equal to zero if the firm has licensed its patent and zero otherwise. The sample covers both the patents which have been licensed and those which the firm is willing to license but has not yet licensed. This corresponds to the ex-post decision as specified in equations (1) and (2) for a unilateral license. Since there is a missing variable q^* in our estimation for equation (1), it will cause some upward estimation biases with respect to the coefficient of q, even though the sample is selected based on the same set of independent variables as for the ex-ante decisions and the error term in equation (1) is not observable even by a licensor ex-ante[16]. That is, if we denote the coefficient of the regression of q^* on q by κ, the estimated coefficient of q is larger by $\kappa\omega\,(>0)$. We will discuss more the implications of such effect later. We also estimate the third model (Model 3), which is a logit model for an actual license, non_conditional on the licensor being willing to license, for the purpose of a comparison with the use equation.

Although we do not have a direct measure of uncertainty of the value of a patent, we can use the characteristics of the invention as its measures. We use the stage of the research from which the patent is generated, the importance of scientific literature for suggesting the research and the importance of suppliers or users as a knowledge source for the research as its indirect measures. While the patents with high scores for these indicators could have not only

[15] As shown in Figure 4, unilateral licensing is dominant on the average.
[16] Generally there can be a sample selection problem. However, unfortunately, we do not have good instruments to control for it.

high value uncertainty but also have higher mean values, we can control the latter effects by introducing the variables measuring the quality of the patents. We will confirm this by estimating the following two Models. We will see whether the patents with high scores for these indicators have significantly lower incidence of internal use by licensing firms in Model 4 which is a logit model for an internal use (*use2*). In addition, we will also inquire whether their economic values are not significantly different from the mean, once we control for the invention and patent qualities, in Model 5 which is an ordered logit model for an economic value of the focal patent (*valued2*), which is from the survey. Our survey asked the inventors to evaluate the relative economic value of his invention in the respective technology field by four ranks (top 10%, top 25%, top half and the bottom half). We asked a respondent to rank his invention among the technical accomplishments in the same technological field during the same period with the invention. Given these results, we can test Proposition 1 (1), by examining whether these uncertainty measures enhance the willingness to license more than the actual license conditional on the willingness to license. As for signals on patent quality, we will focus on three indicators of the patent value (the importance of the first mover advantage, triadic patent status and the frequency of citations by the other inventors).

The empirical implication of Proposition 2 is straight forward. We will focus on the willingness to license and estimate their determinants both for the sample of the patents which are used internally by the firms (Model 6 and 7 in Table 7) and for the sample of the patents which are not internally used by the firms (Model 8 and 9), in order to see whether the patent quality indicators have smaller effects for the first sample. We use the aggregated indicator for patent quality in Model 7 and 9.

The empirical implications of Proposition 3 and 4 are also straight forward. Before examining that, we will estimate the logit model with a dependent variable being the willingness to license (Model 10 in Table 3) as well as that with a dependent variable being the actual license non-conditional on the willingness to license (Model 11), introducing the size of bundle as a independent variable. It is for evaluating the effect of the size of bundle on the license as a whole. Then, we estimate the model which differentiate the unilateral license and cross license (Model 12). We use a multinomial logit model for the license decision type (*licensed_4*), where we distinguish unilateral license, cross-license, unknown type and no license (*licensed_4*=1, 2, 3 and 4 respectively). 10 % of the patents are unilaterally licensed and 4% involve cross-licensing. Since the inventor did not know for 5 % of the patents whether cross-licensing was involved, we include these cases as one separate case (*licensed_4*= 3). Thus, the sizes of the coefficients of both the unilateral and cross license alternatives are estimated downwards, but we are primarily interested in the difference of the coefficients. We use the fourth outcome as the base.

We use clustering on applicant firms and report robust standard errors.

4.2 Independent variables

The independent variables (*X)* , most of which are common to all estimations, are the following. We introduce the set of variables for measuring the business objective of R&D, the stage of research, the invention quality and its patent scope, the information sources and the existence of collaborations for R&D, invention types (targeted invention or not, product patent, and process patent), the size of an applicant, and the other control variables.

(1) Business objective of R&D

We use a variable (*objective3)* to indicate 4 business objectives of the R&D projects of the applicant firm which yielded the invention: enhancing the core business, its non-core business, unclassified existing business, new business, and enhancing technology base not directly linked to a business line. We use the enhancement of the core business as the base. Since the complementarity between the invention and the assets of the firm is higher for the invention from the R&D project enhancing the core business of a firm than that from the R&D project enhancing the non-core business of a firm, the incentive for unilateral license tends to be low while the incentive for cross license tends to be high for the patent for the core business of a firm. However, such invention may also have more useful applications outside of the firm than the invention for non-core business (both $a\theta$ and $a^*\theta^*$ are large). This latter effect tends to enhance incentives for both unilateral and cross license. Thus, cross license is more enhanced on both accounts but the effect on unilateral license is not clear. Exclusivity may be more important in new business in order to prevent duplication of business development cost (k^s in equation (1)). If this is important, the patents for new business would be less likely to be licensed. The invention for technology base would not involve immediate commercialization possibilities by the licensor, so that the rent dissipation effects would be smaller. On the other hand, such invention is also unlikely to be easily commercialized by a licensee.

(2) Stage of underlying R&D.

We use an index variable (*rd_upstream*), indicating where the research underlying the invention is positioned in the entire stages of research: from *basic research, applied research, development and the implementation stage such as technical service (*the index goes from 4 to 1*).* A more upstream patent involves more uncertainty in payoff, so that the variance of the return is larger for a given expected return. From proposition 1, since such uncertainty is significant for an upstream patent, we expect that the more upstream patent is no less offered for a license, even if such patent is less likely to be actually licensed.

(One important characteristic of an invention from basic research is that the additional investment for commercializing the invention is high and the existing complementary assets of the patentee is low ($a\theta$ is small) and. Complementary assets for such invention may be more easily obtained outside of the firm ($a^*\theta^*$ is not so low). In addition, the rent dissipation effect is small due to low level of $a\theta$. The profitability of licensing such patent may not be so low).

(3)*Quality of an invention and its patent scope*

Although our quality variable *q* is a composite of the invention quality and the patent protection, we separate them empirically to the extent possible. We use both the subjective measure and the bibliographic indicators. The first measure of the invention quality is the average score in terms of 5 point Lickert scale of the importance of the first mover advantage as an appropriation mechanism in the follower up research and patenting and that in its commercialization (*fmv_2*). The importance of such appropriation mechanism increases with the quality of an invention. That is, the additional value due to bringing that invention faster into the market would increase monotonically with the quality of an invention, since a high quality invention generates high profit per period. Similarly, the importance of the follow up research and patenting also rises with the quality of the initial invention. Secondly, we have a dummy indicating whether the firm has secured the US patent grant and has applied for an EPO patent (*triadic*). An invention which resulted in a triadic patent tends to be a high value patent, since it was screened not only by the examination by the USPTO but also by the costs of international patent applications. Note that the question for an inventor on licensing status in our survey focuses on that of the Japanese patent, so that the triadic patent status does not directly represent the effectiveness of the patent protection[17]. We also use the logarithm of the number of forward citations (*ln1cited_inv*) made by the inventors in describing their inventions (not including the citations made only by

[17] An indicator of whether the firm has already secured the domestic patent right or it intends to do that is highly correlated with the willingness to license and with the actual license. Such correlation is likely to be highly endogenous, since a licensee would seek for the clarification of the patentability before agreeing on the contract. The invention with no patentability has zero licensing value, since our population covers only applied patents (not business secrets) which are automatically disclosed in Japan.

examiners)[18], the logarithm of the number of claims (*lnclaims*), and the logarithm of the number of technology classes covered by the patent (*lnnum_ipc*). The latter two measures would represent not only the quality of the invention but also the scope of patent protection.

(4) Size of the complementary patents (*Bundl2*)

We use the survey response to the question which identifies the size of the complementary patents (*Bundl2*) which need to be used together with the focal patent. This variable is used only in the third type of specification. It identifies 6 categories: 1, 2-5, 6-10, 11-50, 51-100 and 101 or more. This question was asked only for the patent which has been commercialized internally by the firm, so that the test using this variable is conditional on this sample selection[19]. Thus, we implement estimations with and without this variable. The base of the estimation is the case where the patent under the survey can be commercialized on a stand-alone basis

(5) *Information sources and collaborations for R&D*

We use the indicators of the importance of four knowledge sources for the conception of inventions as well as the indicators of the existence of collaborations for R&D, to characterize the nature of inventions, in particular uncertainty involved. The score of importance for a knowledge source varies from non-use (0) to very important (5). They are *cncpt_sci* for scientific literature, *cncpt_pat* for patent literature, *cncpt_v* for the max of the importance of suppliers or that of customers and *cncpt_res* for the max of the importance of the university and the other public research institution. The indicators of the existence of collaborations for R&D cover both co-inventions with the inventors affiliated with external organizations and the other types of research collaborations: those with suppliers or customers (*collab_v*) or with a university and other public research institution (*collab_res*). The invention which depends

[18] We use dummies for patent application years, to control for truncations and recognition lag.
[19] There can be some bias due to the fact that an invention which requires a larger bundle of the patents may be less commercialized.

significantly on the scientific literature, similar to an upstream invention, is likely to have a lower chance in commercialization but can have a large return once commercialized[20]. Thus, we expect that higher science linkage is significantly negatively associated with the actual license, while it may not be negatively associated with the willingness to license, due to its high option value. Such reasoning would also be applicable to the invention for which a university and the other public research institution is an important knowledge source. On the other hand, the invention for which collaboration with a user or supplier is important is likely to involve smaller uncertainty, since such invention would address mainly the problems of existing products or technologies.

(6)Invention types

We introduce a dummy variable (*target),* indicating whether the invention meets the original objective of the R&D (the other types are expected or unexpected by-product of an R&D, invention involving only development or no R&D) *as a control.* An invention which was the main target of the R&D would involve less uncertainty in commercialization, while it is more complementary with the existing assets. We also introduce the dummies differentiating *product patent*, *process patent* and the *dual* (product patent as the base) as another control. Licensing of a process patent may involve a less rent dissipation for a licensor than that for a product patent, if the product is highly differentiated among firms while many firms may use a similar production technology. In this case, process patent is more likely to be offered for a license and more likely to be licensed.

(7)*Firm size*

We use the indicators of the four classes of firm size (large: 501 or more employment, medium: 251-500, small: 101-250 and very small: 100 or less). A large firm is the base. A small firm has

[20] 44% of the inventions using scientific literature most intensively is used internally, while 60% of the inventions which do not use scientific literature is used internally.

less complementary assets (smaller *a*), which would imply a positive effect of a small firm dummy on unilateral licensing if the rent dissipation effect is important, but a negative effect on cross license (Position 2). Such firm is likely to patent only higher quality inventions, due to its weaker appropriation capability. Thus, the positive coefficient of a small firm dummy may indicate either its small complementary asset and/or its high quality invention.

(8)*Other controls*

We introduce the following controls: the *priority year* of the invention and *technology class dummies* for inventions (30 ISI technology classifications). These variables control for the difference in technology and market conditions, competition, the age of the invention, the truncation of the forward citation, among others. We also account for the potential correlation of error terms among inventions of the same firm by clustering based on the identity of applicant firm.

5. Estimation results and discussions

5.1 Effects of uncertainty

In this subsection we first focus on the comparison of the determinants of the willingness to license (*willingness to license*) and those of the incidence of the actual license (*licensed*) conditional on the willingness to license, focusing on Proposition 1. Model 1 and Model 2 in Table 1 provide the specifications and the results. These two models pool all licenses, although the results mainly reflect the nature of unilateral license, since it accounts for 70% of the licenses. Model 3, Model 4 and Model 5 show the results of the estimation for the incidence of actual license, that of the internal use by the applicant, both of which are non-conditional on the willingness to license, as well as the value of the focal patent to assess the nature of independent variables for Model 1 and 2. First, we look at the evidence on the effects of uncertainty, based on Model 1 and 2. We focus on three variables (*rd_upstream*, *cncpt_sci*, *cncpt_v*), which represent (positively or negatively) uncertainty of the invention process. As shown in Model 5, these three variables do not significantly affect the economic value of an invention once we control for the quality characteristics of the patent, while the first two variables reduce the probability of the internal use significantly while the last variable increases it significantly, as shown in Model 4. These results support our interpretation that they mainly measure uncertainty of the inventions (not the mean value) once we introduce the patent quality variables separately.

According to Model 1, a firm is no less willingness to license the patent involving more upstream research (the coefficient of *rd_upstream* is negative but not significant), even though such patent is significantly less likely to be actually licensed according to Model 2. Very similarly, a firm is no less willingness to license the patent using scientific and technical literature more intensively as its knowledge source (the coefficient of *cncpt_sci* is only slightly negative), even though such patent is significantly less likely to be licensed according to Model 2. Furthermore, the invention using the knowledge sources of suppliers or users more intensively (with large *cncpt_v*) is significantly more licensed once offered for a license, even though it is not more likely to be offered. These results strongly support Proposition 1. That is, when the value of a patent is uncertain (at least toward higher value), the firm is more willing to incur a setup cost for a license in order to capture the option value even if it is less licensed on average. The reverse is true for the invention for which uncertainty is small, such as the invention inspired by the knowledge from suppliers or users.

These effects are significant in accounting for the gap between the willingness to license and the actual license: an actual license conditional on the willingness to license is 15 percentage points lower for an invention from basic research than that from development, according to the marginal effects (3*0.05, according to the last column of Model 2), even though the willingness to license is lower only by less than 1 percentage point. Given that an actual license conditional on the willingness to license is around 50%, such effect alone is equivalent to more than one third of such gap. Similarly, the incidence of actual license conditional on the willingness to license decreases by 9 percentage points (see the last column of Model 2) while the willingness to license is barely affected, as the importance of scientific literature as knowledge source increases by 3 points in 5 point Likert scale. This effect is equivalent to about one fifth of the above gap. Finally, the incidence of actual license conditional on the willingness to license decreases by 7.5 percentage points, as the importance of user or supplier as knowledge source increases by 3 units in 5 point Likert scale.

(Table 1)

An patent with high quality in terms of the importance of the first mover advantage (*fmv_2*) significantly enhances both the willingness to license and the actual license conditional on the willingness to license, but more significantly the willingness to license (In terms of marginal effects, a two units increase of the importance in Likert Scale results in 11% point increase of the willingness to license and 7% points increase of an conditional probability of actual license according to marginal effects). A triadic patent dummy is also highly significant for both the willingness to license and for the actual license (it results in 9% points increase of the willingness to license and 12% points increase of an actual license, conditional on the willingness to license), but it is more significant for actual license. On the other hand, the level of forward citations is significant only for the willingness to license, once we introduce the above two quality measures[21], and the number of claims and the number of IPC classes covered by the patent are not significant. Thus, a higher quality patent is more likely to be offered for a license and more likely to be licensed once offered for a license, indicating that the rent dissipation effect is significantly controlled (we will analyze this in more detail later). The

[21] If we remove the triadic patent dummy, the forward citation becomes significant for actual license conditional on the willingness to license.

results are consistent with the finding of Gambardella et al (2007) based on European survey, although they use a different set of the quality measures (the number of designated European states, opposition, the number of claims and the number of IPC classes covered etc.).

The coefficient of the importance of the first mover advantage is larger in the willingness to pay equation than in the conditional actual license equation, while the reverse is the case for the triadic patent dummy. The ratio of the coefficients is twice larger for the first mover advantage than that for the triadic patent dummy (1.5=0.237/0.161>1> 0.7=0.376/0.536), although the difference is not statistically significant[22]. One potential explanation for such difference is the effect of a missing quality variable q^* in Model 2 on actual license. The triadic patent dummy may be more closely correlated with such variable than the importance of the first mover advantage, since the latter may depend more on the local information specific to the licensor (the assets of the licensor). As a result, the coefficient of the triadic patent dummy captures more the effect of such missing variable. Another complementary interpretation is that the quality signal based on first mover advantage involves more information asymmetry and more ex-post correction of the patent quality expectation through incorporating the licensee's signal (Proposition 1). Anticipating this, the licensor is more willing to license for the invention with high score in such signal. In either case the finding that a more subjective value indicator (the importance of the first mover advantage in appropriation) is more significant in the willingness to pay than in the actual license, relative to a more objective value indicator (a triadic patent status) provides some evidence for the importance of additional information held by the licensee affecting the actual licensing decision.

We look at the other significant results. According to Model 1 in Table 1, an invention involving direct collaboration with the users or the suppliers (it has one for dummy *collab_v*) is

[22] Nonlinear test of the equality of the ratios of the two equations suggest that it is significant only at the level of 26%.

more likely to be offered for a license, although once given for a license, it is no more likely to be realized. One interpretation of these results is that a vertical collaborator is likely to be a clear candidate for a licensing[23] so that the ex-ante decision for licensing involves a smaller set-up cost *(f* in equation (6)), but the ex-post licensing decision depends on whether the knowledge of vertical collaborators is significantly used for the invention (that is, *cncpt_v* is large). In addition, Table 1 suggests an interesting point that the process invention is more likely to be offered for a license as well as more likely to be actually licensed once offered for a license. That is, patented process technology is more widely shared among firms than patented product technology is. This may suggest the importance of product differentiation as modes of competition and the relevancy of a monopolistic competition model. In such model, each firm is specialized in each distinct product, so that the rent dissipation through sharing process technology is weak while sharing the product technology itself makes the recovery of the product development cost difficult.

One major difference of our result from the European result (Gambardella et al (2007)) is that there is no significant difference in the probability of the willingness to license across different firm size. The survey over the US inventors produced the result similar to Japan (see nagaoka and walsh (2009)). A potential reason for the difference is that our main sample is the triadic patents, so that it may screens out many lower quality patents held by large firms, although further analysis is warranted. Another potential difference between the EU and Japan is that the Japanese survey does not limit the licenses to those for unrelated parties. That is, our license data covers the domestic license by a large firm to its subsidiaries[24]. Finally, the invention for new business is less offered for a license (see Model 1), relative to a core

[23] Note that we focus on the patents with a single applicant, implying that a vertical collaborator can use the invention only if it is licensed.
[24] Note that our questionnaire covers licensing of only a domestic patent.

technology, perhaps due to the motivation to avoid duplicative cost of new business development and therefore the rent dissipation.

Model 3 and 4 present the results of estimations on non-conditional probabilities of the actual license and the internal use of the invention. The patterns of the estimated coefficients are very similar. In particular, the invention quality indicators are highly significant and positive (although the frequency of forward citation is not significant in license equation), while the indicators of uncertainty (upstream nature of an invention and the use of scientific knowledge) are significant and negative. They confirm that these indicators do capture the effects of what we would like to measure (namely, the invention quality and uncertainty). In addition, the results also indicate that the indicator of upstream invention and of the invention based on the collaboration with a university has a significantly larger negative coefficient in the use equation than in the license equation, even though the invention quality indicators (such as first mover advantage and the triadic patent status) have the coefficients of similar size. This indicates that a license becomes more important for an upstream invention.

Finally, Table 2 in the Appendix provides the results based on fixed effects estimation (each applicant is given a fixed effect). No substantial differences emerge from such estimations. Thus, our results are robust to firm level missing variables.

5.2 Examining the rent dissipation effects: willingness to license internally commercialized patents and non-commercialized patents

Model 6 and 8 in Table 2 allow us to compare the estimation results for the willingness to license with respect to the internally commercialized patents and for that to the internally non-commercialized patents. If the rent dissipation effect is an important constraint on licensing, the responsiveness of the willingness to license to the value of the focal patent would decline if the patent is internally commercialized. Perhaps surprisingly, the licensor is more willing to license the patent for which the first mover advantage is important when the patent is used, according to Model 6. On the other hand, it is not more willing to license the patent for which the first mover advantage is important when the patent is not used, according to Model 8. Moreover, the coefficient and the marginal effects are larger for the case where the patent is used. These results are not consistent with strong constraint on licensing due to rent dissipation. On the other hand, the triadic patent status and the frequency of forward citations are significantly more important for the firm becoming willing to license when the patent is not internally used than when it is internally used. This is consistent with the view that the rent dissipation effect constrains a firm to license high quality patents.

(Table 2)

One potential source of the above conflicting results is the different accuracy of three quality indicators, depending on whether the focal patent is used by the licensor or not. In particular, the index based on the licensor's assessment of the importance of first mover advantage (*fmv_2*) may be more accurate when the patent is used by the licensor, so that it has a larger estimated coefficient in Model 6 than in Model 8. In order to take this into account, we developed the composite indicators of the patent quality (*quality*), based on the weighted average of three indicators. The weights are estimated based on the regressions on the economic value indicator (the same specification as Model 5 in Table 1). It is the average of the coefficients estimated for the sample where the patent is internally used and for the sample where it is not: *quality = 0.534*fmv_2 + 0.422*triadic +0.082*ln1cited_inv*. Variable *fmv_2* has a larger estimated coefficient for the sample where the patent is used, although it is highly significant in both samples, as we expect. Model 7 and Model 9 shows the results based on this quality index. It is positive and significant in both equations. It has a larger coefficient in Model 8 where the focal patent is used, although the difference is not significant. These results suggest that the rent dissipation effect may be significantly controlled by contractual mechanism such as running royalty or it is weak due to competition in technology market, so that it does not significantly constrain licensing of a patent that is used by a firm and is valuable.

A supporting evidence for this interpretation is that the non-core business dummy (*non-core*) is significantly negative when the patent is internally used while it is not and has a smaller coefficient when the patent is not used. That is, when the invention is developed for the core business, it is more likely to be licensed than when it is developed for non-core business (see Model 6 and 7). These results indicate that the licensor is more willing to provide a license for the patent which is generated from a R&D project targeted to the core business of a firm. On the other hand, we have also found some evidence for rent dissipation as an important consideration for licensing. A firm is less willing to license a patented invention developed for establishing new business, especially when the patent is used internally by a firm. These findings are not contradictory, since the rent dissipation through lower product price due to stronger competition can be controlled by imposing royalty while the duplication of fixed cost of entry can be prevented only by refusing to provide a license.

5.3 Unilateral and cross license

Table 3 provides the results evaluating the effect of the bundle size of the patents for the sample where we have information on the size of complementary patents of the focal patent, which is the sample where the applicant uses the invention internally, which is around a half of the entire sample. First we take a look at the determinants of willingness to license, introducing the size of the bundle as a additional independent variable, pooling unilateral and cross license. As shown in Model 10 in Table 3, the variable for the size of the bundle of the patents (*Bundl2)* is highly significant in accounting for the increase of willingness to provide a license, once the size of the bundle exceeds 50. When the size of the bundle is between 51 to 100, the probability of being willing to license is 20 percentage points higher than the case where the size of the bundle is 50 or below. If the size of the bundle exceeds 100, the probability of being willing to license increases further by 12 percentage points (32 percentage points increase in total), making the willingness to license exceed 70%.

Model 11 provides the results on the incidence of actual license which is not conditional on the willingness to license. The patterns of the coefficients are very similar. In particular, the incidence of the actual license is significantly enhanced by the size of the bundle of the patents, once the size of the bundle exceeds 50. Since the sample is screened by the internal use of the invention, it is not surprising that the coefficients of the risk related variables (*rd_upstream, cncpt_sci* and *cncpt_res*) are not significant in both Models. However, the value indicator (*fmv_2*) as well as the dummy of vertical collaboration (*collab_v*) remains significant and positive.

Model 12 is a multinomial model, which accommodates the estimations of the coefficients for unilateral license and for cross license separately, conditional on the willingness to provide a license (either for a unilateral or cross license). The base of the estimation is no license (but used internally). The size of the bundle is significant for both types of license decisions, especially for a cross license, but in the opposite directions: significantly positive for a cross license and significantly negative for a unilateral license. The incidence of cross license increases significantly and monotonically with the size of the bundle. The probability increases by 11 percentage points, when the size of the bundle increases to 2-5 patents from a single stand-alone patent, according to the marginal effects. When it increases to 101 or more, the probability increases by 24 % percentage points in total, relative to a single stand-alone patent. On the other hand, that of the unilateral license decreases significantly as the size of the bundle rises. The estimations which are not conditional on the willingness to license give similar results[25].Since the initial increase of the incidence of the cross license is similar to the initial decrease of the incidence of unilateral license in terms of marginal effects, the total incidence of license dose not rise until the size reaches the class of 51-100, as we observed for Model 10 and 11. Beyond that, the increase of the cross license dominates. These results provide support to Proposition 3.

Model 12 also shows that the invention for non-core business is significantly less licensed in the case of cross-license relative to that for core-business (10% level), while the reverse tends to be the case for unilateral license. In addition, the patent of the smallest firms is more unilaterally licensed but not significantly more cross licensed. These results support Proposition 4. The coefficients of the invention quality or the uncertainty of the invention quality are not significant, which are not surprising, given that the sample covers only the inventions used internally by the applicant firm, which implies higher value and less uncertainty. Finally, the invention for which the vertical knowledge is important is more licensed for either a cross license and for a unilateral license, but more so for a unilateral license.

6. Conclusions

This paper has provided novel analyses of the effects of uncertainty, rent dissipation and the patent bundle on corporate license, exploiting newly collected large scale micro data on 4,000 patents and the underlying R&D projects in Japan. First, we have developed a simple model explaining the gap between the willingness to license and the actual license, focusing on uncertainty in commercialization of the patent, including the addition of a signal of a licensee with regard to patent quality at the license contracting stage. We have found strong empirical evidence that uncertainty of licensing value of the patent increases significantly the licensor's willingness to license, for a given license possibility, and therefore it is a significant factor explaining the large

[25] The results are available on request.

gap between the willingness and the actual license (only half of the patents which the licensor are willingness to license are actually licensed). Thus, as the invention become more upstream, the rate of actual license declines, although to a smaller extent than the rate of internal use.

Second, we have found that a higher quality patent is more likely to be offered for a license and more likely to be licensed once offered for a license. This is consistent with the finding of Gambardella et al (2007) based on European survey. In addition, we have found that a more subjective quality indicator (the importance of the first mover advantage in appropriation) of the focal patent predicts the willingness to license more than the actual license, compared to a more objective value indicator (a triadic patent status) does. Such evidence provides some evidence for the importance of the arrival of important new information from a licensee on the patent quality at the actual license stage.

Third, we tested the importance of rent dissipation effects as a constraint on licensing by examining whether the patent quality affects the willingness to license less if the patent is used internally. Somewhat surprisingly, we have found that a licensor is no less willing to license the patent for which the first mover advantage is important or which has high score in the composite quality index, even if the patent is used internally by the applicant firm. This suggests that the rent dissipation effect is significantly controlled contractually or it is weak due to competition in technology market. On the other hand, we have also found that a firm is less willing to license a patented invention developed for establishing new business, when the patent is used internally by a firm. These findings are not contradictory, since the rent dissipation through lower product price due to stronger competition can be controlled contractually by imposing royalty while the duplication of fixed cost of entry can be avoided only by not providing a license.

Fourth, we assessed how the determinants of the incidence of cross-license differ from those of the incidence of unilateral license. We have found that the size of the complementary patents to be jointly used with the focal patent enhances cross license, but reduces unilateral license, both relative to no license (exclusive use by a firm). As the size of the bundle increases, the former effects dominate so that the overall incidence of license increases. We have also shown that the patent for core business tends to be more cross licensed and the patent of the smallest firms is more unilaterally licensed. Thus, there is a significant difference between the unilateral license and cross license, which is consistent with our theoretical model.

Our analysis also provides some evidence that a process patent is more likely to be offered for a license as well as more likely to be actually licensed once offered for a license. This suggests the importance of product differentiation as modes of competition. In a monopolistic competition model, where each firm is specialized in each distinct product, the rent dissipation through sharing process technology is weak while sharing the product technology makes the recovery of entry cost difficult. Our analysis also provides some evidence that license becomes more important for an upstream invention, since a firm may not always have complementary assets to best exploit such invention.

There are several important implications of our study on policy, management and future research. First, a large gap between the willingness to license and the actual license does not necessarily show the existence of market failure. In fact, we may conclude that such gap reflects importantly efficient functioning of the technology market. Innovation process is uncertain and especially so if it is based on an upstream invention from basic research. Such invention may have a very high value once commercialized and external parties may have very important information in that regard which the inventing firm does not. Then, such firm may well be more willing to license such invention, in order to exploit the option value of a license, even though the license probability per se is low on the average. Such high willingness to license in turn facilitates more innovations based on an upstream invention.

At the same time, there may be an important market failure. The lack of demand side information may discourage a potential licensor to actively search for a licensee and the scope of the candidate patents for licensing may be too narrow. On the other, a potential licensee may not be willing to reveal their valuations so as to prevent the licensor from “stealing” the idea on the potential use of the patent. Thus, development of a commitment mechanism for a licensor on licensing fees may be useful for enhancing the voluntary revelation of such valuation information by potential licensees and for expanding the scale of the technology market.

Second, although rent dissipation may potentially constrain licensing significantly, our research suggests that the existing contractual mechanism may significantly control it or the rent itself may be small due to competition in technology market. An important research question would be to identify the cause. In any case, the patent quality (including invention quality) rather than rent dissipation may constrain licensing more. Third, our finding of the sharp differences of the determinants for cross license and unilateral licensing has also an important implication. Since cross license occupies a significant part of licensing practices, cross license would need to receive separate treatment in analysis and management.

Appendix Inventor survey in Japan

A.1 Basics of the survey

The survey in Japan was conducted by the RIETI (Research Institute of Economy, Trade and Industry) between January and May in 2007. It collected 3,658 triadic patents, with priority years from 1995 to 2001, and 1501 non-triadic patents with application years from 1995 to 2001[26]. The survey used both mail and web (post-mail out and response by post or web) and the response rate was 20.6% (27.1% adjusted for undelivered, ineligible, etc.). The questionnaire consists of the following six sections: (1) Inventor's Personal Information; (2) Inventor's Education; (3) Inventor's Employment and Mobility; (4) Objective and Scope of R&D and the Invention Process; (5) Inventor's Motivations; (6) Use of invention and the patent.

A.2 The sampling strategy

The main focus of the survey is the OECD's Triadic Patent Families database (OECD, 2006) which includes only those patents whose applications are filed in both the Japanese Patent Office and the European Patent Office and granted in the United States Patent and Trademark Office. There are both practical and theoretical advantages to oversampling the TPF patents. Practically, we could utilize the enormous databases provided by all three patent offices. Furthermore, focusing on triadic patents can avoid sending most questionnaires to economically unimportant patents, given the highly skewed nature of the value of patents, since filing in multiple jurisdictions works as a threshold. The number of basic patents (first priority patent) of TPF account for only 3% of the domestic applications in Japan. One caveat here is that this characteristic of TPF may favor large and multinational firms[27].

Using the patent-based indicators for all patents in the sample, we tested response bias,

[26] A survey also includes a small number of important patents identified by the JPO and the essential patents of the standard.

[27] According to the comparison of the characteristics of triadic and non-triadic patents (See Nagaoka and Tsukada (2007)), the differences are often small. For an example, the share of small firm with 250 employment or less account for 10.2% of non-triadic patents and 8.7% of triadic patents.

in terms of application year, the number of assignees, the number of inventors, the number of claims, and the number of different International Patent Classes. In general, the test results did not show that there were very significant response biases. There are some differences in application year (the responses have newer applications by 1 month), the number of claims (the responses have smaller number of claims by 0.37, significant at 5%).

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Figure 1. Incidence of a high valued patent and incidence of use by stage of research

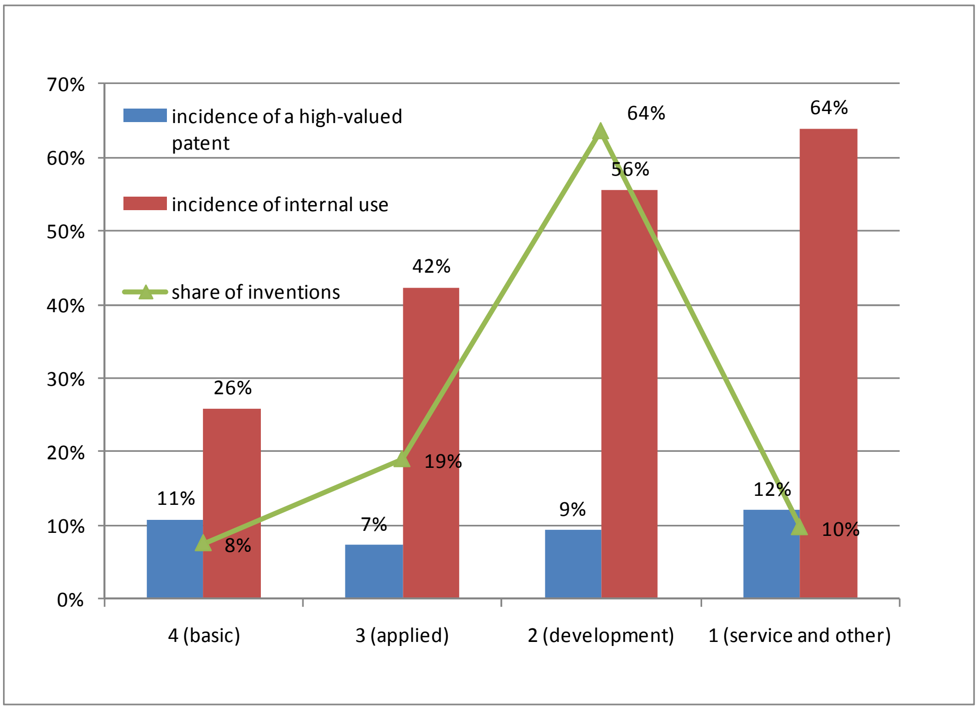


Figure 2. Willingness to provide a license (WTL) vs. Actual license by the business objectives of the underlying R&D

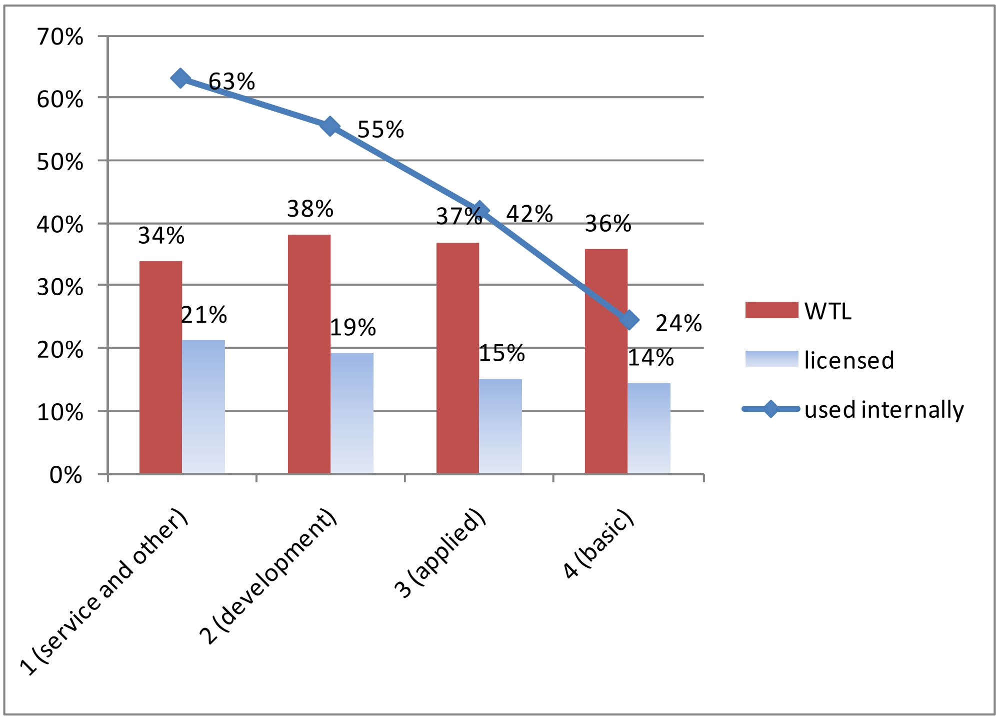


Figure 3 Willingness to provide a license (WTL) vs. actual license by the business objectives of the underlying R&D

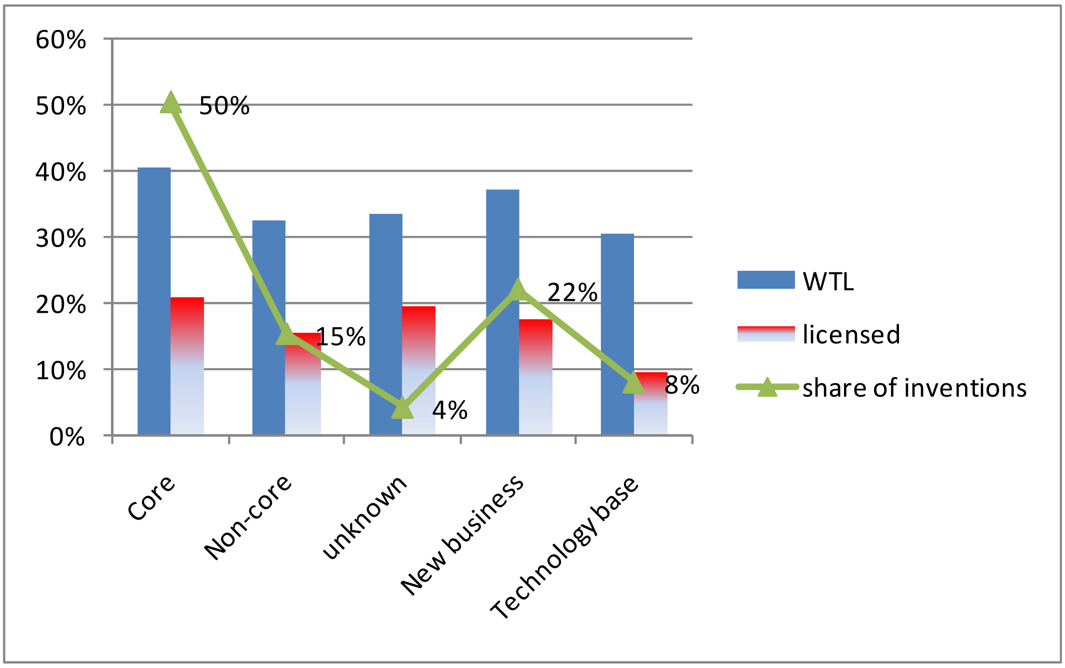
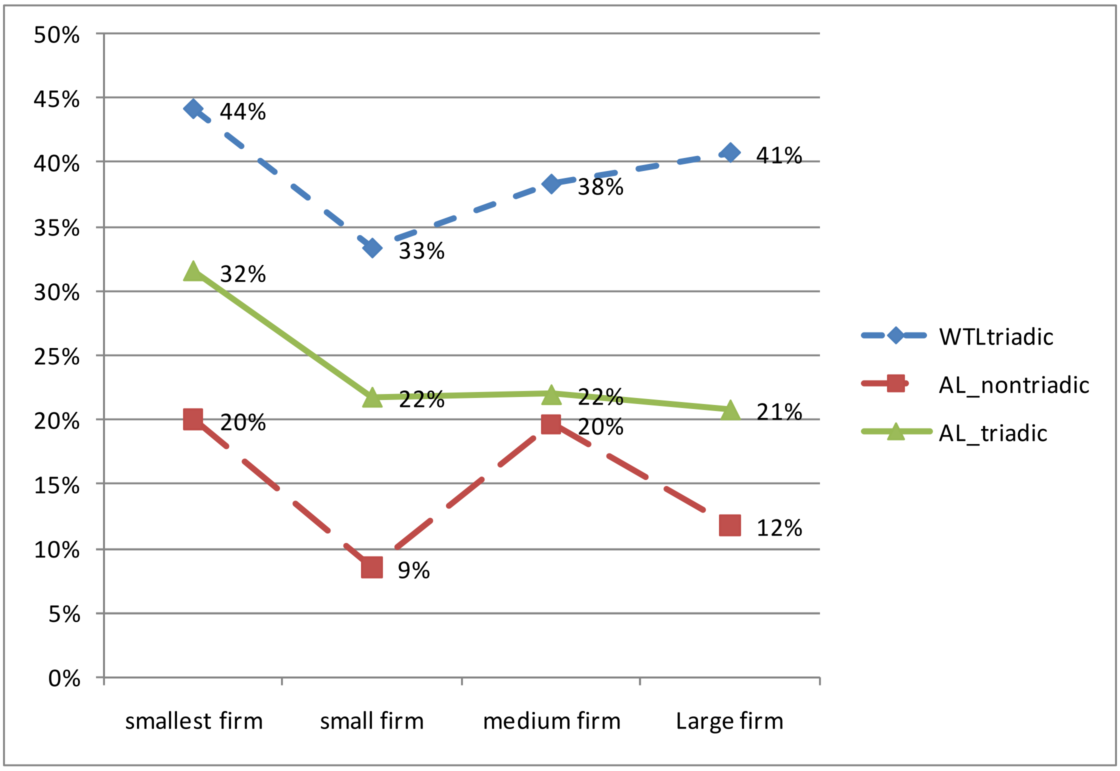


Figure 4. Willingness to license (WTL) and actual license (AL) by firm size and by patent quality



Note) large: 501 or more employment, medium: 251-500, small: 101-250 and very small: 100 or less.

Figure 5. Distribution of inventions by the size of the bundle of complementary patents and the incidence of cross-licensing

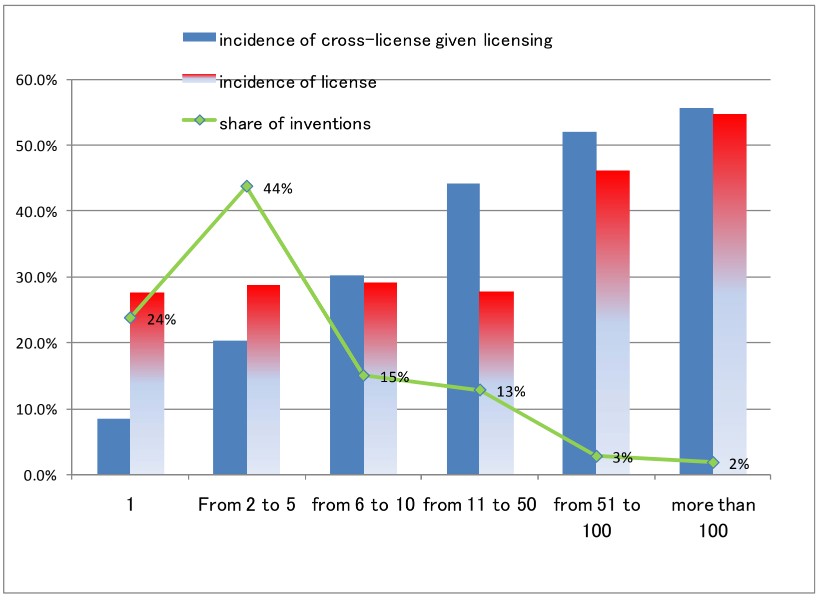


Figure 6 Three outcomes with respect to license by invention quality and its uncertainty (Case where licensing profit rises with invention quality

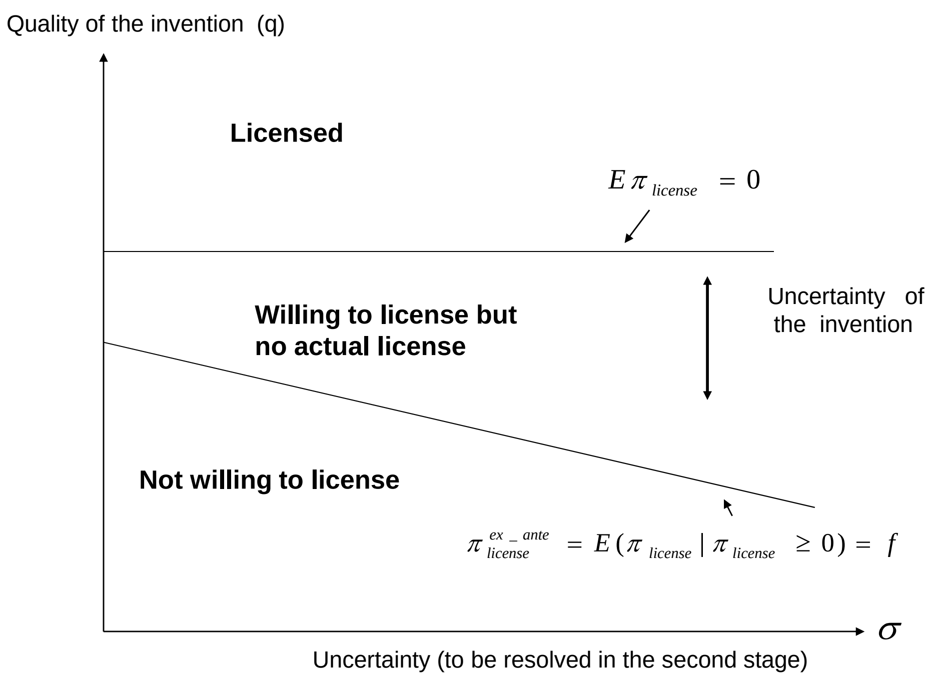


Table 1. Logistic regressions for willingness to license and actual license

		Willingness to license vs. Actual license								Actual license, internal use (non-conditional) and the economic value of the focal patent									
		Model 1(Logistic) (Ex-ante) Willingness to license				Model 2(Logistic) Actual license conditional on willingness to license				Model 3 (Logistic) :Licensed (Non-conditional)			Model 4 (Logistic) :Use (Non-conditional)			Model 5 (Ordered Logistic) :Value			
		Number of obs = 3731, 859 clusters Log pseudolikelihood =-2397.2152 , Pseudo R2 = 0.0276				Number of obs = 1393 482 clusters Log pseudolikelihood = -875.59934 Pseudo R2 = 0.0928				Number of obs = 3727, 859 clusters Log pseudolikelihood =-1663.6291 , Pseudo R2 =0.0612			Number of obs = 3727 859 clusters Log pseudolikelihood =-2232.2406 Pseudo R2 = 0.1355			Number of obs = 3727 859 clusters Log pseudolikelihood =-2232.2406 Pseudo R2 = 0.1355			
	Variable	Coef.	Robust Std. Err.		Marginal effects	Coef.	Robust Std. Err.		Marginal effects	Coef.	Robust Std. Err.		Coef.	Robust Std. Err.		Coef.	Robust Std. Err.		Marginal effects
Business objective (base: core business)	non-core	-0.299	0.116	***	*-0.068*	-0.065	0.170		*-0.014*	-0.277	0.141	**	-0.285	0.100	***	-0.423	0.105	***	-0.030
	unclassified existing business	-0.271	0.184		*-0.062*	0.409	0.325		*0.090*	-0.008	0.216		-0.202	0.187		0.004	0.191		0.000
	new business	-0.174	0.096	*	*-0.040*	-0.044	0.168		*-0.010*	-0.152	0.132		-0.357	0.101	***	-0.001	0.093		0.000
	enhancing technology base	-0.263	0.137	*	*-0.062*	-0.302	0.256		*-0.066*	-0.503	0.195	***	-1.556	0.162	***	-0.012	0.177		-0.001
	others	(omitted)			*(omitted)*	(omitted)			*(omitted)*	(omitted)		***	(omitted)		***				
Invention qualtiy and patent scope	fmv_2	0.237	0.052	***	*0.053*	0.161	0.089	*	*0.035*	0.286	0.073	***	0.354	0.056	***	0.621	0.057	***	0.049
	triadic	0.376	0.085	***	*0.085*	0.536	0.146	***	*0.118*	0.592	0.118	***	0.647	0.084	***	0.391	0.094	***	0.031
	ln1cited_inv	0.094	0.048	**	*0.021*	0.072	0.075		*0.016*	0.074	0.056		0.233	0.053	***	0.144	0.051	***	0.011
	lnclaims	-0.020	0.047		*-0.005*	-0.046	0.092		*-0.010*	-0.038	0.068		-0.137	0.054	**	0.032	0.045		0.003
	lnnum_ipc	-0.059	0.066		*-0.014*	-0.166	0.107		*-0.036*	-0.140	0.075	*	-0.266	0.064	***	0.063	0.062		0.005
upstream invention	upstream	-0.014	0.022		*-0.002*	-0.233	0.085	***	*-0.051*	-0.157	0.065	**	-0.453	0.053	***	-0.064	0.056		-0.005
Information sources and collaborations for inventions	cncpt_sci	-0.002	0.027		*-0.001*	-0.135	0.047	***	*-0.030*	-0.089	0.034	***	-0.078	0.028	***	0.034	0.030		0.003
	cncpt_pat	-0.037	0.026		*-0.008*	-0.036	0.047		*-0.008*	-0.036	0.034		-0.110	0.030	***	-0.043	0.035		-0.003
	cncpt_v	-0.017	0.022		*-0.004*	0.113	0.037	***	*0.025*	0.039	0.028		0.080	0.022	***	-0.017	0.022		-0.001
	cncpt_res	0.063	0.031	**	*0.014*	0.042	0.046		*0.009*	0.083	0.035	**	0.019	0.029		0.069	0.028	**	0.005
	collab_v	0.249	0.093	***	*0.056*	0.044	0.139		*0.010*	0.235	0.107	**	0.267	0.094	***	0.157	0.096	*	0.012
	collab_res	0.254	0.156		*0.057*	-0.117	0.239		*-0.026*	0.096	0.199		-0.471	0.174	***	0.424	0.198	**	0.034
Invention type (targetted invention)	target	0.056	0.076		*0.012*	0.222	0.130	*	*0.049*	0.164	0.104		0.445	0.081	***	0.579	0.074	***	0.046
Invention type (base: product patent)	process	0.163	0.089	*	*0.037*	0.267	0.147	*	*0.059*	0.285	0.113	**	0.363	0.091	***	0.129	0.092		0.010
	dual	0.145	0.096		*0.033*	-0.151	0.155		*-0.033*	0.024	0.120		0.144	0.103		0.221	0.091	**	0.018
Firm size (base : a large firm)	medium	0.025	0.173		*0.006*	0.155	0.282		*0.034*	0.076	0.193		0.232	0.188		0.204	0.177		0.017
	small	-0.292	0.221		*-0.065*	0.221	0.388		*0.049*	-0.186	0.305		0.528	0.231	**	0.068	0.232		0.005
	smallest	0.002	0.213		*0.000*	0.754	0.257	***	*0.166*	0.296	0.237		0.407	0.200	**	0.842	0.205	***	0.088
No. of applicants	lnapplicants																		(omitted)
*** significant at 1%, **significant at 5%, * significant at 10%																			
Coefficients for technology class du																			

Table 2. Logistic regressions for willingness to license (internally used vs. unused patents)

		Model 6(Logistic) Willingness to license, internally used patents				Model 7 (Logistic) Willingness to license, internally used patents				Model 8(Logistic) Willingness to license, internally unused patents				Model 9(Logistic) Willingness to license, internally unused patents			
		Number of obs = 1914, 623 clusters Log pseudolikelihood = −1271.736 , Pseudo R2 = 0.0336				Number of obs = 1914, 623 clusters Log pseudolikelihood = −1272.8501 Pseudo R2 = 0.0328				Number of obs = 1813 517 clusters Log pseudolikelihood = −1064.3004 Pseudo R2 = 0.0338				Number of obs = 1813 517 clusters Log pseudolikelihood = −1071.2008 Pseudo R2 = 0.0276			
	Variable	Coef.	Robust Std. Err.		Marginal effects	Coef.	Robust Std. Err.		Marginal effects	Coef.	Robust Std. Err.		Marginal effects	Coef.	Robust Std. Err.		Marginal effects
Business objective (base: core business)	non-core	−0.362	0.142	**	*−0.086*	−0.361	0.142	**	*−0.085*	−0.171	0.180		*−0.034*	−0.168	0.180		*−0.034*
	unclassified existing business	−0.398	0.259		*−0.094*	−0.387	0.261		*−0.092*	−0.059	0.254		*−0.012*	−0.057	0.255		*−0.012*
	new business	−0.224	0.132	*	*−0.053*	−0.222	0.133	*	*−0.053*	−0.098	0.136		*−0.020*	−0.090	0.133		*−0.018*
	enhancing technology base	−0.042	0.282		*−0.010*	−0.047	0.284		*−0.011*	−0.126	0.160		*−0.025*	−0.132	0.160		*−0.027*
Invention qualtiy and patent scope	fmv_2	0.310	0.071	***	*0.073*					0.109	0.073		*0.022*				
	triadic	0.048	0.112		*0.011*					0.523	0.128	***	*0.105*				
	ln1cited_inv	0.028	0.064		*0.007*					0.164	0.081	**	*0.033*				
	quality (composite variable)					0.479	0.116	***	*0.113*					0.446	0.127	***	*0.090*
	lnclaims	0.008	0.064		*0.002*	−0.015	0.089		*−0.004*	0.001	0.067		*0.000*	−0.035	0.093		*−0.007*
	lnnum_ipc	−0.011	0.091		*−0.003*	0.073	0.071		*0.017*	−0.052	0.097		*−0.010*	0.054	0.082		*0.011*
upstream invention	upstream	0.074	0.071		*0.017*	0.014	0.034		*0.003*	0.045	0.081		*0.009*	−0.003	0.038		*−0.001*
Information sources and collaboratio	cncpt_sci	0.013	0.034		*0.003*	−0.018	0.035		*−0.004*	0.000	0.040		*0.000*	−0.045	0.040		*−0.009*
	cncpt_pat	−0.022	0.036		*−0.005*	−0.036	0.032		*−0.009*	−0.038	0.041		*−0.008*	−0.015	0.033		*−0.003*
	cncpt_v	−0.036	0.032		*−0.009*	0.060	0.038		*0.014*	−0.012	0.032		*−0.002*	0.057	0.042		*0.011*
	cncpt_res	0.062	0.038		*0.015*	0.328	0.125	***	*0.078*	0.061	0.043		*0.012*	0.091	0.151		*0.018*
	collab_v	0.329	0.126	***	*0.078*	0.125	0.254		*0.030*	0.083	0.151		*0.017*	0.427	0.199	**	*0.086*
	collab_res	0.122	0.254		*0.029*	−0.071	0.100		*−0.017*	0.443	0.201	**	*0.089*	0.114	0.111		*0.023*
Invention type (targetted invention)	target	−0.068	0.102		*−0.016*	0.104	0.119		*0.025*	0.079	0.111		*0.016*	0.113	0.130		*0.023*
Invention type (base: product patent)	process	0.103	0.119		*0.024*	0.093	0.131		*0.022*	0.123	0.130		*0.025*	0.148	0.134		*0.030*
	dual	0.095	0.130		*0.023*	−0.175	0.223		*−0.041*	0.124	0.134		*0.025*	0.267	0.290		*0.054*
Firm size (base : a large firm)	medium	−0.183	0.223		*−0.043*	−0.826	0.293	***	*−0.195*	0.249	0.293		*0.050*	0.404	0.321		*0.081*
	small	−0.833	0.291	***	*−0.197*	0.018	0.275		*0.004*	0.458	0.324		*0.091*	−0.255	0.327		*−0.051*
	smallest	0.004	0.271		*0.001*	0.004	0.271		*0.001*	−0.206	0.324		*−0.041*	−0.206	0.324		*−0.041*

*** significant at 1%, **significant at 5%, * significant at 10%

Coefficients for technology class dummies and application years not reported. Sample: 70% of the sample are triadic (USPTO grant) patents.

Table 3. Logistic and Multinomial logistic regression for unilateral and cross license with the size of the bundle

		Model 10: Willingness to license				Model 11: Actual license, non-condtional				Model 12(1): Unilateral license, condtionnal on willingness to license				Model 12(2): Cross license, condtionnal on willingness to license			
		Logistic: Number of obs = 1878 619 clusters Log pseudolikelihood =−1238.8036 Pseudo R2 = 0.0402				Logistic: Number of obs = 1878 619 clusters Log pseudolikelihood =−1051.4748 Pseudo R2 =0.0535				Multinomial logistic: Number of obs = 837 369 clusters Log pseudolikelihood = −910.50647 Pseudo R2 = 0.1483							
	Variable	Coef.	Robust Std. Err.		Marginal effects	Coef.	Robust Std. Err.		Marginal effects	Coef.	Robust Std. Err.		Marginal effects	Coef.	Robust Std. Err.		Marginal effects
Size of the minimal patent porfolio (base:1)	Bundl=2−5	0.151	0.139		0.035	−0.007	0.150		−0.001	−0.473	0.257	*	−0.114	1.032	0.524	**	0.107
	Bundl=6−10	0.292	0.173	*	0.068	0.109	0.186		0.021	−0.704	0.321	**	−0.177	1.297	0.640	**	0.133
	Bundl=11−50	0.054	0.175		0.013	−0.032	0.211		−0.006	−0.621	0.377	*	−0.174	1.993	0.570	***	0.193
	Bundl=51−100	0.837	0.299	***	0.196	0.801	0.302	***	0.151	0.144	0.584		−0.035	2.377	0.664	***	0.203
	Bundl=101−	1.348	0.460	***	0.315	1.124	0.377	***	0.212	−0.342	0.735		−0.171	2.723	0.810	***	0.237
Business objective (Base: core business)	non−core	−0.347	0.143	**	−0.081	−0.408	0.162	**	−0.077	0.124	0.240		0.091	−1.035	0.605	*	−0.080
	unclassified existing business	−0.314	0.268		−0.073	−0.086	0.280		−0.016	0.368	0.553		0.045	−0.317	0.838		−0.052
	new business	−0.251	0.135	*	−0.059	−0.242	0.155		−0.046	−0.005	0.272		0.024	−0.143	0.373		−0.005
	enhancing technology base	−0.120	0.289		−0.028	−0.190	0.332		−0.036	−0.326	0.674		−0.050	−1.216	0.932		−0.103
Invention qualtiy and patent scope	fmv_2	0.285	0.074	***	0.067	0.222	0.088	**	0.042	0.125	0.152		0.040	−0.121	0.216		−0.010
	triadic	0.055	0.113		0.013	0.247	0.132	*	0.047	0.392	0.214	*	0.037	0.545	0.350		0.026
	ln1cited_inv	0.024	0.064		0.006	0.043	0.069		0.008	0.153	0.118		0.020	−0.107	0.178		−0.019
	lnclaims	0.017	0.064		0.004	0.027	0.079		0.005	0.000	0.128		−0.003	0.226	0.183		0.021
	lnnum_ipc	−0.033	0.095		−0.008	−0.088	0.095		−0.017	−0.096	0.169		−0.008	−0.162	0.202		−0.009
upstream invention	rd_upstream	0.069	0.073		0.016	0.020	0.082		0.004	0.029	0.152		0.019	−0.301	0.216		−0.025
Information sources and collaborations for inventions	cncpt_sci	0.025	0.035		0.006	−0.012	0.039		−0.002	0.012	0.071		0.015	−0.111	0.094		−0.006
	cncpt_pat	−0.043	0.036		−0.010	−0.072	0.040	*	−0.013	−0.070	0.071		−0.006	−0.071	0.091		−0.002
	cncpt_v	−0.030	0.032		−0.007	0.078	0.033	**	0.015	0.248	0.063	***	0.032	0.179	0.074	**	0.004
	cncpt_res	0.059	0.038		0.014	0.043	0.040		0.008	−0.096	0.073		−0.024	−0.039	0.104		−0.003
	collab_v	0.328	0.128	***	0.077	0.244	0.136	*	0.046	−0.156	0.209		−0.036	−0.037	0.314		−0.001
	collab_res	0.101	0.254		0.024	0.125	0.271		0.024	0.367	0.455		0.124	−0.789	0.832		−0.069
Invention type	target	−0.064	0.103		−0.015	−0.026	0.114		−0.005	−0.077	0.186		−0.029	0.017	0.279		−0.001
	process	0.083	0.122		0.019	0.160	0.143		0.030	−0.016	0.238		−0.028	0.086	0.304		0.000
	dual	0.050	0.134		0.012	−0.101	0.151		−0.019	−0.685	0.268	**	−0.146	0.278	0.347		0.044
Firm size (base : a large firm)	medium	−0.113	0.229		−0.026	0.032	0.231		0.006	0.421	0.386		0.075	−0.319	0.875		−0.047
	small	−0.847	0.293	***	−0.198	−0.846	0.375	**	−0.159	−0.172	0.512		0.027	−0.182	1.491		0.009
	smallest	0.001	0.260		0.000	0.297	0.266		0.056	1.016	0.385	***	0.174	0.776	0.613		0.035

*** significant at 1%, **significant at 5%, * significant at 10%
Coefficients for technology class dummies and application years not reported.
Sample: 70% of the sample are triadic (USPTO grant) patents.

Appendix Table A.1 Descriptive statistics

Variable	Obs	Mean	Std. Dev.	Min	Max
will_license	3,731	0.373	0.484	0	1
licensed2	3,731	0.183	0.386	0	1
licensed_4	3,731	0.318	0.766	0	3
use2	3,727	0.514	0.500	0	1
valued2	2,713	3.086	0.935	2	5
objective3	3,731	2.223	1.451	1	5
fmv_2	3,731	3.998	0.747	1	5
triadic	3,731	0.699	0.459	0	1
bundl	1,878	2.353	1.172	1	8
forwdcite_inv	3,731	1.266	5.845	0	279
claims	3,731	7.651	8.309	1	176
num_ipc	3,731	2.547	1.876	1	28
rd_upstream	3,731	2.238	0.722	1	4
basic	3,731	0.192	0.394	0	1
applied	3,731	0.367	0.482	0	1
dev	3,731	0.693	0.461	0	1
service	3,731	0.087	0.281	0	1
oth_stage	3,731	0.013	0.115	0	1
cncpt_sci	3,731	2.940	1.758	0	5
cncpt_pat	3,731	3.315	1.646	0	5
cncpt_v	3,731	3.062	1.818	0	5
cncpt_res	3,731	1.529	1.603	0	5
collab_v	3,731	0.216	0.412	0	1
collab_res	3,731	0.060	0.237	0	1
target	3,731	0.461	0.499	0	1
typeinvention	3,731	1.774	0.787	1	3
org	3,731	1.217	0.670	1	4
year_ad	3,731	1997.763	1.825	1995	2001

Appendix Table A.2 Fixed effects estimation (fixed effect for an applicant)

		Willingness to license vs. Actual license					
		Model A.1(Linear probability model, Fixed effects) (Ex-ante) Willingness to license			Model A.2 (Linear probability model, Fixed effects) Actual license conditional on willingness to license		
		Number of obs = 3556, 858 clusters, R-sq: within = 0.0361, between = 0.0125 , overall = 0.0290			Number of obs = 1329 481 clusters R-sq: within = 0.1162 between = 0.0258 overall = 0.0599		
	Variable	Coef.	Robust Std. Err.		Coef.	Robust Std. Err.	
Business objective (base: core business)	non-core	-0.067	0.031	**	-0.031	0.051	
	unclassified existing business	-0.089	0.045	**	0.061	0.078	
	new business	-0.053	0.025	**	0.017	0.048	
	enhancing technology base	-0.084	0.034	**	0.031	0.072	
Invention qualtiy and patent scope	fmv_2	0.050	0.013	***	0.020	0.025	
	triadic	0.094	0.019	***	0.097	0.042	**
	ln1cited_inv	0.021	0.013		0.030	0.023	
	lnclaims	0.003	0.014		-0.016	0.028	
	lnnum_ipc	-0.005	0.017		-0.048	0.033	
upstream invention	upstream	0.010	0.015		-0.084	0.025	***
Information sources and collaborations for inventions	cncpt_sci	-0.005	0.008		-0.030	0.013	**
	cncpt_pat	-0.003	0.007		-0.003	0.012	
	cncpt_v	-0.002	0.006		0.026	0.010	***
	cncpt_res	0.017	0.008	**	0.015	0.014	
	collab_v	0.045	0.024	*	-0.068	0.042	
	collab_res	0.030	0.045		-0.099	0.068	
Invention type (targetted invention)	target	0.016	0.020		0.097	0.038	**
Invention type (base: product patent)	process	0.029	0.026		0.044	0.045	
	dual	0.029	0.025		0.028	0.048	
*** significant at 1%, **significant at 5%, * significant at 10%							
Coefficients for technology class dummies and application years not reported. Sample: 70% of the sample are triadic (USPTO grant) patents.							